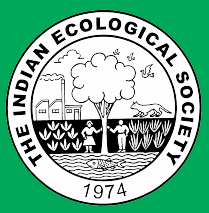
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Spatial Modelling of Agro-Ecological Condition of Soils in Steppe Zone of Ukraine

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Abstract**:** Soil degradation is the main problem of the decrease of their fertility. This problem in Ukraine occurs due to a number of problems. Active use of lands has led to the fact that about 93% of the territory of Ukraine is used by various economic activities. Plowing is the main problem between others which occupies over then 53% of the territory of the country, which is much higher than allowed in agricultural countries of the European Union, where the maximum use of land for growing crops is only 34%. Another important factor is the afforestation of Ukraine, the area under the forests and shelterbelts is currently only 17%, which means that there is an environmental imbalance, for example, this indicator in the European Union averages between 31-37%. The Southern steppe zone is considered to be the most plowed part of the country. Here the area of plowing is almost 90% of the territory. The problem of plowing is strengthened by non-professional use of land, which is expressed in excessive depletion due to improper crop rotations and lack of black fallow of the fields which leads to a decrease of the humus layer. The difference between the humus content in virgin chernozems and those which are under agricultural use is very significant. The virgin soils have in the fertile layer about 10% of humus, but in steppe soils this indicator is about 4%. Excessive land use, according to some scientists, also contributes to an increase in CO_2 in the air, as soils are a natural storehouse of carbon. As a consequence of this the expansion of the steppe zone in Ukraine is occurs. Therefore, modern situation in agricultural land use requires constant monitoring of the agro-ecological condition of soils to identify changes in their fertile qualities, which will allow timely decision making to take the necessary measures to ensure proper soil condition. And spatial modelling of agro-ecological properties is an instrument of GIS-technologies which helps to present all collected data in the form of maps, which simplifies the perception of information.

Keywords: Agro-ecological condition, Spatial modelling, Heterogeneity, GIS-technologies

Under the conditions of modern intensive agriculture, Ukraine, whose chernozem soils are considered to be the most fertile in the world, suffers from significant problems of soil condition, which is expressed in a decrease of their fertility due to reducing the humus content and nutrient imbalance (Boiko et al 2018). The task of the ecological monitoring is to control, assess, forecast and manage the state of the main indicators of soil fertility in order to obtain high and stable crop yields of good quality as well as to prevent pollution of the natural environment. In modern conditions, the agrochemical maintenance of arable lands provides a periodic receipt of monitoring data on the content of humus, nutrients and a limited range of trace elements. Spatial modelling will provide better understanding of the current state of agricultural lands (Zelenskaya et al 2018). One of the aims of soil monitoring is to develop the economy capable to solve the food security problems of countries to ensure the effective functioning of the domestic markets, fair competition among agricultural producers, confidence of consumer, rational land use and use of natural resources, creating conditions for preservation of soils and increasing of their fertility (Breus et al 2018). Spatial modelling is an integral part and the main stage of comprehensive monitoring of soils. Spatial modelling methods are based on stochastic and deterministic models, the use of which began in the 30s of 20th century by E.N. Gapon. The scientist proposed a thermodynamic model to describe cations exchange in soils, and also created a model to describe the heterogeneity of the distribution of soil properties (Domaratskiy et al 2018). Spatial modelling is a process of determining the spatio-temporal patterns of heterogeneity of changes in soil fertility to determine their suitability by agrochemical and ecological-toxicological properties for growing crops (Pichura et al 2021).

Fried proposed a classification of description models of the soils state by types. The first type of models is based on elements of fertility and is divided into information and management models. Information models is a set of knowledge about fertility and the ability to order them. Management models allows to make a decisions in economic activities based on the components of soil fertility to achieve the desired result (Dudiak et al 2020). Models of fertility management with minor soil disturbances has no significant changes in structural and functional characteristics, and if there are strong changes in soils - management is aimed at creating new models with better characteristics and their

subsequent bringing to the established level of functioning. The main requirements for models are their ability to implement, as well as economic efficiency. The second type of models is dynamic, which are divided into long-term, describing long-term phenomena; medium-term - describe the agricultural season, year; short-term - associated with the characteristics of the stage of plant development in shorter periods. For this type of model, time is used as a variable indicator. The third type is related to the territorial boundaries of fertility models, this type is close to the traditional practice of soil science in the field of mapping and zoning. Among the models of this type there are global models, which are built for the entire land area or large countries, regional models, which include limited areas with similar characteristics of climate and relief. The fourth type of models is characterized by differences in the presentation of the model, namely, tabular form, mathematical formulas, graphical or computer software (Borisochkina et al 2019). In the 21st century, the information about the environment has increased significantly, which led to the introduction and development of geoinformation technologies for agri-environmental monitoring purposes. Geoinformation technologies, in our understanding, are a set of tools and methods of information processes for the rapid collection, processing and dissemination of geospatial information on the structure, area volume, condition and productivity of agricultural land, which will predict amount of agricultural production and market prices for agricultural products (Dudiak et al 2019). The use of soils for agricultural purposes leads to disruption of the natural course of humus formation, which affects the intensity and direction of humification processes. Lisetskii (2017) observed that steppe soils, including territory of the steppe part of Ukraine, were formed with an annual productivity of 11000 kg ha^{-1} of plant residues, due to which the annual formation of humus was about 2400 kg ha^{-1} and as the anthropogenic impact on steppe ecosystems increased, the role of this source of humus decreased by 25 per cent (Lisetskii et al 2017). The objective of study is to determine agro-ecological condition of soils in steppe zone of Ukraine, using cartographic and statistical models of spatial heterogeneity of nutrient distribution.

MATERIAL AND METHODS

One of the main prerequisites for rational land use is the spatio-temporal assessment of changes in soil fertility and determination of their quality by agrochemical and ecological-toxicological properties. These properties in the steppe zone soils were studied according to the generally accepted methods in the certified laboratories of the Kherson branch of the State Institution "Institute of Soil Protection of Ukraine" according to 296 stationary monitoring posts of agro-ecological studies of soil conditions in the layer 0-20 cm of the XI-th round of agrochemical certification of lands (Breus et al 2019). The main types of soils of the steppe zone of Ukraine (Fig. 1) are southern chernozem, which occupy 43.7% of the total area of agricultural land, and dark-brown soils (30.7%).

The study of spatial heterogeneity of soil fertility and the dynamics of its change was carried out by visualizing cartographic information and research results, which were carried out using software packages ArcGIS 10.1. This provided a qualitative interpretation of spatial and graphical information and modelling results. The spatial heterogeneity of the distribution of soil properties is marked by the non-stationary (atypical) nature of their distribution on agricultural lands, which is determined by the culture of agriculture and soil diversity.

RESULTS AND DISCUSSION

The soil cover is characterized by low-humus soils with humus content in the range of 0.30-3.85% (Fig. 2). The highest humus content (3.50-3.85%) was in soils of northern part of the Kherson region of Ukraine (Vysokopilsky and Novovorontsovsky districts). The lowest humus content (0.30-1.00%) in the soils of south-western part of the Kherson region of Ukraine (Oleshkivsky and Holoprystansky districts). The highest average weighted humus content of 3.04% was recorded in ordinary chernozems, which are located in the northern part of the region (Fig. 2a). The autocorrelation method was used to establish the maximum distance of distribution and preservation of the spatial energy of typicality of agroecological properties of soils. The minimum (r = 0.39) and maximum (r = 0.14) radius of typicality of humus ranged from 2.5 km (lag 1) to 12.5 km (lag 5). The insignificant relationship between spatial lags indicates significant variability in the distribution of humus within different types (subtypes) of soils. The functions of spatial distribution (Fig. 2b) and the provision of soils with humus (Fig. 2c) make it possible to determine its content in different spatially distributed climatic and economic conditions of the Kherson region.

Humus: The humus content on 72.5 % of the area corresponds to the medium (2.10-3.09 %) and increased 3.10-4.09 % qualitative gradations (Table 1).

Nitrogen*:* Graphical and statistical characteristics of the spatial heterogeneity of nitrogen distribution are presented on Figure 3. The autocorrelation analyzes of the spatial heterogeneity of nitrogen formation, were minimum (r = 0.095) and maximum (r = 0.044) radius of typicality of nitrogen formation conditions, which is from 2.5 km to 5.0 km.

The highest nitrogen content (38.2-41.3 mg ha^{-1}) detected in soils of Bilozersky and Henichesky districts and lowest content (3.4-10.0 mg kg^{-1}) in the soils of Oleshkivsky district. The nitrogen content in soils, which corresponds to qualitative gradations from medium to increased content (>21.0 mg kg^{-1}), characterizes 47.4% of the researched area of agricultural lands (Table 2). The largest share of agricultural lands with medium-increased nitrogen content with nitrification capacity was observed in the central and eastern parts of the region.

Phosphorus*:* The autocorrelation analyzes of the spatial heterogeneity of mobile phosphorus formation, were the minimum (r = 0.340) and maximum (r = 0.180) with radius 2.5 to 12.5 km. The highest phosphorus (>60 mg kg^{-1}) detected in soils of Velykooleksandrivsky and Belozersky districts and lowest (<16.0 mg kg^{-1}) in soils of Verkhnorogachytsky and Novotroitsky districts (Fig. 4). The phosphorus content in soils corresponds to qualitative gradations from high to very high (>31.0 mg kg^{-1}) characterizes 87.3% of the studied area (Table 3). The predominant part of the region (56.2%) with high and very high content of phosphorus located near the buffer zones of irrigated lands.

Table 1. Distribution of humus content in soils of agricultural lands of the region

Humus content (%)		Total	
		Thous. ha	%
Very low	<1.10	112.0	6.3
Low	1.10 - 2.09	376.9	21.2
Medium	2.10 - 3.09	1066.6	60.0
Increased	3.10 - 4.09	222.2	12.5
Total		1777.6	100

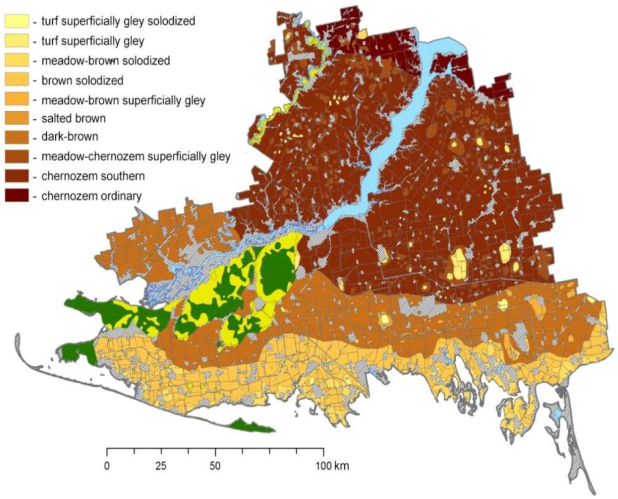
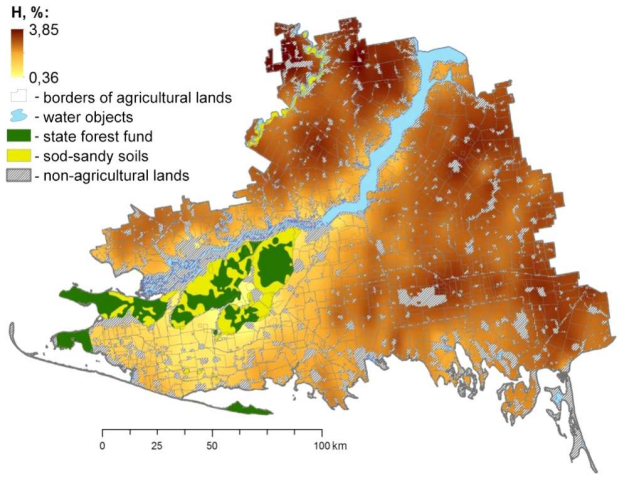


Fig. 1. Cartogram of soil types of steppe zone of Ukraine

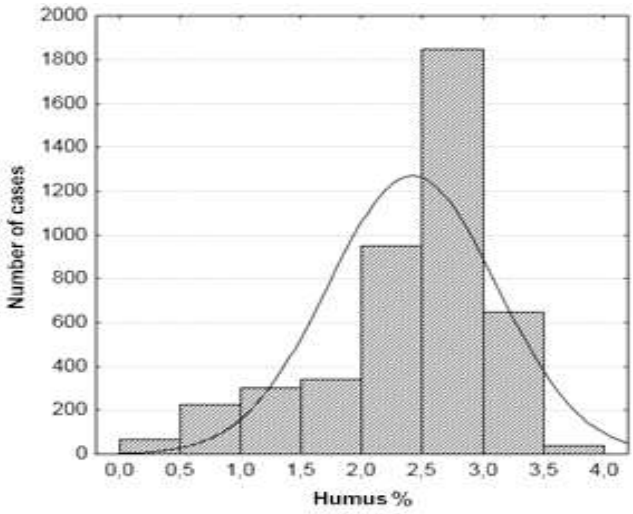


a

F(h) = 25.14.x – 11.98.y+0.07.x^2 – 0.63.x.y+0.36.y^2-168.97; R=0.58
where, x – longitude, decimal degrees, *y* – latitude, decimal degrees

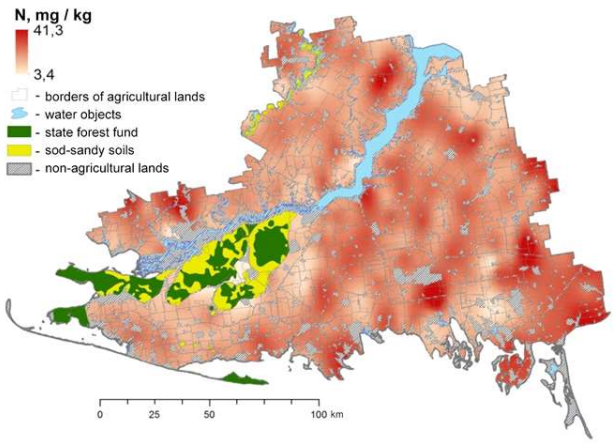
b

$$f(h) = \left\{ \begin{array}{c} \int_0^{60} -0.2447\ .Ln(x) + 3.61 \\ \int_0^{60} -0.0013\ .x^2 + 0.1581\ .x - 2.39; r = 0.98 \end{array} \right\}$$



The total number of cases	296
Average value	2.40
Confidence average interval	0.02
Median	2.60
Mode	2.92
Min	0.29
Max	3.83
Percentile 10,0	1.25
Percentile 90,0	3.10
Level of variation, %	26.65
Dispersion	25.54
Standard deviation	0.48
Standard error of the mean	0.69
Asymmetry	0.01
Kurtosis	–1.08

Fig. 2. Statistical-cartographic characteristics of humus distribution in the layer of 0...20 cm in soils of the region: *a* - cartogram of distribution; *b* - the function of spatial distribution; *c* - the function of providing soils with humus; *d* - statistical characteristics



a

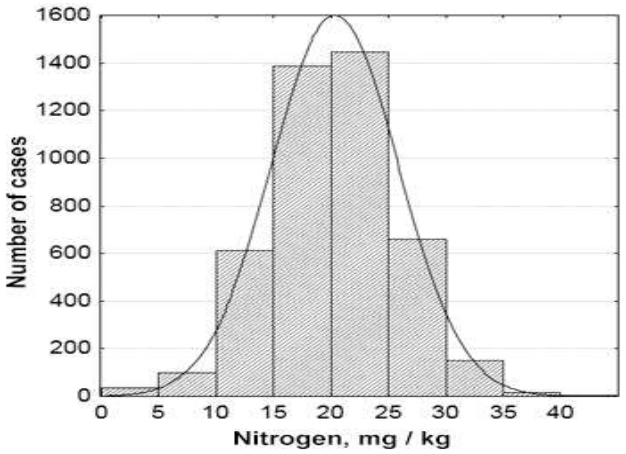
$f(NO_3) = 155.52.x – 149.83.y+1.07.x^2 – 4.83.x.y+0.13.y^2-612.06;$ $R=0.58$

where, x – longitude, decimal degrees, *y* – latitude, decimal degrees

B

$f(NO_3) = 298.6.sin*0.0219x+1.8888+306.2.sin (0.0319x+4.588)+74.66.sin (0.04581x+7.087;$ $r=0.988)$

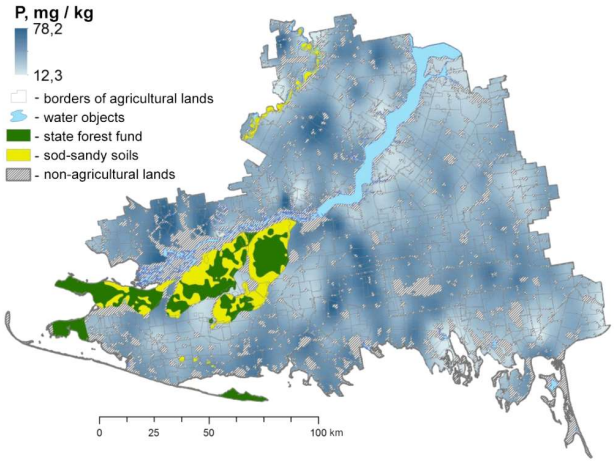
c



d

The total number of cases	296
Average value	20.25
Confience average interval	0.16
Median	20.2
Mode	-
Min	3.53
Max	41.1
Percentile 10,0	13.61
Percentile 90,0	26.94
Level of variation, %	27.01
Dispersion	29.96
Standard deviation	5.47
Standard error of the mean	0.08
Asymmetry	0.03
Kurtosis	0.44

Fig. 3. Statistical-cartographic characteristics of nitrogen distribution in the layer of 0...20 cm in soils of the region: *a*-cartogram of distribution; *b*-the function of spatial distribution; *c* - the function of providing soils with humus; *d* - statistical characteristics



a

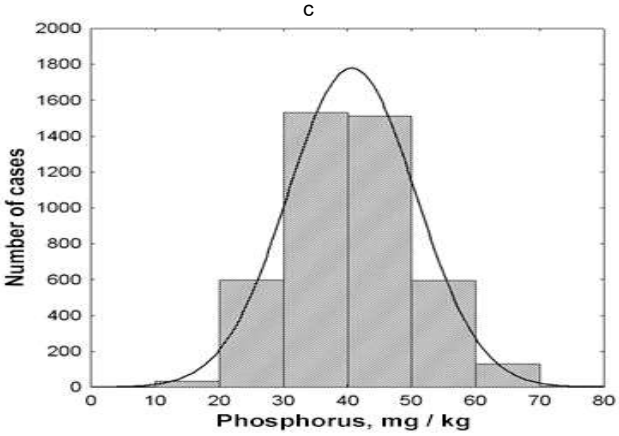
$f(P_2O_5) = 281.4.x + 1103.71.y – 1.92.x^2 – 5.43.x.y – 9.90.y^2 - 31949.82;$ $R=0.38$

where, x – longitude, decimal degrees, *y* – latitude, decimal degrees

B

$f(P_2O_5) = 281.4.sin (0.006052x+2.682) + 60.87.sin (0.03122x+4.653)+7.576.$ $sing (0.06488x+6.113);$ $r = 0.996$

c



d

The total number of cases	296
Average value	40.55
Confidence average interval	0.57
Median	40.21
Mode	-
Min	13.25
Max	77.82
Percentile 10,0	27.71
Percentile 90,0	52.93
Level of variation %	24.02
Dispersion	94.79
Standard deviation	9.74
Standard error of the mean	0.15
Asymmetry	0.25
Kurtosis	0.07

Fig. 4. Statistical-cartographic characteristics of phosphorus distribution in the layer of 0...20 cm in soils of the region: *a* - cartogram of distribution; *b* - the function of spatial distribution; *c* - the function of providing soils with humus; *d* - statistical characteristics

Potassium: Soils that are characterized by a sufficient level of calcium can by limited in the sorption of potassium that increases its content in the soil solution, high concentrations of other cations, especially Ca^{2+} and Mg^{2+}, prevent the adsorption of potassium by plants, due to competition on the surface of the roots. Thus, grown on carbonate soils, crops have a potassium deficiency even if soils are sufficiently available with potassium. The autocorrelation analyzes of the spatial heterogeneity of the formation of exchangeable potassium, were the minimum (r = 0.413) and maximum (r = 0.170) with radius 2.5 to 12.5 km (Fig. 5). The content of exchangeable potassium in soils (Table 4), which corresponds to qualitative gradations from medium to very high content (>200 mg kg^{-1}), characterizes 85.8% of the area. The highest content of exchangeable potassium (> 600mg kg^{-1}) detected in soils of Vysokopilsky and Henichesky districts and lowest (<200 mg kg^{-1}) is typical for soils of Oleshkivsky and Hornostaivsky.

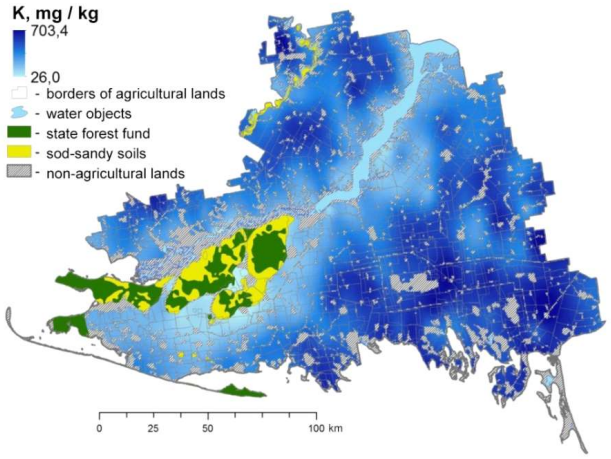
Soil acidity (pH): Assimilation of trace elements strongly depends on soil acidity. Best adsorption of these elements will be on slightly acidic soil or neutral soils (pH 5.5 to 7.0). The indicator of acidity or alkalinity of soils has a significant impact on the development of roots and plant nutrition through the absorption of nutrients. The reaction of the soil (pH) is a sign on which the agrochemical properties of soils and plant growth largely depend. Soil acidity is a property of soils due to the presence of hydrogen (H^+) ions in the soil

Table 2. Distribution of nitrogen content in soils of agricultural lands of the region

Nitrogen content (mg kg^{-1})		Total	
		Thous. ha	%
Very low	<10.0	56.9	3.2
Low	11.0 - 20.0	876.4	49.3
Medium	21.0 - 30.0	794.6	44.7
Increased	31.0 - 45.0	48.0	2.7
Total		1777.6	100

Table 3. Distribution of phosphorus content in soils of agricultural lands of the region

Phosphorus content (mg kg^{-1})		Total	
		Thous. ha	%
Medium	16.0 – 30.0	225.8	12.7
Increased	31.0 – 45.0	959.9	54.0
High	46.0 – 60.0	540.4	30.4
Very high	>60.0	51.6	2.9
Total		1777.6	100.0



a

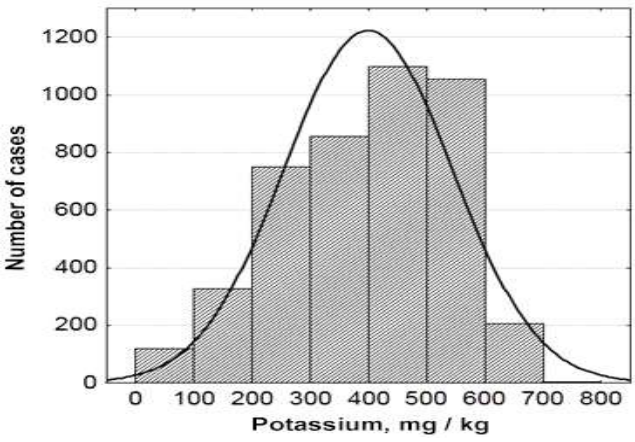
$f(K_2 0) = 9628.88.x - 3150.26.y + 11.05.x^2 - 220.27.x.y + 112.49.y^2 - 88216.68;\ R=0.46$

where, x – longitude, decimal degrees, *y* – latitude, decimal degrees

b

$$f(h) = \left\{ \frac{\int_0^{30} -42.95 \,.Ln(x) + 660.28}{\int_{30}^{100} -0.0504 \,.x^2 + 1.0186 \,.x - 495.29 ; r = 0.98} \right\}$$

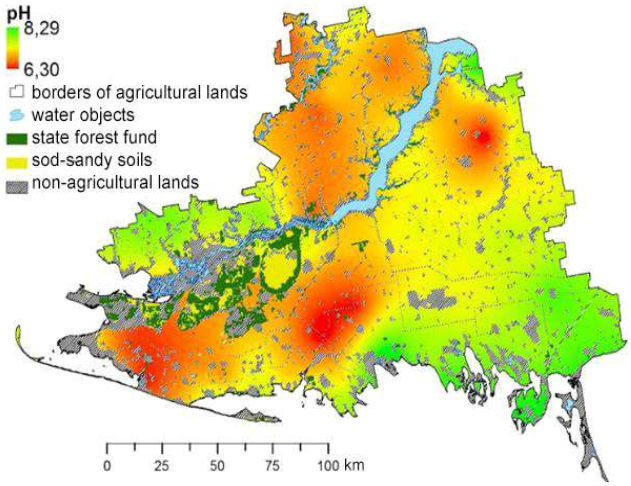
c



d

The total number of cases	296
Average value	396.78
Confidence average interval	4.24
Median	414.94
Mode	–
Min	23
Max	703.1
Percentile 10,0	199.63
Percentile 90,0	572.48
Level of variation, %	36.23
Dispersion	20669,97
Standard deviation	143.77
Standard error of the mean	2.16
Asymmetry	–0.37
Kurtosis	–0.64

Fig. 5. Statistical-cartographic characteristics of potassium distribution in the layer of 0...20 cm in soils of the region: *a* - cartogram of distribution; *b* - the function of spatial distribution; *c* - the function of providing soils with humus; *d* - statistical characteristics



a

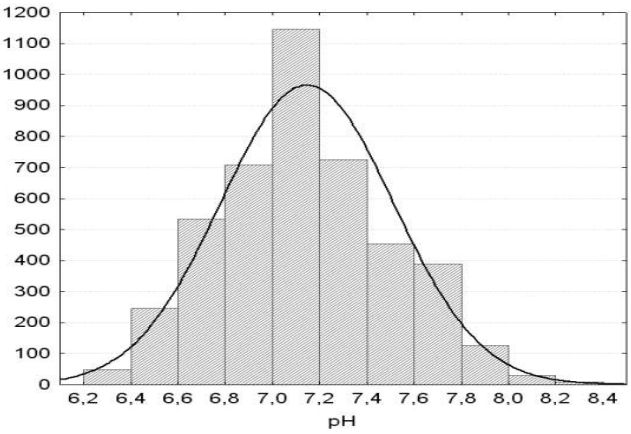
f(pH) = 13.09.x + 2.71.y + 0.19.x2 – 0.55.x.y+0.17.y2 – 274.74; R = 0.66

where, x – longitude, decimal degrees, *y* – latitude, decimal degrees

B

*f(pH) = 44.2 . sin (0.02298.x+0.7929) + 37.11 . sin (0.02589.x+3.815) + 0.3988*sin (0.06104.x+5.379); r = 0.0993*

c



d

The total number of cases	296
Average value	7.14
Confidence average interval	0.01
Median	7.13
Mode	7.69
Min	6.24
Max	8.52
Percentile 10,0	6.65
Percentile 90,0	7.65
Level of variation, %	5.1
Dispersion	0.13
Standard deviation	0.36
Standard error of the mean	0.005
Asymmetry	0.2
Kurtosis	–0.26

Fig. 6. Statistical-cartographic characteristics of soil distribution in the region (layers 0 ... 20 cm) by acidity (pH): *a* - cartogram of distribution; *b* - the function of spatial distribution; *c* - the function of providing soils with humus; *d* - statistical characteristics

Table 4. Distribution of exchangeable potassium content in soils of agricultural lands of the region

Exchangeable potassium content (mg kg^{-1})		Total	
		Thous. ha	%
Very low	< 100	64.0	3.6
Low	101 – 200	190.2	10.7
Medium	201 – 300	414.2	23.3
Increased	301 – 400	517.3	29.1
High	401 – 600	538.6	30.3
Very high	> 600	55.1	3.1
Total		1777.6	100.0

Table 5. Distribution of soil acidity in soils of agricultural lands of the region

Exchangeable potassium content (mg kg^{-1})		Total	
		Thous. ha	%
Neutral	6.1 - 7.0	636.4	35.8
Weakly alkaline	7.1 - 7.5	730.6	41.1
Medium alkaline	7.6 - 8.0	364.4	20.5
Strongly alkaline	8.1 - 8.5	46.2	2.6
Total		1777.6	100.0

solution. Under the influence of high acidity, harmful for plants substances may appear in the soil, for example soluble aluminum or excessive amounts of manganese. They may disrupt the carbohydrate and protein metabolism of plants. Increased soil acidity inhibits the activity of beneficial bacteria involved in the decomposition of manure, peat, compost and other fertilizers (Breus et al 2020). The autocorrelation analyzes of the spatial heterogeneity of the pH parameter, were minimum (r = 0.166) and maximum (r = 0.027) radius of typical conditions for pH, which is from 2.5 km to 7.5 km (Fig. 6). The lands of Henichesky and Chaplynsky districts have the highest soil pH. The lowest rate is in Oleshkivsky and Velykolepetysky districts. Among surveyed area, the share of alkaline soils (pH> 7.0) is 64.2%, among which strongly alkaline (pH > 8.0) - 2.6 %, medium alkaline (pH = 7.6-8) - 20.5%, slightly alkaline (pH 7.1–7.5) - 41.1%, neutral and close to neutral - 35.8% (Table 5).

CONCLUSIONS

The spatial modelling, the current state of spatial heterogeneity of the distribution of agroecological properties of soils in the steppe zone has been established. The soil cover of the region is characterized by low-humus soils with humus content in the range of 0.30-3.85%. The nitrogen content in the soils of agricultural lands of the region varied from 3.4 mg kg^{-1} to 41.3 mg kg^{-1}, phosphorus - 12.3 mg kg^{-1} to

78.2 mg kg^{-1}, potassium - 26.0 mg kg^{-1} to 703.4 mg kg^{-1}, the reaction of the soil solution (pH) varied from neutral 6.30 to strongly alkaline 8.29. Further preservation of soil cover and improvement of agro-ecological condition of soils depends on the development and implementation of methods for protecting soil from pollution and preserving its fertility. The stopping soil erosion processes is possible only if special measures are developed to classify lands according to erosion resistance, introduction of effective crop rotations, restoration of the field protective plantations (shelterbelts) that inhibit water runoff and the negative impact of wind on the humus layer in fields. Reducing of further chemical contamination of soils is possible by limiting the use of chemicals by farmers, and by using of environmental methods of plant protection through organic fertilizers based on the principles of organic farming, formulated by the International Federation of Organic Agriculture Movements (IFOAM).

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An Empirical Study on Attitudes towards Willingness to Pay for Forest Ecosystem Services at Simlipal National Park

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***Abstract*:** Forests provide innumerable positive externalities which are not just region-specific but they benefit globally. However, activities of forest-fringe households for survival often lead to degradation or depletion of natural resource base which affect global atmosphere. Under this circumstance, if the poor forest dwellers are forced to plug in to the system to mitigate environmental hazards what they create without offering alternate survival options to them that will affect their livelihoods and well-beings. The use and non-use values of forests must be understood by the forest dwellers so that they may eager to value the forests realizing the long term benefits. This paper is an attempt to determine the mean willingness to pay of the forest-fringe households for the ecosystem services provided by the Simlipal National Park, Odisha, India, and to determine the key factors affecting the willingness to pay through econometric modelling after creating environmental awareness in the studied region. The findings depict significant responses from the forest-fringe households regarding conservation measures and sustainable use of natural resources.

***Keywords*:** Economic valuation, Climate change, Natural resource management, Sustainability, Livelihood and Well-being

Activities of people always matter in making a world better irrespective of the fact wherever they reside. However, people need to be aware of how their day-to-day traditional practices spot on the world environment. According to the study of Wainger et al (2018), role of forest is multi-dimensional in protecting eco-systems and human well-beings. In developing countries, people residing in the forest areas derive a considerable share of their income from activities linked to the forests (Angelsen and Wunder 2003). Deforestation takes place when land covered with natural tree species is converted to meet certain human demands (Kumari et al 2019). Hence, deforestation is a dynamic process of forest loss (Armenteras et al 2017). The UN Food and Agricultural Organization (FAO and UNEP 2020) estimated the rate of deforestation at 10 million hectares per year globally between 2015 and 2020. Although the total forest area was estimated at approximately 5000 square metre per person but forests are not equally distributed around the globe. The study reflects more than 86 million green jobs were provided by the forests as a support of livelihoods. Over 90 per cent people were found as dependent on forests for their livelihoods by any means.

There are proximate and underlying drivers of deforestation that impact forest cover and result in loss of carbon stocks. The occurrence of forest declination in India is clearly reflected in the study of Umesh Babu and Nautiyal (2015), where the forest people are observed to utilize natural resources rather than conservation. India State of Forest Report (ISFR 2019) states that forest cover in India has been raised by 3976 square kilometres along with a slight increase in carbon stock by 0.04 tonnes per ha in 2019 from the previous assessment period, 2017. Among the number of states where green cover has raised with a fall in carbon stock, Odisha is one of them. Odisha's forest cover has increased by 273.51 square kilometres but with a surprising note of fall in carbon stock by 4.46 tonnes per ha during 2017-2019. Since forest is considered as natural carbon sink, so the fall in carbon stock in Odisha challenges environmental sustainability in mitigating climate change. Moreover, the studies of Rout et al (2010), Sahoo et al (2013), Dash and Behera (2012, 2013 and 2016) explore peoples' dependence on forests and the issue of sustainability in Odisha's forest, particularly at Simlipal National Park. Therefore, conservation strategy needs to be strongly focused upon.

In the context of safe guarding natural resources, valuation of forest becomes important. It is so because forest-fringe households who depend on forests should perceive environmental benefits from self-realizations. If seen economically then, Willingness to Pay (WTP) for the existence of forest significantly depends on the preference of the individuals from the ground of sustainability (Bamwesigye et al 2020). In the theory of environment and resource economics, WTP of any community for the real or virtual changes in the quality of environmental good can be measured either through the revealed preference method or stated preference method. Several studies (Chukwuone and

Okorji 2008, Bal and Mohanty 2014, Ansong and Roskaft 2014, Bamwesigye et al 2020) have been conducted worldwide to estimate the mean WTP of the forest dwellers for enjoying forest ecosystem services and the factors influencing WTP using stated preference method, particularly Contingent Valuation Method (CVM). In this study, we attempt to analyse the factors determining the WTP values of the forest-fringe households for forest preservation based on the prevailing socio-economic condition, and calculate the mean and median WTP values for the studied households for better conservation in future at Simlipal National Park region.

MATERIAL AND METHODS

Description of the study area: Forest being a rich ecosystem holds uncountable biodiversity (Kamri, 2013), and makes nature's value visible providing provisioning, regulating, supporting, and cultural services (The Economics of Ecosystem and Biodiversity). Our study is restricted to Simlipal National Park region of the state Odisha, India. The park is in the Mayurbhanj district of Odisha and full of diversified even endangered species of flora and fauna along with the home of indigenous tribal population. Indigenous tribal inhabitants carry ancestral knowledge and wisdom of biodiversity. Their active participation in conservation programmes helps the resource use more cost-efficient and environmental-friendly. ISFR (2019) states that Odisha has 33.15 percent (in India) and Maurbhanj district itself has 39.30 percent (in Odisha) of forest cover - both are more than the Indian average of 21.67 percent. Therefore, being a major biodiversity hotspot and having capability to maintain ecological balance, Simlipal National Park opens up the opportunity for future research. Similipal National Park covers 2,750 km^2 comprising three forest zones – core, buffer and transitional. In the core zone area, resource use and human settlement are restricted from biological perspective. In the buffer and transitional zones, different forestry operations continue under the safe limit. The park includes Tiger Reserve and Elephant Reserve as well.

Data and sampling: In the study, primary data have been collected from the forest dwellers at household level through an interview schedule to meet the objectives of the study. Procedure of data collection is depicted in (Table 1). Data are collected from varied forest zones in the expectation that both socio-economic-demographic variants of the forest dwellers and biogeographic consideration of the sudy area might affect the extent of forest dependence; which have direct impact on valuation in terms of WTP of forest dwellers for resource conservation. In the study of Garekae et al (2017), human dependence on forests is reflected as a multifaceted phenomenon, where the reliance varies geographically over time across varied communities.

Table 1. Procedure of data collection

Forest zones	Blocks	Number of surveyed household
Buffer	Bisoi	44
	Thakurmunda	45
Core and Buffer mix	Jashipur	42
	Bangiriposi	41
Transitional	Khunta	55
	Shamakhunta	35

Source: Primary data

In the present study, ten villages under the six above-mentioned blocks are chosen following convenience sampling method. Proportionate sampling method is used to collect information from the blocks at household level (33% population from each block). It is anticipated that motivation of conservation can truly be captured by considering all the household members collectively in the form of a subscription per month. On behalf of choosing households, systematic random sampling method is used. Every third household in a block is considered for the survey starting from a particular household determined randomly. Therefore, the sample holds the population characteristics based on the objective of the study.

Method used for analysis: In literature, though there are innumerable techniques to value environmental goods, but the use of a particular technique depends on whether the good concerned possesses use value or non-use value. Revealed preference methods are used for the goods possessing use value. Alternatively stated preference methods are useful for the goods possessing non-use value. Among several forest ecosystem services; provisioning service and recreational service may or may not be marketed always but regulatory and supporting services do not possess marketability at all. Therefore, while valuing forest ecosystem services economically, often the need of non-market based valuation techniques arise.

In the context of valuing environmental goods through non-market based valuation techniques adapting stated preference approach, at first hypothetical and/or experimental markets are created. These types of market are created for comparing the status quo situation and the alternate situation after generating environmental awareness among the people for natural resource use in a particular area. Contingent valuation method (CVM) is the most popular method in this regard where the consumers are asked directly for what they would like to pay for a specific virtual change in the quality of an environmental good or

service, if there is a market at all. However, everybody wants to have a free ride on environmental goods (being public goods) which makes valuation difficult. In our study, we have applied CVM to calculate the values of mean and median WTP of the forest adjacent households who receive benefits from the Simlipal National Park and thus wish to have better conservation in future.

In support of calculating average WTP values through CVM, either the bid for the proposed change in the environmental quality is offered to the respondent and asked for the consent in 'yes' or 'no' form (closed-ended referendum); or the bid amounts are left opened to the respondent (open-ended referendum). In the closed-ended bidding format, due to the presence of starting point and anchoring biases, there remains the chance of getting a biased result in determining the community's mean WTP for forest conservation. Further, immediate quantification of the WTP values is not possible in this method as the responses come in qualitative terms. Therefore, to get the values of WTP of forest-fringe dwellers for forest conservation in quantitative term at the time of conducting survey, open-ended bidding format works well. Among different open-ended bidding formats, open-ended bidding question (other than bidding game and payment card methods) directly quantifies the WTP values of the respondents for any change in the proposed environmental quality in one go. However, spreading of environmental awareness among the population to be surveyed becomes very crucial in case of open-ended bidding question as because illiteracy and lack of environmental concern may over or under estimate the values of WTP. In an under developed region, level of literacy always remains low which is true for our study area also. Therefore, at the phase of pilot survey, Focus Group Discussions were conducted in the villages to generate environmental responsiveness and in turn to get the true values of WTP of the forest-fringe households for the proposed resource conservation programme. Finally, the values of mean and median WTP of the forest-fringe households in monthly basis are calculated from the peoples' responses.

In the study, to determine the factors influencing the values of WTP of the forest adjacent households, regression analysis is done. It captures the strength of association between the dependent variable (WTP values of the forest-fringe households for forest conservation as open-ended bids) and the independent variables (total income, average age, average educational level, possession of agricultural land and domestic animals – all at household level; household size; and average distance between the near by town where the forest dwellers sell the forest products and the village where they reside). Some econometric tests have been performed to judge the validity of the model.

RESULTS AND DISCUSSION

In the study, while dealing with socio-economic-demographic factors responsible for determining WTP of the forest-fringe households, given the varied bio-geographic considerations of the study area, the dependent variable is considered as open-ended bid that the forest dwellers portrayed for forest preservation. The survey was conducted for 262 households. However, after screening the data through outlier tests, 255 households were considered for further analysis. The independent variables used in the study are depicted in (Table 2).

At Simlipal, dwellers are forest dependent in various ways. They collect several non- timber forest products (NTFPs) in different seasons after having permission from the forest officials. Conversely, when the Forest Department takes decision of felling matured trees, the officials seek help of the forest-fringe dwellers under the prevailing participatory forest management system. A part of the revenue from timber collection flows to the forest-fringe villages for regional

Table 2. List of independent variables

Variables	Descriptions
AVG_AGE	Age (in year) of working group population(14-65 years) in a household is considered to calculate average age of a household
AVG_EDU	Level of education of household members in coding [Variants: Illiterate- 0, pre-primary (3-6 years children)- 1, primary (classes 1-5)- 2, medium (classes 6-8)- 3, intermediate (classes 8-10)- 4, higher and undergraduate (above class 10)- 5, technical- 6] is considered to determine average education level of a household
HH_SIZE	Total number of members in a household
AGR_LAND	Agricultural land holding of a household: If Yes =1, No =0 (dummy variable)
DOM_ANM	Possession of domestic animals of a household: If Yes =1, No =0 (dummy variable)
LN_INCT	Rate of growth of total income of a household in monthly basis (in rupee)
AVG_DIST	Average distance between the near by town where the forest-fringe households sell the finished forest products and the village where they reside (in kilometre)

Source: Authors' own

development and well-being of residents through the Forest Protection Committees. The dwellers mostly collect dry leaves, twigs and fire woods as sources of fuel, sal leaves along with resin and seeds, siali and kendu leaves, kusum seeds and flowers, mushrooms, honey, bamboo, thatching grass, wild vegetables and fruits, wild date palm, mahua, etc. for self consumption as well as sale. These are used for making plates and bowls, preparing oil for cooking, soaps, brooms, wine, mats, handicrafts and for medicinal use, etc.

Survey data reveal that the average age of the household members is around 36 years. Mostly the dwellers are illiterate (around 36%). The mean household size is near to 5. Around 75 per cent households possess agricultural land and 87 per cent possess domestic animals. Around 71.31 per cent households are found having mean monthly income less than rupees 5000. In the study area, total income of any household is found varying abruptly over months through out the year as income from forest is seasonal in nature. Therefore, to determine the average monthly income, at first total income of any particular household is calculated annually considering both forest and non-forest income and then average monthly income is settled on. It is viable to assume that the rate of growth of average monthly income may capture the affordability and thus the true WTP for forest conservation of any particular household in the form of subscription per month. Further, the data expose that average distance between the near by town where the forest dwellers sell the final products and the village where they reside is 27.5 kilometres. Often market penetration becomes difficult to the dwellers as a huge time cost is associated with it. Therefore, they sell the products at throw away prices to the local vendors which undervalue their efforts. Food insufficiency as a result of vulnerable economic situation has made the lives of dwellers miserable. Descriptive statistics for the continuous independent variables used in the study is depicted in (Table 3).

The results of regression analysis are depicted in (Table 4). Regression analysis is done to determine the key factors affecting the values of WTP of the forest dwellers. Weighted Least Square technique (in the presence of categorical variables in the model) is used with the rate of growth of total income as weight to overcome heteroskedasticity in the model. Heteroskedasticity does not cause bias in the coefficient estimates, it does make them less precise. Lower precision increases the likelihood that the coefficient estimates are further from the correct population value. Goodness of fit of the estimated model is shown by the value of R-squared, which is 0.16 for this cross section data. This indicates that 16 per cent of the variation in the data of dependent variable is due to the variations in the data of independent variables collectively. The value of F-statistic is 6.81. The associated P-value of F-statistic is 0.00, which

Table 4. Results of Regression with white-Heteroskedasticity-consistent standard errors

Variable	Coefficient	Standard Error	Probability
C	-101.6860	30.3871	0.0009
AGR_LAND	-8.5445 **	4.2273	0.0443
AVG_AGE	0.3713 **	0.1929	0.0555
AVG_DIST	-0.1782 **	0.0855	0.0382
AVG_EDU	5.1940 ***	1.7633	0.0035
DOM_ANM	10.2714 **	4.1366	0.0137
HH_SIZE	-1.1983	0.8099	0.1403
LN_INCT	10.1446 ***	2.7956	0.0003

Weighted Statistics

R-squared 0.1618
Adjusted R-squared 0.1380
S.E. of regression 22.9726
Log likelihood-1157.012
F-statistic6.8103
Prob(F-statistic 0.0000
Akaike info criterion 9.1373
Schwarz criterion 9.2484
Hannan-Quinn criterion 9.1820

Unweighted Statistics

R-squared 0.1595
Adjusted R-squared 0.1357
S.E. of regression 22.3793

N: 255
Weighting series: LN_INCT
Weight type: Inverse standard deviation
White heteroskedasticity-consistent standard errors & covariance

*** denotes significant at 1 per cent level, ** denotes significant at 5 per cent level

Source: Calculated by authors

Table 3. Descriptive statistics of continuous independent variables

Variable	Observation	Mean	Standard deviation	Minimum value	Maximum value
HH_SIZE	255	4.89	1.91	1	11
AVG_AGE	255	36.69	9.24	17.33	62.5
LN_INCT	255	10.66	0.63	8.79	12.47
AVG_DIST	255	27.75	16.33	8	55

Source: Authors' own

indicates that overall the regression result statistically significantly predicts the outcome variable.

The estimated results show that the independent variables like agricultural land holding, average distance (between the near by town where the forest dwellers sell the forest products and the village where they reside) and household size have negative coefficients whereas, the coefficients of other independent variables are positive. In real life, households with a lot of members extract much forest resources for survival which lead to natural resource depletion (Adhikari et al 2004 and Tugume et al 2015). In the study area, it is found that with the increase in household size, WTP of households for forest conservation trims down due to reduced affordability. Asset base deeply impacts forest dependency of a household (Dash and Behera 2016, Fisher 2004). Agricultural land holding as an important asset base is treated like alternative source of earning which lessens forest dependence. In the study area, it is found that people having agricultural land wish to pay less for forest protection since the use of forest resource is nominal for farming households. Further, increase in average distance between the near by town where the forest dwellers sell the forest products and the village where they reside reduces WTP for forest conservation as it is associated with higher time cost and effort of the forest-fringe households to get involved in market activities for earning.

On the contrary, increase in educational level creates environmental responsiveness which helps in raising WTP of the forest dwellers. In the study, households with higher average education levels indicate the presence of more educated members, which endures positive impact on environmental protection. Further, with the increase in age, realization develops for the uneventful happenings of environment and need for preservation of natural resource base (Cavendish 2000). This urge for preservation, which develops through age, leads to the increase of WTP values. In the study, households with higher average age indicate the presence of more aged members. The extended outlook of resource conservation by the aged members lifts up the WTP values. Conducting a survey of people residing near by Gunung Gading National Park, Sarawak, Kamri (2013) reveals that WTP is strongly influenced by gender, education and income of the dwellers. The study also demonstrates that open-ended CVM is a useful tool to manage natural resources in developing countries. The study of Jacobsen and Hanley (2008), considering 145 WTP estimates for biodiversity conservation from 46 contingent valuation studies across six continents exhibits that demand for biodiversity restoration rises with a nation's wealth, but the income elasticity of WTP is less than unity. Increase in income intensely impacts affordability and WTP values of the dwellers for forest protection. In the study, a positive correlation between the increase of WTP values and the rate of increase of total income is clearly visible for the forest adjacent households. While dealing with livestock, often it is found that households possessing them require enough pasture land for feeding. Therefore, forest-fringe households remain against of depletion and interested in preservation of natural resource base, which enhance their WTP values. This is also true at Simlipal region.

All the variables except household size are turned out as statistically significant in the model. Rate of growth of total income and average education are significant at 1 percent level. Average age, domestic animal, average distance and agricultural land are significant at 5 per cent level. The test for multicollinearity is performed for the above regression model to identify the correlation between the independent variables and the strength of that correlation. The result of testing multicollinearity is depicted in (Table 5).

In Table 5, centred VIF is numerically identical to the VIF formula. The mean VIF of the model is 1.35, which is within the threshold value of 10. Therefore, the result indicates almost the absence of multicollinearity. Since the presence of multicollinearity makes it tedious to assess the relative importance of independent variables in explaining the variation caused by dependent variable, this test is crucial for any cross section data.

Finally, after confirming that none of the important variables are omitted in the model, the average WTP values of the forest-fringe households collectively for forest conservation are calculated in monthly basis. Since the exact information for the values of WTP are available in quantitative term straight away in case of open-ended bid, the averages are calculated using arithmetic mean and median. The calculated mean and median WTP values of the households

Table 5. Test for multicollinearity of the estimated regression model

Variable	Coefficient variance	Centered VIF
C	923.3777	NA
AGR_LAND	17.8699	1.4444
AVG_AGE	0.0372	1.1085
AVG_DIST	0.0073	1.3562
AVG_EDU	3.1091	1.0985
DOM_ANM	17.1118	1.5391
HH_SIZE	0.6560	1.4652
LN_INCT	7.8154	1.4916
Mean VIF		1.35

Source: Calculated by authors

are Rs. 20.235 and Rs 10 per month respectively in the study. Median WTP is less than Mean WTP since the lower bids are more likely than the higher bids in case of environmental goods possessing the property of free riding. Similar kind of valuation result is reflected in the work of Bal and Mohanty (2014), but through Travel Cost Method, surveying the visitors to capture their WTP for maintenance of Bhitarkanika National Park, Odisha. The authors have suggested that rising of entrance fee from Rs 20 to Rs 40 might be useful for better conservation.

In the model, ethnic composition - sex, religion and caste have not shown any significant relevance in determining WTP of the forest-fringe households and hence those variables are not considered in the regression analysis. The sex ratio in the study area is M:F = 51:49. Around 95.21 percent people belong to tribal population (*Khadias, Mankadias, Gonda, Munda, kol, Erenga, Bhumija,* etc) and around 82.87 percent people holds the religion *Hinduism*. It is revealed from the study that despite the poor economic condition, most of the dwellers have keen interest in resource preservation. Almost 77 per cent of households wish to pay for conservation either from savings or reducing the amount of daily expenditure. The dwellers who denied paying for forest preservation, they are economically vulnerable. In this circumstance, government's initiative for livelihood promotion might be beneficial for increasing WTP values of the forest adjacent households for taking up forest restoration programme. Basu (2020) focuses on peoples' forest dependence and the need for preservation of forestry resources analyzing the data collected from nine villages covering 252 households in Purulia district of West Bengal. His work has important policy implication, but at the same time uncovers the fact that creation of alternative employment and income from off-farm sector might help forest conservation. Collection and pattern of utilization of NTFPs in Nagaland, India, have been portrayed in the study of Das et al (2020) collecting 100 samples from ten villages. Since NTFPs are treated as significant contributors of rural households' income, so the authors state that efforts should be on channelizing the products from local to commercial markets which might enhance their income. Therefore, households' wealth and income play a significant role in natural resource preservation programme. Yen et al (2020) examined the level of payment of forest ecosystem services in Vietnam from these perspectives.

CONCLUSION

In the study, after analysing status quo situation of the forest-fringe households, factors affecting WTP values for forest conservation have been analysed. Consequently, the mean and median WTP values for forest conservation have been derived. It is revealed that rate of growth of total income, level of education, presence of aged members, market proximity and asset base of the households influence WTP values of the forest adjacent households significantly for forest preservation. Therefore, policies should be oriented towards generating alternative sources of income for livelihood promotion and creation of asset base. Government might take a lead in creating environmental awareness with the provision of education and through campaigning, so that the dwellers can understand the need of conservation at the early stage from the perspective of intra and inter generational equity. Further, government might think of regional development so that the people can penetrate in market activities in profit mode. It is likely that the concerns for preservation of natural resources will help not only at local level, but the fruits can be perceived globally through improvement in climatic conditions. Therefore, proper policy designs and implementations from the government level keeping in mind the needs of forest dwellers might help develop the society with maintaining ecological balance as the people are keen to preserve natural resources at Simlipal National Park. Limitations of the study are deep-seated in the facts that the data set may be extended and the other valuation techniques under closed-ended bidding format may be used to calculate mean or median WTP of the forest dwellers for forest conservation which might increase the reliability of the study.

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Review on Water Holding Capacity of Soil Across the Tropical and Subtropical Forests in India

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Abstract: India is one of the world's mega-regions for biodiversity, with 64M ha of protected land comprising 23% of its land. Among these 51M ha of forests are tropical forests rich in vegetation and home to numerous rare, endangered and threatened species. Tropical forests are decreasing at an alarming pace due to various natural factors (floods, cyclones, etc.) and man-made factors (forest fire, clear-cutting, mining, etc.) and this has also led to a decrease in soil quality, which later renders them abandoned. The physiochemical properties of the forest soil differ depending on time and weather, such as temperature, precipitation cycles, topography variability, vegetation cover, various microorganism activities, and other biotic and abiotic factors. The soil- water system is one of the most important soil factors for plant production, carbon allocation, efficiency in photosynthesis, nutrient cycling and biological growth. Water Holding Capacity (WHC) is one of the key parameters that is essential for forest productivity and is significantly associated with increased tree height. The analysis of research papers of past 4 decades was taken into account and found that WHC is one of the key factor that can be used assess forest situations and productivity. Therefore, proper monitoring of this parameter should be carried out in order to conserve and protect the forest ecosystem and for sustainable forest management.

Keywords: Water holding capacity, Moist tropical forest, Dry tropical forest, Sub-tropical forest

According to the Global Forest Resource Assessment, the land extending over 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees capable of meeting these *in situ* thresholds is called as forest. Land used for agricultural purposes and urban land use is not considered forest despite having tree coverings. Around 30% of the land on Earth is covered by trees, which is 4.03B ha of land. The five tree-rich countries that reside in these areas are the Russian Federation, Canada, Brazil, America and China, and 53% of the total forest area are present in these countries (FAO 2010, Pan et al 2013). The tropical forest covers 1.73B ha of land . These forests lie in the tropics, the location between latitudes 23.5°N (Tropic of Cancer) and 23.5°S (Tropic of Capricorn), and have two well-known rainy and dry seasons (Osman 2013). Since these forests are situated in the tropical zone, the sunlight projects to the earth's surface at an angle of 90°, and the rate of water evaporation on the oceans and evapotranspiration on the tropical land is very high. Forests situated between the tropics (23.5°) and 30°N & 30°S can be called subtropical forests, and are considered the transitional forest between tropical and temperate forests. Such regions receive rainfall of 600-700 mm per annum (Corlett and Huges 2015). India falls in the tropical area of Earth, and the Tropic of Cancer moves through it. It has 64 million ha of forest land which is 23% of its land area, and 51 million ha or 80% of its forests belong to tropical forests (Poker and MacDicken 2016, Ravindranath and Sukumar 1998). Within this, 64% of the forest accounts for moist deciduous tropical and dry deciduous forests and 8% of tropical wet evergreen forests (Ravindranath and Sukumar 1998).

Due to topography, temperature, rainfall pattern and site quality the tropical forests are rich in vegetation and have intact habitats. For this reason, several uncommon, native, threatened, and endangered species have been attracted by the forest (Nawaz 2018). Land vegetation has a significant effect on the origins of the forest soil because of its canopy, roots, littering and biomass. Additionally, forest soil has an effect on forest vegetation dynamics. Forest soil and vegetation are also interdependent on one another (Osman 2013). The physiochemical properties of the forest soil fluctuate depending on time and condition such as climate, weathering processes, the difference in topography, vegetation cover, various activities involving microorganisms and other biotic and abiotic factors (Sharma et al 2017).

The soil-water system is one of the soil's influences, which is most important for plant production, carbon allocation, photosynthesis efficiency, nutrient cycling and microbial activity. The soil, water holding capacity (WHC) is the maximum amount of water that can be stored by a soil after saturation and available to the plant, and is the factor used to indicate the capacity of the soil to provide water for

plant growth and development. WHC may also be defined as the difference between field capacity and wilting point of the water content. This trait can be suitable for different types of vegetation development and combined with climatic conditions enables determination of the soil, water balance (Piedallu et al 2011). Regardless of the presence of high organic content in it, clay soil holds more water than other types of soil, because it has a high propensity for moisture (Nath 2014). Since the pore size is very small, the suction holds water in clayey soil while the pore size for sandy soil is so large that water cannot be held in it as gravitational force would be higher than the surface tension. Thus texture is one of the important parameters which determine the WHC of the soil. When viewed with time function, the permeability and temperature also influence WHC (Lund 1959). WHC is very important for forest productivity and is significantly linked to the growth of tree heights. Studies have shown that mapping WHC of soil could be used to predict potential forest strands development (Harding and Grlgal 1984, Piedallu et al 2011). Hence WHC can be used as one of the parameters to evaluate forest conditions and productivity.

India has 5 major forest types and 16 subtypes according to the Champion and Seth classification (Champion and Seth 1968). The first three forms in this fall under the tropical and subtropical forests. Given there are thousands of endangered living species in Indian forests, their productivity should be protected, well managed and monitored. The primary aim of forest management is to protect forest health and its ecological services. Our review highlights the research work carried out at WHC in the various tropical and subtropical forest soils in the past 4 decades. This review focuses on how the WHC of the soil differs throughout the tropical and subtropical forest regions of India and how it affects the development and services of its particular forest.

WHC in Various Moist Tropical Forest Regions

Tropical forests are situated in the tropics, which is the region between 23.5°N and 23.5°S latitudes and has two well-known rainy and dry seasons (Osman 2013). Tropical, moist forests are the most complex in the world and have a variety of ecosystems (Myers 1980). They are biologically abundant, have high productivity and play a very important role in the management of the carbon cycle and water (Bhat et al 2017). The principal identification of these forests is the wide range of tree species, lianas, orchids, mosses, ferns, bromeliads, and palms (Osman 2013). Tropical forest soils have moderate to low fertile soils, and nutrients are stored in plant biomass. This biomass is available to plants and animals, and the plants achieve certain adaptive mechanisms for holding and acquiring nutrients (Lalnunzira and Tripathi 2018). Moist tropical forests fall into 4 subtypes (Champion and Seth 1968).

Tropical wet evergreen or tropical rainforests are found mostly in Southeast Asia in India, Sri Lanka, Bangladesh, Indonesia, Myanmar, Brunei, Malaysia and Papua New Guinea, and are found as patches in India, Bangladesh and Sri Lanka (Osman 2013). In India they are found in the western sides of Western Ghats, Arunachal Pradesh, Nagaland, Tripura, Mizoram, Manipur, upper Assam and Andaman and Nicobar Islands. Such forests are growing where annual rainfall is about 250 cm, humidity is about 77% and the temperature is about 25-27°C (Khullar 2014). The area covered by this forest is 5414k ha in India and almost 1700 M ha in the world (Kumar et al 2012). The forest is said to be semi-evergreen forests, when the proportion of evergreen is greater than that of deciduous forests (Osman 2013). The annual rainfall is 200-250 cm and humidity is about 75%. These forests are more found in Assam, Western coast, Odisha, some parts of Eastern Himalayas and Andamans (Khullar 2014). In India, this forest occupies 2946k ha of land and there are 15363.42 km^2 of this forest in the north-east. The upper canopy is defoliated during dry seasons, and the lower canopy is foliated. Tropical semi-evergreen forests are rich in flora and fauna and are home to many species that are critically endangered (Kumar et al 2012, Majumdar 2015). Tropical Moist Deciduous Forest covers some 24284k ha of India and 1300M ha of world's land. *Shorea robusta* is the key plant species, and species have low branching and are less abundant in this area [FAO 2015, Osman 2013). Approximately 100-200cm of annual rainfall and 60-75% of humidity is there in these forests. During the early summer, the trees shed their leaves, and grow when rain occurs. These forests can be seen in Western Ghats, Chota Nagpur Plateau, Odisha, Manipur, Mizoram, some parts of Madhya Pradesh, Chhattisgarh and West Bengal and on the islands of Andaman and Nicobar (Khullar 2014). This forest is dominated by arbors such as *Shorea robusta*, *Dalbergia sissoo*, *Butea monosperma*, *Tectona grandis* and bamboos (Saikia 2017). Further recognized as tidal forests seem to be littoral and swamp forests as they grow in the area where tidal influence is more like deltas, estuaries ad creeks and covers 481k ha of Indian land. They are characterized by the presence of mangroves and are present in the Ganga, Brahmaputra, Godavari, Krishna, Mahanadi, and Cauvery deltas of river. The Sunderbans is India's largest mangrove forest, present on the Ganga river delta (Khullar 2014, Kumar et al 2012). High levels of sand and silt for tropical mangrove habitats indicate the presence of a relatively high energy climate with very successful winnowing activity (Rajal et al 2019)

The forest soil's WHC was found to be decreasing with respect to human-induced disturbance. In the tropical wet evergreen forest found in Arunachal Pradesh's Namdapha National Park, soil's WHC was found to be 66.48±2.60% in the undisturbed area, 52.03±1.44% in the moderately disturbed region, and 38.40±2.82% in the extremely disturbed region (Nath et al 2005). The WHC of disturbed, moderately disturbed and undisturbed site was found at Deomali Reserve Forest, Arunachal Pradesh, to be 40.02±1.16%, 45.77±6.85% and 59.99±1.96% respectively (Barbhuiya et al 2004). Similarly, the WHC of disturbed and undisturbed sites in the tropical moist deciduous forest of the Lacchiwala Forest Reserve in Dehradun, Uttarakhand, was 45.77±6.50% and 58.88±1.16% respectively (Sharma et al 2017). Forest vegetation has been found to be decreasing as regards the rise in disturbances (Nath et al 2005). As the disturbance index increased, the density of vegetation and the basal area decreased for the tree and shrub and increased for the herb. More grasses have been detected in the undisturbed area (Barbhuiya et al 2004). The area experienced an increase in light intensity, humidity, temperature and pH due to the lesser number of trees in the disturbed region compared with the undisturbed (Sharma et al 2017). The soil's sandy texture was found to be high, and there was less silts and clay content in the disturbed area. Hence the content of clay and organic matter in the undisturbed area was high. It was also found that the litters and fine roots diminished with that disturbance (Nath et al 2005, Sharma et al 2017). Bacterial and fungal population and microbial biomass C, N and P, due to the rich organic matter, were high in the undisturbed site of the selected forest region. There was strong positive correlation ($P < 0.05$) between plant density and bacterial ($r = 0.937$) and fungal ($r = 0.931$) populations in the soil (Barbhuiya et al 2004). The seasonal floods, tree felling and grazing also had an impact on the number of seedlings and saplings in moderately disturbed areas and the collection of firewood, grazing and clearing vegetation for cultivation in highly disturbed areas has resulted in a decrease in the number of seedlings and saplings in Namdapha National Park (Nath et al 2005).

The Sanyasimalai Reserve forest of the Shervarayan hills, Salem, Tamil Nadu, is found at an altitude of 460-1600 m, on the south-western part of the Eastern Ghats, and semi-evergreen forest are in between 1400-1600 m altitudes. Consideration was provided to four sites (SM1-SM4), and WHC was determined at different depths. For the SM1, for the depths 0-10 cm, 10-20 cm and 20-30cms, WHC was found to be 72.6%, 90.3% and 84.7%, respectively. For SM2, WHC at 0-10cm was 66.2% and for SM3 it was 74.6%, 73.8% and 75.0% at 0-10cm, 10-20cm and 20-30cm, respectively. For SM4, WHC was 63.9%, 71.2%, 71.5% and 69.0% at 0-10cm, 10-20cm, 20-30 cm and 30-50cm, respectively. In SM4 the density of the forest was significantly greater, as it was away from social human presence. The expanding population structure has shown the site has mature stands with good regeneration. But to protect the forest, the expansion of plantation and aluminum mines should be controlled. Otherwise, the forest ecosystem will decline in later years and may pose a significant threat to the species over there (Kadavul and Parthasarathy 1999).

WHC also increased with a rise in elevation. This pattern was noticed in the studies carried out in Western Ghats' tropical wet evergreen forest and its foothill forests and tropical moist deciduous forest in Garhwal Himalayas present in Uttarakhand (Kadamannaya et al 2010, Sheikh and Kumar 2010). The WHC was found to be 57.19± 2.65% and 49.95 ± 0.26% in the Western Ghats and its foothill forests, and 65.34 ± 0.58% and 51.43 ± 1.70% respectively in plantations in those areas. In the forest region the organic C has been found to be significantly higher. WHC was found to be 36.64±0.69% in the western coastal plane. The biomass and abundance of pill millipede was found to be higher in the plantations due to the high WHC and low bulk density (Kadamannaya et al 2010). In two forests of Garhwal Himalayas oak (*Quercus leucotrichophora A Camus*) and pine (*Pinus roxburghii* Sarg.) present in Uttarakhand has an average WHC of 31.28% and WHC was found high in the oak forest due to its dense canopy which produces more litter which in turn improves the soil texture (Sheikh and Kumar 2010).

In the tropical moist deciduous forest of Katerniaghat Wildlife Sanctuary, present in the Upper Gangetic Plains of Uttar Pradesh, there are five plant community structures consisting of dry miscellaneous forest, salt mixed forest, teak plantation, lowland diverse forest, and savanna ecosystem. The highest WHC was found in the teak plantation (48±11.1%) and the lowest in the savanna ecosystem (40±7.3%) (Mishra et al 2017). However, in the case of Dudhwa National Park, UP, the maximum WHC has been found in Lowland Miscellaneous forest and low in man-made teak plantation habitats. The WHC was found to be 91.65±3.07%, 64.70±22.38%, 81.07±8.61%, 53.63±10.97% and 54.87±2.68%, respectively in Lowland Miscellaneous Forest, Sal – Asna Miscellaneous Forest, Sal Miscellaneous Forest, Teak Plantation and Eucalyptus Plantation. The study indicates that the seven edaphic variables, which are electrical conductivity, bulk density, soil porosity, WHC, P, K and total organic N, affect the community building process (Bajpai et al 2020). Increase in WHC and decrease in the bulk density of the forest compared to the savanna ecosystem

reveals that soil structure and hydrothermal conditions have increased, increasing the area's vegetation cover. Where the WHC was more, more species richness was found, which says WHC plays a significant role in the vegetation cover (Mishra et al 2017). The Veerakkal forest area situated in the Western Ghat in Tamil Nadu has tropical moist deciduous forest. In a study conducted in these forests on dominant patches of *Pongamia pinnata,* co-dominant species of *Terminalia arjuna* and associated species like and *Gardenia resinifera* and *Celtis phillipensis,* it was found that WHC ranged from 15.69-41.82% and highest was in *Pongamia pinnata.* It was found that WHC was found to increase with depth irrespective of the season and high value indicated the good condition of soil and forest (Ramya et al 2021)

The Mudumalai Tiger Reserve's moist deciduous forest, Tamil Nadu, which is part of the Nilgiri Biosphere Reserve, is frequently exposed to forest fires caused by poaching, grazing, antler collection, etc. The 2 soil types found in this Reserve are red heavy loam soil and black sandy loam containing 50% sand and gravel for rest. WHC conducted at 6 sites with increasing incidents of forest fires, it was found that with the multiple occurrences of fires, WHC has decreased. It ranged from 54.83±3.09% at the control site where there has been no fire in the last 15 years, to 43.50 ± 4.00% at the site where the field was 6 times burned. In this bulk density was increased with increasing frequency of fire, which reveals that the WHC and bulk density are negatively correlated with each other under any circumstances. The forest fire destroys the soil's WHC in the organic horizons and it burns the organic matter (pyrolysis), which creates vapors which travel down due to the temperature gradient and is condensed on the soil's particles, making them water repellent (Verma and Jayakumar 2018). WHC was 48.26 ± 2.9%, 51.62 ± 3.83% and 54.19 ± 5.73% respectively in the same forest that experienced forest fire in 2 years, 5 years and 15 years ago. The WHC was found to develop when the forest fire didn't occur over the years, which shows that forest fire reduces the quality of the soil (Verma et al 2019).

Sunderbands are India's most extensive mangroves (Khullar 2014). The WHC was found to be 67.89%, 72.95%, 75.23%, 67.69%, 65.5%, 71.5% and 63.5%, in a study conducted on various Sunderbans Islands, namely Prentice, Thakuran, Natidhopani, Chitori, Harinbhanga, Khatoajhori and Jhilla, respectively. In the regions in which there was high WHC, two mangrove species, *Avicennia alba* and *Acanthus ilicifolius*, were reported (Matilal et al 1986). The Gulf of Kuchchh, Gujarat has India's second-largest mangrove. In a study conducted at 10 different forest sites, it was found that WHC ranged from 4.89% to 76.71% and was high at the Dedeka Mundeka site during the pre-monsoon and low at Mandvi during the same season (Rajal et al 2019).

The two Muthupet mangrove forest locations, Tamil Nadu, which are Manakkattai and Xaviermunai, present on the Cauvery River deltas, the WHC was 27.45%, and 21.56%, respectively. In Manakkattai the organic C and organic matter levels found to be higher and low in Xaviermunai (Vijayakumar 2014). Another two forests in Ratnagiri district, Deogad creek and Mumbra creek respectively had WHC of 22.92% and 51.12%. The sand composition in the Deogas creek soil (83.42%) was high compared with the Mumbra creek (81.17%). Certain mineral nutrients at the Deogas creek were also found to be lower (Kotmire and Bhosale 1979). But there is no significant difference in the composition of the sand, but the WHC has shown great variation which should be further investigated.

WHC in Dry Tropical Forests in India

Tropical dry forests differ in form, from the tall, closed-canopy forest to the short scrub vegetation. Within this forest, the grasses are fewer and encounter less fires (Dexter et al 2018). The season is long, extreme, and dry. Tropical dry forest promotes full-plant diversity and offers more products and services to the ecosystems. Those are really prime land for cultivation, as they have a high content of carbon and biomass. Because of this, most of these forests are turned into agricultural land and these forests should, therefore, be protected in a larger context.

Tropical dry evergreen forests are located along India's Coromandel coast and occupy only 165k ha of Indian land. These are three-layered trees, which typically rises to an altitude of around 9-12m and above. Except for the Point Calimere Wildlife Sanctuary, Nagapattinam and Kurumbaram portion of the Marakanam Reserve Forest, these forest occur as patches. Most of these forests are being covered by the presence of sacred groves within them (Kumar et al 2012, Parthasarathy et al 2008). The region's annual rainfall is around 100 cm and 75% humidity (Khullar 2014). Tropical dry deciduous forests occur in the region with very low rainfall of 100-150cm with 5-6 dry months (Singh and Chaturvedi 2017). These trees are transitional in nature, as the forest is moist deciduous when it is wetter and degenerates into thorns. They are found sparsely from the Himalayas to the Kanyakumari region, with the exception of Western Ghats, Rajasthan, and West Bengal and cover Indian land in 19158k ha (Kumar et al 2012, Khullar 2014). Tropical moist deciduous forest is typically three storied and the upper canopy is 15-25m thick, with very few grasses and herbs growing on the ground cover. The lianas are very common in the denser forests. The soils are simple, alluvial, ferruginous, black soil on the trap and thin laterite, well-drained under the teak but ferrallitic or ferruginous under the

sal (Meher-Homji 2008). Tropical thorn forests occur in the area with very low rainfall of less than 75cm and very low humidity of less than 50%. The trees are widely spaced, and the height is lower. These forests are in the state of Rajasthan, Haryana, Kachchh, some parts of Saurashtra and leeside on the Western Ghats (Khullar 2014). The forest occupies an area of some 1827k ha of the Indian forest (Kumar et al 2012).

The Kuzhanthaikuppam and Thirumanikkuzhi, two tropical dry evergreen forests present near the Cuddalore along the Coromandel Coast, Tamil Nadu has red ferralitic soil. These are sacred groves and are home to many varieties of plants. At these sites, respectively, the WHC was 36.33% and 28.65%, which was achieved during the pre-monsoon period and species wealth was greater in the Kuzhanthaikuppam region. From this site, organic C, total N and P were also found to be much more. However, the major challenge to the ecosystems was its collection of firewood, grazing, and surrounding agricultural land (Parthasarathy and Karthikeyan 1997). The soil was also found to be red ferralitic at another location in the reserve forest of Marakkanam on the Coromandel Coast and WHC was 32.9%. In another Puthupet Sacred Grove site, litter production was higher than in the Marakkanam Reserve Forest, but the organic C, N, and P were very low at Puthupet, despite high litter production. Fine root development in Puthupet was strong as the litter seems to be more and when limited life, because nitrogen leaching was more due to the alluvial nature and very low WHC, was found in a sandy loamy soil (Visalakshi 1994).

In the Uttar Pradesh districts of Mirzapur and Sonbhadra, the soil from the 6 study site was observed to be good – drained Utisols with red to reddish brown color and sandy to sandy loam texture. The soil has very low organic content and WHC of Hathinala moist site, Hathinala dry site, Kotwa hilltop, Kotwa hill base, Barkaccha and Telburva was 46.4%, 45.6%, 45.2%, 38.1%, 40.1% and 41.0%, respectively. Among the 6 sites, Hathinala moist site was high in organic C and N content which reveals high organic matter due to dense Sal forest in this site. Deforestation for fuel and cattle grazing had led to a decrease in the Telburva region's organic C and N content and thus more action should be taken to conserve the forest over this area otherwise plants with low mineral content would not be able to thrive in those (Shankar and Kashyap 2007). Xerophytes lead to those regions because of low nutrients and organic matter. Hence, the presence of xerophytes indicates that this soil's nutrient content is very poor and in effect WHC (Singh and Shrivastava 2007, Sanjay et al 2018). This finding was made in studies carried out in the Ranthambhore Tiger Reserve, Rajasthan and 6 Sacred groves in Maharashtra. The 3 major soil types, reddish-brown sandy-loam soil, blackish-brown clay-loam soil and light brown sandy soil had WHC of 25.76 %, 33.06 % and 28.45%, respectively, in a comprehensive study conducted in the Ranthambhore Tiger Reserve, Rajasthan (Singh and Shrivastava 2007). The assessment was done in 6 sacred groves of the Aarewadi, Banali, Dandoba, Raywadi, Sagareshwar and Shukacharya from the arid area of the district of Sangli, Maharashtra the WHC were 45%, 41%, 38%, 39%, 49% and 44% respectively. It was found that the soil of those groves has more gravel and sand. Since the region received only very few rainfalls during the rainy season, and it was noticed that the water level was very low (Sanjay et al 2018). The organic matter and nutrients in these 2 regions were found to be very small and thus xerophyte growth is seen in these regions due to this edaphic condition (Sanjay et al 2018, Singh and Shrivastava 2007).

Jhunjhunu district in Rajasthan has salt-affected sandy and black soils. The soil surface WHC study was found to be higher for 60% for the rainy season and low for the summer (27.6%) in 2017 and 58.7% for the winter and 19.5% for the rainy season in 2018. Due to the sandy aspect of the soil, the WHC was found in lower at all the sites. For these regions, salt content was found to be high and N and K were found to be low as well .

Hastinapur is situated in Uttar Pradesh 's north upper Gangetic plains, and has fertile soil. Three sites were chosen, the extremely disturbed Hillock, the moderately disturbed Block 1 and the least disturbed Block 2 and the WHC were 91.51%, 78.82% and 72.39% respectively. The number of trees was found to be low in Hillock relative to other sites due to frequent anthropogenic disturbance (Khurana 2009). Shisham (*Dalbergia sissoo* Roxb.) are deciduous forests in the sub-Himalayan and outer valleys of the Himalayan. A study was carried out in these forests located in the district of Udham Singh Nagar, in the south of the central Himalayan Outer Shiwalik range, India. As tested on forests aged 5, 10 and 15, the WHC has been found to increase, which is 86.7%, 87.1% and 87.6%. Within these forests, the overall vegetation and litter biomass were also found to increase with the age. It is well understood from this that forest age plays a major role in deciding WHC, and soil quality is increased as the forest age increases (Lodhiyal et al 2002).

WHC of Forest Regions of Montane Sub-Tropical

With an average rainfall of 75-125 cm and average humidity of 80%, Sub-Tropical Broad Leaved Hill forest covers 303k ha of land. Such forests are located mostly in the eastern Himalayas at an altitude of 1000-2000 m, and in the hills of Niligiri and Palani at an altitude of 1070-1525 m. Epiphytes and climbers are common in this area, and oaks,

pines and chestnuts are common tree species. Subtropical Moist Pine forests cover the Naga Hills, Khasi Hills, Meghalaya, Arunachal Pradesh and Manipur. Chir is the most dominant type of arboreal. The basement is very small, and has a grassy foundation. The forest covers 4743k ha of Indian ground and are located between 1000 - 2000 m above sea level (Kumar et al 2012, Khullar 2014).

Cherrapunjee plateau, Meghalaya has a sandy loam soil texture and is acidic in nature. The top thickness of soil would be just 30cm. The WHC was found to be 20.57±1.12%, 25.35±0.08%, 24.70±0.495% and 19.22±0.43% respectively, in a study performed in undisturbed forest (UF), 1-year-old recovering stand (CF1), 5-year-old recovering stand (RF5) and 10-year-old recovering stand (RF10). Due to clear-cutting, it was clearly seen that the number of tree species in CF1 stands was 41% of the UF stands which suggested that the number of tree species is drastically reduced. It has been shown to increase in 5 years and 10 years of recovering strands, which is said to increase the number of tree species during the early years of secondary succession. In clear-cutting, the number of shrubs and herbs has been found to increase. Shrub species have been found to grow 64% in CF1 and 129 percent in RF5 compared to UF. CF1 had high herbal species but declines in RF5 and RF10 were observed (Mylliemngap et al 2015).

A research on the soil of dead standing pine trees (*Pinus roxburghii* Sarg.) was performed in Sitlakhet and Bimola in Uttarakhand. During the rainy season, the WHC at both sites was higher (26.59±3.01%; 29.37±1.19%) and small in the summer (20.22±2.09% ; 21.69±1.98%)and was found to be declining with soil depth. The study shows that dead trees possess the ability to store C-stock. Because of its decomposition, the dead trees raise the biomass of the forest floor (Gosain 2016). In an Indian Central Himalayan study conducted in degraded and non-degraded pine and oak forests, it was found that the soil texture in degraded forests was loamy and in non-degraded soil was sandy loam. In the rainy season, the WHC was high and found to be between 43.34±1.26% and 45.27±0.72%. For degraded or regenerating forests the WHC was found to be the maximum (Jina et al 2011).

The WHC of 3 sites in Arunachal Pradesh District of West Siang, Shagong, Hanuman Camp and Yarlung of Mechuka, is 63.87%, 64.68% and 65.05% respectively. The soil of this area was found to be sandy clay loam, and with the WHC it was found that organic C and N content increased. In this research, seedling survival and its growth of 2 *Rhododendron* sp. along with the altitude gradient, they were analyzed and found to be affected by the altitude and the atmosphere. Due to the cold climate, seedling mortality was high at high altitudes, i.e. in Yarlung during Nov-March, and low after March-July. These sites are present at various altitudes and, similar to the observations made in Kadamannaya et al 2010 and Sheikh and Kumar 2010, WHC has been found to increase with the altitude (Bharali et al 2012). But at the lowest altitudes, maximum WHC was found at Banj-oak and Chir pine forests in Garhwal Himalayans. The WHC was found high at a depth of 0-20 cm, and the maximum was 59.50±22.06%, respectively and 47.88±18.13%, and decreased with depth (Kumar et al 2013). However, WHC increased with depth in the oak, pine, and salt forests of the Betalghat area of the Kumaun Himalayas. The WHC found to be high at 21-30 cm deep and for these 3 forests, it was 69.27±0.58%, 49.±0.54% and 61.23±0.52% respectively. The WHC has shown a negative association with clay, C, K and organic material in the Banj-oak and Chir-pine forests (Pandey et al 2018). Bulk density increased with a decrease of WHC (Kumar et al 2013).

A research was carried out in three types of forest in the Central Himalayan area near Nainital, Uttarakhand, which are Banj-Oak (*Quercus leucotrichophora* A Camus), Chir-pine (*Pinus roxburghii* Sarg) and mixed oak-pine forest. The WHC varied between 48.5±0.71% -51.50±0.50% in Banj-oak forest, 36.65±0.69%-38.50±0.53% in Chir-pine forest, and 41.47±0.69%-45.65±0.43% in mixed oak-pine forests. With clay content, the WHC has been found to increase. The high quantity of litter production in the Banj-oak forest has contributed to a rise in soil WHC (Bargali et al 2018). In another study conducted by Joshi et al 2021, WHC at oak stand was found to be 58.68±4.29% and chir-pine stand was 51.96±1.25% during the study period of 2017-2019. The species diversity was highest in chir-pine and forest floor mass was found to be higher in oak stand. The higher biomass will enable the growth of more species depending on the soil properties such as WHC and as well as the rainfall pattern.

CONCLUSION

Our review is a groundbreaking attempt to establish that WHC can be used as an important criterion for forest health assessments and the ecosystem services they provide. The analysis of research papers of past 4 decades on the WHC across the Tropical and Sub-tropical forest revealed that WHC is one of the important parameter of tropical and sub-tropical forest soils. Tropical forests are biodiversity rich and offer lot of ecosystem services to the mankind. However, their functions are severely affected by the natural and man-made reasons. The global climate change has led to the increase in the annual temperature of the Earth and rainfall pattern, which has affected the equilibrium of the ecosystem. The

frequently occurring natural disasters like flood, cyclones, forest fires, etc. has damaged the ecosystem very severely. Since the majority of the tropical forest floors has low nutrient content in them, the regeneration process will be very much low. The human invasion and anthropogenic activities are also increasing in an uncontrollable manner. This has led to decrease the nutrient content and quality of the soil. Most of the forests are converted to agricultural and grazing lands and collection of firewood from the forest are another disturbance mainly caused in the forest ecosystem. The increasing human population and development in India has led to the expansion of human settlement area and for more space, the forests are been cut down. The fragmentation of the forest has led to loss of endemic species, loss of population size, reduced reproductive success, etc. This has led to the increase in human-animal conflicts and has become a very serious problem. If the quality of the soil is getting decreased in a way that's occurring now, then as the time pass by, the forest will be soon converted into desert and we could see loss of species from the ecosystem. Therefore, soil quality of each and every forest should be assessed frequently in order to check the health of the soil. Frequent monitoring should be done on the activities taking place in a particular ecosystem. Various awareness programs should be made to the people especially those living on the outskirts of the forest region and should be educated regarding the need and conservation of the forest. Government should provide the people with modern approaches for cooking purpose, which will make them less dependent on the forest for firewood. Mining, hunting, clear cutting of forest for agriculture and plantations should be strictly prohibited in the forest area. The present policies and regulation has to be modified on the frequent basis, based on the condition and activities that is blocking the way for conservation of the ecosystem. Therefore, Government with the help of various NGOs and local peoples should join hands for the proper conservation of the forest ecosystem and for sustainable forest management.

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Agricultural Sustainability in Indian Himalayan Region: Constraints and Potentials

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***Abstract*:** The sustainable agriculture is a holistic approach that covers use of existing resources (*viz.* soil, water and biodiversity etc.) to meet the requirement of present and future generations. The agriculture sustainability not only underpins the global food security but also ensure profitability, environmental health and social and economic equity. The Indian Himalayan Region (IHR) is one of the most fragile ecosystems that have faced significant transformation due to harsh environmental conditions, habitat degradation and fragmentation. Despite the huge abundance of natural resources in the IHR, the farmers still practice subsistence agriculture due to poor infrastructure, lack of facilities and vulnerability from natural disasters. The goals for no poverty and zero hunger specified in SDG 1 and SDG 2 can only be achieved by sustainable agriculture. This paper reviews the status of the Indian Himalayan Region (IHR) with respect to the constraints challenging the agricultural sustainability, and potentials which offer scope and opportunities for the food, nutrition and economic security of hill people. Several international organizations are feeling concerned about the impacts of climate change on agriculture and the social and economic security. Government of India has set up five thematic working groups to study and report the status of agriculture in the IHR. The aim is to contribute towards sustainable development in the Indian Himalayan Region.

***Keywords*:** Agricultural productivity, Agricultural sustainability, Hydrology, Indian Himalayan Region, Land use planning

The mountain ecosystems cover around 22 per cent of the world's land surface area (Xu et al 2019), inhabiting millions of people depending primarily on agriculture for their livelihood security. The Himalayas are the highest and the youngest mountain chain on the planet Earth which is still evolving. It is the third largest deposit of ice and snow in the world. '*Himalaya*' is a *Sanskrit* word-from *Him* ("snow") and *alaya* ("abode"). It extends from 15.95° to 39.31° N and 60.85° to 105.04°E across eight South Asian territories of Afghanistan, Pakistan, China, India, Nepal, Bhutan, Bangladesh and Myanmar (Bajracharya and Shrestha 2011, Das and Meher 2019). This grand mountain chain covers an area of nearly 7,50,000 km^2, spanning over 3,000 km in length, 250-300 km in width, at an elevation of 300 to >8000 m above mean sea level (GOI 2006).

Major chunk of Himalayan range falls in India, called the Indian Himalayan Region (IHR). The IHR is an important region of India. It provides water to a large part of the Indian subcontinent; serves as a potential source of medicinal plants; and abounds in genetic diversity of all types of flora and fauna. The Indian Himalayan rivers run off around 1,600,000 million m^3 of water annually for drinking, irrigation, hydropower, etc. A large percentage of crude drugs in the Indian market come from this Himalayan region (Bhushan et al 2016). Despite the abundance of natural resources, most of its people are marginalized and still live on subsistence level.

Agriculture has been the primary livelihood option for the IHR populace. The Himalayan agro-ecosystem has been characterized by fragility, marginality, inaccessibility and lack of infrastructure (roads, electricity, irrigation facilities, etc.). In spite of such constraints the agricultural system in the Himalaya has sustained over years, fulfilling the household food requirements. But presently the Himalayan agriculture is challenged by several social, economic and environmental stresses, viz. land fragmentation, small and unviable land-holdings per family, increased rural migration, declining labour availability, higher cost of production, poor financial resources and climate change etc. Lot of disturbances are happening in IHR due to climate change like flooding, landslides, drought, wildfire, and over-exploitation of resources etc. It has led to increased agricultural land abandonment in Himalayan region (Tiwari and Joshi 2015). Food and nutritional insecurity is becoming a major concern. Around 50 per cent of the population in Hindu Kush Himalaya (HKH) region including, IHR has been reported to suffer from some form of malnutrition (Rasul et al 2019). Overall, 38 per cent farmer families of Indian Himalaya are facing transient/transitory food insecurity (IMI FAO Report 2019).

Nevertheless, the IHR is also bestowed with opportunities which are unique to these agro-ecosystems. There are several niche areas suitable for cultivation of high value crops including medicinal and aromatic plants, organic agriculture and several agriculture-based subsidiary occupations. With proper planning, scientific investment and careful management of available natural resources it is possible to sustain agriculture sector in this region.

The Indian Himalayan Region

The Indian Himalayan Region (IHR) stretches about 2,400 km across the northern border of India, between the eastern border of Pakistan in the west and frontiers of Myanmar in the east. The geo-dynamically complex young mountains of the IHR occupy a special place in the mountain ecosystems of the world (Singh 2006). The IHR is formed due to the long term convergence of Indian landmass against Eurasia about 45-50 mega annum (Ma) (Thakur et al 2013).Geographically, the IHR between Indus and Brahmaputra river systems covers about 5,33,604 km^2 (16.2 per cent of total geographical area of the country) and is inhabited by about 40 million people (about 3.5 per cent of total population of the country) in little over 73,000 villages and nearly 500 towns (Singh 2013).The IHR covers partially/fully twelve states of the country *viz.,* Jammu & Kashmir, Himachal Pradesh, Uttarakhand, Sikkim, Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura, Meghalaya and hill regions of two states *viz*. Assam (Karbi Anglong and Dima Hasao) and West Bengal (Darjeeling and Kalimpong). As per a recent FAO report (IMI FAO Report 2019), nearly 70 and 30 per cent population in IHR is rural and urban, respectively. Himachal Pradesh dominates in rural population (90%), followed by Uttrakhand (70%) and Mizoram (50%).

Physiography

The IHR extends from 26^{0}20' to 35^{0}40' N and 74^{0}50' to 95^{0}40' E, covering 16.2 per cent of the India's landmass (Dikshit et al 2020). The Medlicott's classification of northwest Himalaya is one of the old records that classify the Indian Himalaya into Sub-Himalayan (*viz.* Upper, Middle and Lower Shiwalik) and Himalayan series (metamorphic and non-metamorphic material) (Medlicott 1861, 1864, Dhital 2015a). These litho-units are divided as per local geology and tectonic set up as described in detail by many researchers (Hodges 2000, DiPietro and Pogue 2004, Sati 2014, Mukherjee et al 2015). Based on the altitude, physiography and geologic history, the IHR has been divided into three parallel vertical divisions: (i) The Outer or Sub-Himalaya (the *Shiwaliks*), (ii) The Lesser Himalaya (*Himachal*), and (iii) The Greater or Higher Himalaya (the *Himadri*) (Fig. 1). The Himalayan region beyond north in Tibet is the Trans-Himalaya.

The Outer Himalaya

The Outer Himalayan region, also called the *Shiwalik* range, covers the area along Indo-Gangetic plains abruptly rising along the tectonic boundary along the Himalayan Frontal Thrust (HFT) (Fig. 1). The *Shiwalik* range marks the southern part of the Himalayan Mountain at an elevation of 900-1,500m amsl with valley sub-region and area with moderate topography. The *Shiwalik* hills are geologically youngest east-west mountain chain of the Himalaya which represents one of the largest fluvial deposits on the Earth. The *Shiwalik* deposits cover the repetitive sequence of Upper, Middle and Lower *Shiwaliks* which cover sediments of mudstones, siltstones, sandstones, and conglomerates. The overall geomorphology of the area is controlled by their rock texture, structure and varied fluvial environments with the age ranging from Middle Miocene to early Pleistocene (Dhital 2015b).

The Lesser Himalaya

Tectonically, the area between the Main Boundary Thrust (MBT) and the Main Central Thrust (MCT) comes under the Lesser Himalaya region (i.e. *Himachal*) (Fig. 1). The MBT is the major tectonic unit that separates *Shiwalik* and the Lesser Himalaya (Sinha and Sinha 2016). The Lesser (and Middle) Himalaya, about 80 km wide along the Kumaun and the Garhwal regions, lies to the north of *Shiwalik* range at an elevation of 1,500-4,600m amsl, representing the central chain of alternating ranges and valleys. This zone covers the mountain range that rises to 4,500 m and valleys with elevations up to 900 m.

The Greater Himalaya

The Greater Himalaya (i.e. *Himadri*) is asymmetrical northernmost range of glaciers and lofty snow peaks at an elevation of 4,600m amsl. It has a granitic core and is characterised by metamorphosed sediments. Tectonically, this zone is marked by Indus-Tsangpo Thrust (ITT) or Main Mantle Thrust (MMT) in Pakistan with Late Precambrian to the Lower Eocene sedimentary sequence. The Greater Himalaya is dominated by crystalline rocks along the Main Central Thrust (MCT) with Proterozoic basement, a part of the upper–middle crust evolved through continent-continent collision during Himalayan origin. The predominant rocks include mica schist, quartzite, paragneiss, migmatite and leucogranite (Dhital 2015c). The ranges, plateaus and basins lying to the north of the Greater Himalaya are collectively called the Tethys or Tibetan Himalaya and the Trans-Himalaya.

Hydrology

The Himalayan Mountain chain is the third-largest deposit of ice and snow in the world, serves as an important source of freshwater for the 1.3 billion population living in the

lowlands of river basins of Indus, Ganga and the Brahmaputra (IGB) covering eight countries (Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan) (Barnett et al 2005, Bajracharya and Shrestha 2011, Schickhoff et al 2016).

The Himalayan range encompasses about 15,000 glaciers and accounts for 70 per cent of the world's non-polar glacier, which stores around 12,000 km^3 of freshwater (Nandy et al 2006, Chandra et al 2018).They feed river systems including Ganges, Brahmaputra, Indus, Irrawady, Mekong, Amu Darya, Salween, Tarim, Yangtze, and Yellow Rivers, covering an area of more than 4,192,000 km^2.

The Indus, Ganga and the Brahmaputra constitute the major river systems in the IHR, covering a basin area of around 31,289 km^2 (34 %), 861,452 km^2 (82.04 %) and 194,413 km^2 (33.52 %), respectively (Qazi et al 2020). The rainfall decreases as one move from east to west along the Himalaya.

Climate: The climate ranges from tropical at the base of the mountains to permanent ice and snow at the highest elevations. The agro-climatic zones of IHR are given in Table 1. Climatically, the IHR under the HKH plays an important role in regulating the global weather patterns (Frei et al 2012). The climate of this region is suitable for diversified agricultural, horticultural and flower crops. The adverse impacts of climate change (variability in temperature and rainfall events) have already started showing on biophysical (mountains, rivers, floods, forests, land degradation, etc.) as well as the socio-economic systems (hill communities, agriculture, animal husbandry, etc.) in the region (Karma et al 2010, IPCC 2014). Bolch et al (2019) reported a 30 per cent reduction in snowfall due to rise in temperature in the IHR. The climate change studies forecast reduction in availability of drinking and irrigation water, increasing instability of crop yields, increased probabilities of failure of rainfed farming systems, occurrences of extreme drought and rainfall events, invasion of field crops with new weeds, pests and diseases etc. (Negi et al 2012, Ramesh et al 2017). Himalayan communities have a large dependency on climate sensitive rainfed agriculture. They have limited livelihood options. They are highly marginalized due to inadequate physical infrastructure like roads and transport, markets, power supply and communication, etc. They are highly dependent on natural resources. These constraints increase the vulnerability of Himalayan communities to climate change. It makes, therefore, measures for adaptation to climate change most imperative.

Soils: A variety of soil types with varied thickness of sediment on the ridges and the valleys occur in IHR due to its highly varied geological, physiographic and the climate characteristics. The current soil resources are the results of long term erosion and the deposition from the youngest mountain ranges of the Himalaya. The soil is fertile, but fragile and consequently prone to soil erosion (Mandal and Sharda 2011, Mahapatra et al 2018). The composition of the soil and its quality depend upon the various intrinsic (soil forming factors and the parent rock) as well extrinsic (agriculture management practice) factors (Davatgar et al 2012). The steep slopes and the active tectonic movements increase the vulnerability of the IHR to landslides, rockfalls and soil erosion. Information with respect to soil resources of the IHR is limited. Soils in the highlands are of morainic origin. Some studies have used spatial data and GIS technique for reporting the nutrient status of IHR soils to understand the variation and provide input for soil resource management (Bhunia et al 2018, Rahul et al 2019, Kumar et al 2021).

Agriculture in Indian Himalayan Region

Himalayan agriculture has traditionally been 'subsistence based' or 'family farming' system wherein agricultural production has been family-based and for local consumption (Schroeder 1985). The land resources in IHR may be grouped into two categories: (i) *the crop lands* which remain under cultivation of annual field crops and/or perennial horticultural crops, and (ii) *the support lands* which support farming-based livelihoods. The crop lands across different ecological regions in IHR have variable constraints and potentials. The support lands may partially or totally support the livelihood security of people. For example, in north-west Himalaya (Ladakh, Kashmir and Sikkim), the people completely depend on pastoral and agro-pastoral

Table 1. Agro-climatic zone of the Indian Himalayan Region

Agro-climatic zone	Climate	Rainfall (mm)	State/regions
Zone I	High altitude temperate (humid to cold arid)	<1200	Jammu & Kashmir
Zone I	Hill temperate (per humid to sub-humid)	1200-1800	Himachal Pradesh and Uttaranchal
Zone II	Per humid to humid	1800-2200	Nagaland, Mizoram, Manipur and Tripura
Zone II	Per humid to humid	2200-2800	Sub Himalayan West Bengal, Sikkim, Assam and Meghalaya
Zone II	Per humid to humid	>2800	Arunachal Pradesh

Source: Agro-climatic Regional Planning, Planning Commission, 1989

(support) lands. In north-east Himalayan region, shifting cultivation is an important support land-based livelihood system. The forest and range lands have been used as support lands in majority of IHR region.

The land-use during 1998-99 in the IHR, as per the Technical Committee on Co-ordination of Agricultural Statistics set up in 1948 by the Ministry of Food & Agriculture, is shown in Figure 2. Major land use distribution pattern in the IHR is also shown in Table 2. The Land Use Policy (2016) has acknowledged the right of the local communities, marginalized farmers and the ethnic minorities for the available land resources. The average size of the land holdings for the agriculture has declined significantly over the years (Maikhuri et al 2001). The current land holding per family on an average is less than 1.0 ha (IMI FAO Report 2019).

Many times, the ethnic and socio-cultural affiliation and territorial rights of resource access of the people, in addition to environmental issues, significantly influence land use patterns and livelihood strategies. A better understanding of the diversity, complexity and dynamics of regional land-use systems, therefore, requires identification and evaluation of the historical dimension of human-environmental interaction.

Natural vegetation: The IHR is bestowed with diverse natural vegetation which can be broadly grouped into four categories depending on the climatic conditions: tropical, subtropical, temperate and alpine. The local relief and exposure to sunlight significantly influence the microclimate and the vegetation association. The humid foothills of the eastern and central Himalaya inhabit tropical evergreen

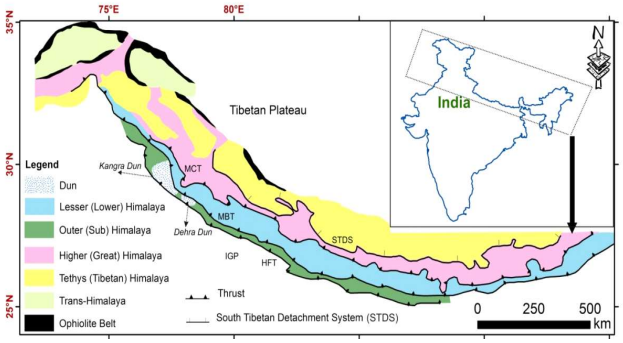


Fig. 1. General view of the Indian Himalaya Region with major litho-tectonic unit abbreviations: HFT (Himalayan Frontal Thrust), IGP (Indo-Gangetic Plain), MBT (Main Boundary Thrust), MCT (Main Central Thrust)

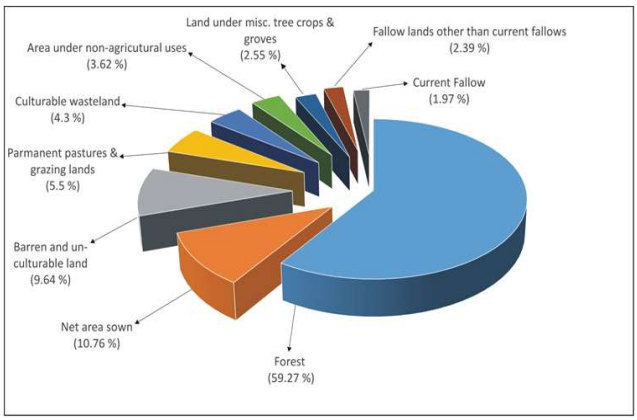


Fig. 2. Major land use classification in the Indian Himalayan region (1998-99) (adapted from Resource Database of Indian Himalayas)

Table 2. Major land use distribution pattern in the Indian Himalayan Region (adapted from: Wastelands Atlas of India 2000 & FSI 2000)

States/Regions	Geographical area (km^2)	Per cent of area under		
		Agriculture land	Wastelands	Forest cover
Jammu & Kashmir	2,22,236	4.7	64.6	9.6
Himachal Pradesh	55,673	14.5	56.9	25.8
Uttaranchal	53,483	12.5	30.1	44.8
Sikkim	7,096	16.1	50.3	45.0
West Bengal hills	3,149	43.5	2.2	68.7
Meghalaya	22,429	48.2	44.2	69.5
Assam hills	15,322	10.5	56.6	79.8
Tripura	10,486	29.6	12.2	67.4
Mizoram	21,081	21.2	19.3	83.0
Manipur	22,327	7.3	58.0	75.8
Nagaland	16,579	38.4	50.7	80.5
Arunachal Pradesh	83,743	3.5	21.9	81.3
India	32,87,263	55.8	20.2	20.6

rainforests (Ceylon ironwood, bamboos, alder trees etc.), while western Himalaya grows mostly tropical deciduous forests (sal etc.). Farther west follows steppe forests (grasslands dotted with trees). Temperate mixed forests, containing conifers and broad-leaved temperate trees, are found between 1,400 and 3,400 m elevation. Evergreen forests of oaks and conifers (chir pine, deodar cedar, blue pine and spruce) are the typical vegetation of the Lesser Himalaya. Various studies reveal that *Shiwalik* up to about 1000 m height primarily support tropical sub-humid sal-forest (*Shorea robusta*); the Lesser Himalaya with an elevation of 1500 to 3000 m is dominated by *Pinus roxburghii* forest (Ohsawa et al 1986); the Greater Himalaya is dominated by glaciated mountain peaks (6000-7000 m), with the narrow transversal valleys covered by montane forests and alpine grasslands. Evergreen oak forests alternating with conifers or deciduous trees, and different species of maples (*Acer* spp.) are abundantly found in montane forests of Greater Himalaya. Above the tree line begins the alpine zone. It extends between 3,200 and 4,200 m in the western Himalayas, and between 3,200 and 4,500 m in the eastern Himalaya. This zone grows vegetation like *Juniper* sp., *Rhododendron* sp., mosses and lichens, and flowering plants.

Agriculture: The agriculture sector provides the direct or indirect source of livelihood for over 70 per cent of the population residing in Hindu Kush Himalaya (HKH) including IHR (Wang et al 2019). The agriculture system in entire Himalayan region has been based on locally available natural resources involving complex linkages among farm, forests and livestock systems (Tiwari and Joshi 2015). It has been a perfect example of stability and diversity with long-term sustenance. The agrarian practices may vary in different parts of Himalayas, but the basic features of agriculture remain almost the same throughout the region.

Five types of farming systems commonly occur in IHR (IMI FAO Report 2019):

1. Rainfed crop livestock mixed farming system (subsistence farming)
2. Horticulture-based system (commercial farming)
3. Fruit and vegetable-based farming system (commercial farming)
4. Swidden slash and burn farming culture of north east Himalaya
5. Pastoral & Agro-pastoral system of the Himalayan Nomads
6. The Himalayan people practice integrated farming, agro-forestry, animal husbandry and forestry. The most common integrated production systems in the western Himalayan region of India (Jammu & Kashmir, Himachal Pradesh and Uttrakhand states) are Agri-Livestock-Fish-Horticulture, Agri-Horti-Livestock-Fish, Agri-Horti-Livestock-Pasture-Fish, Livestock-Silvipasture-Agriculture (Roy and Kumar 2018). The agro-pastoral land use constitutes the economic backbone of these communities. Horticulture dominates in greater and middle Himalaya, while field crops dominate in outer and lesser Himalaya. Due to inaccessibility and poor road connectivity, commercial agriculture in hills is not as high yielding and profitable as in the plains. Some agricultural components in IHR are briefly discussed below:

Crop production*:* Around 76 per cent of the gross cropped area of the entire Himalayan region is under staple food grain crops (Partap 2011). Wheat, rice and maize invariably dominate the Himalayan region.

In western Himalaya (the Kashmir Valley, the Kangra Valley, the Sutlej River basin, and the terraces flanking the Ganges and Yamuna rivers in Uttarakhand), rice, maize, wheat and millets are major cereal crops; barley, buckwheat, pulses and oilseeds are also widely grown. Uttarakhand, however, has more area under millets and pulses. In the central Himalaya (Nepal) rice is the major cereal crop while corn, wheat, potatoes, and sugarcane are also cultivated on large scale. In eastern Himalaya, agriculture conditions vary widely in different parts of the region. In the highlands spring crops are grown abundantly on terraced lands on hill slopes. Rice is the staple food crop occupying about 81 per cent of the cropland area under food crops. Mixed farming is popularly practiced with a mixture of diverse 8 to 10 crops. Agriculture is dominated by swidden farming i.e. shifting cultivation (also called slash-and-burn agriculture or *Jhum/Jhoom* cultivation), supplemented by hunting, fishing and barter trade.

In *Jhum* cultivation, the land is cleared of vegetation by cutting and burning of plants in a forest or woodland to create fields for cultivation of field crops. The fields are cultivated for 3-5 years in a row, then abandoned due to depletion of nutrients, loss in soil productivity and build-up of weeds and pests. The cultivation is shifted to a new site. It may take 5-25 years, depending on ecological conditions, to re-build soil's productivity and resume cultivation cycle. The *Jhum* cycle, however, is becoming successively shorter due to growing food needs and increasing human pressure on land, resulting into acceleration in the rate of soil erosion and mining of nutrients. This is a strong indicator of the deteriorating ecological balance of the region. Crop production alone cannot suffice the food requirement of local people. The economy has remained stagnant for centuries due to lack of capital market, entrepreneurship and avenues of investment. According to one study, the contribution of agriculture to income has fallen

from 43 to 7 per cent in the central Himalaya and from 83 to 63 per cent in the eastern Himalaya (Mukerjee et al 2018). A change now is being observed in cropping systems all over the Himalaya. Farmers are shifting from paddy and maize cultivation to cash crops like fruits and vegetables; area under wheat remains unchanged (Partap 2011).

Horticulture*:* The agro-climatic conditions of IHR are favourable for cultivation of wide range of fruits (apples, walnuts, plums, peaches, cherries, almond, citrus fruits, banana, mango, pineapples, kiwi, etc.), vegetables (tomato, radish, potato, cabbage, cauliflower, broccoli, etc.), flowers (orchids, gladioli, marigolds, chrysanthemums, etc.) and cash crops (ginger, chillies, cardamom, saffron, medicinal and aromatic plants, etc.). Horticultural crops are more remunerative than traditional cereal crops. The fruits and vegetables occupy around 16 per cent of crop land in the IHR. The proportion of fruit cultivation is much higher (20% of crop land) in the western than in the central and eastern Himalayan states (5% of crop land). The western Himalayan Region is famous for the cultivation of fruits like apples, peaches, pears, cherries, walnut and almond.

Realizing the vast horticultural potential in the IHR, the Government of India during 8th Five Year Plan launched 'Integrated Horticulture Development' programme. However, with the diversification of farming in the IHR towards horticulture, many second generation ecological (marginal areas coming under fruit cultivation) and social (equity, gender and ethnicity etc.) issues of unsustainability are emerging (Partap 2011), which are great hurdle for the sustainable development in the mountainous region.

Animal husbandry*:* Livestock farming is an integral part of agriculture in Himalayan region. The IHR houses nearly 6 per cent of the human population and more than 21 per cent (about 95 million) of India's cattle population under mixed farming systems. The IHR supports about 50 million domestic animals (1.6 animals/ha): cattle (47.5%), goats (15.8%), buffaloes (12.3%) and sheep (10.4%) (Partap 2011). Cattle dominates (48%) in the central and eastern Himalaya, followed by buffalo (12%), and sheep and goat (11%). Livelihood of more than 70 per cent rural population of Uttrakhand in central Himalaya depends on animals (mostly cattle and buffalo) (Tiwari and Pande 2011). Livestock supplements the family income through dairy products, wool, meat and eggs, in addition to the manure and compost from animal dung and bedding material. Yaks are raised on the rough grazing lands available at high altitudes. Pig husbandry is an integral component of farming systems practiced in eastern Himalayan region. According to one estimate, this region possesses about 23 per cent of the total pig population of India (Moanaro et al 2011).

A shifting trend from local breeds to hybrid cattle has been observed in Himalayan region since the last about two decades (Partap 2011). It is because the indigenous livestock on natural grasslands have been found to be more susceptible to environment, diseases and nutritional stresses than the exotic animals. The Himalayan people who relied more on local breeds, therefore, are increasingly shifting to the exotic animals.

Transhumance (the seasonal migration of livestock) is widely practiced in the temperate and hilly regions at higher altitudes of the Himalayan pastures. The shepherds during summer graze their animals in the pastures at higher elevations (i.e. highlands), and during the winters they migrate with their flocks to lower elevations (i.e. lowlands). This practice continues largely with sheep and goat. The animal husbandry faces constraints from deficiency of quality feed and fodder, scattered and low land holding, poor animal productivity, unhygienic housing/resting place of animals, little knowledge about vaccination of livestock and poor extension services (Singh et al 2004, Meena et al 2007).

Agroforestry*:* Agroforestry is the traditional land use system where the two main components i.e. trees and shrubs are artificially managed with the agricultural crop (Mosquera-Losada et al 2009). This is the one of the autonomous strategies to adapt to a changing climate by integrating trees in farming system. This system in IHR is practiced in about 20 per cent of the land in several variants, *viz*. agri-horticulture, silvi-horticulture, horti-pastoral and silvi-pastoral systems (Nautiyal et al 1998).

Different agro-forestry models have been practiced in western, central and eastern IHR depending on the peoples' needs, resource availability and agro-ecology of the region. The agroforestry systems are invariably more productive than cultivation of solo crops. Agroforestry in India meets requirement of livestock, besides meeting the subsistence needs of households for food, fruit, fiber, medicine, etc. (NRCAF Vision 2013). Agroforestry plays an important role in the Climate Smart Agriculture (CSA) by incorporating positive benefits in carbon sequestration, mitigation of greenhouse gas emissions, adaptation to and mitigation of effects of climate change (Kimaro et al 2019). The carbon sequestration potential of tropical agroforestry system is estimated between 12 and 228 Mg ha^{-1} with a median value of 95 Mg ha^{-1}. Based on the global estimates of area suitable for agroforestry (585-1215 x 10^6 ha), 1.1 to 2.2 Pg C could be stored in terrestrial ecosystems in next 50 years (Albrecht and Kandji 2003).

Constraints and potentials in Agriculture Sector of Indian Himalayan Region

Constraints: The IHR has varied agro-ecological potentials,

constraints, opportunities and agrarian risks. It represents tectonically unstable, ecologically fragile, economically under-developed and most densely populated mountain ecosystems of the world, where more than 75 per cent of the population depends on traditional agro-ecosystems dominated by subsistence agriculture (Tiwari and Joshi 2015). The region possesses some inherent constraints such as remoteness, inaccessibility, fragility and marginality, coupled with several socio-economic constraints (Partap 2011; Gioli et al 2019). The production constraints in Himalayan region may be summarized as follows:

- *Fragile ecosystem* which renders the environment to be easily damaged by natural and human causes and adversely affecting inhabitants of the region.
- *Difficult agro-climatic conditions* (steep slopes, shallow soil depth, excessive soil erosion, low and unstable rainfall, short growing seasons, etc.).
- *Poor infrastructure & service support* (low irrigation, low farm mechanisation, lack of ware-houses, cold storage facilities for perishable agricultural products such as vegetables, fruits, flowers etc., poor marketing and networks, research and extension, credit, schools and health centres etc.).
- *Inaccessibility* (poor road network and transport facilities; even today some areas don't have road access).
- *Active tectonics processes* (earthquakes, fault movements, uplift, landscape etc.)
- *Severe geomorphologic processes* (landslides, flash floods, high rates of fluvial erosion etc.).
- *Poor socio-economic status* of inhabitants (poor resource base, subsistence farming, financial constraints, lack of risk-bearing ability etc.).
- *Climate change* resulting high vulnerability from extreme temperature and rainfall events, droughts, floods, natural disasters, shortening of cropping seasons, agriculture un-sustainability, nutritional insecurity and malnutrition etc.). The impact of climate change has already started showing through changing farming systems, cropping patterns, increased cloud bursts and flash floods, increased Glacial Lake Outburst Flood (GLOF) hazards etc.
- *Small, scattered and unviable land holdings* are of concern in hill farming. Fragmentation continues causing shrinkage of land holdings per family. At present the average land holding in IHR is less than one hectare (IMI FAO Report 2019) which is unviable for food as well as income security. The crop land availability is comparatively better in north-east than in north-west IHR.
- Majority of the crop lands are *rainfed* and vulnerable to climate change. Water springs, which are the lifeline of millions of people in the mountains, are increasingly drying up or becoming seasonal, causing water stress for agriculture and household activities. Due to uncertain and variable rainfall patterns the crop yields in rainfed areas are low and highly unstable.
- Continued dependency of people on *cereal crops*, rather than on high value crops, has kept Himalayan farmers under pressure of food insecurity and poverty. Under the present circumstances, there is little hope that the cereal crop-based farming systems shall improve their economy in near future. Studies indicate that commercial farming households, as in Kashmir (apples) and Himachal Pradesh (vegetables and fruits), have 3-4 times higher annual earnings than from the subsistence hill farming (IMI FAO Report 2019).
- *Menace of wild animals* has become a serious threat to hill agriculture. Many times farmers fail to take home any harvest. They are forced either to shift to other crops which are less economical but little affected by wild animals or abandon cultivation and leave the lands fallow.
- *Deforestation* to clear land for cultivation to meet food, fuel and shelter needs of growing population triggers environmental degradation and associated risks in mountain landscapes. Deforestation has progressed up the steeper and higher slopes of the Lesser Himalayas.
- *Gene erosion* is another issue of concern in Himalayan region. The climate change and rapid expansion of agriculture on new lands and intensification of agriculture is largely causing destruction of biodiversity i.e. gene erosion. It has serious repercussions on future crop and livestock improvement programmes with implications for sustainable livelihood and agriculture sustainability (Saxena et al 2005).
- *Women-centric agriculture* in hills but with women having very little say in decision making; lack of women empowerment hinders progress in agriculture sector in hills.
- *Lack of entrepreneurship* and out-migration of males in search of off-farm employment has become a serious problem in the IHR. There are several challenges to the skill and entrepreneurship development in the IHR, such as: inadequate infrastructure, lack of quality trainers; limited awareness among the youth regarding skill and entrepreneurship development programmes; limited local demand; etc.

The *Shiwaliks* have been identified as one of the eight

most degraded rainfed ecosystems of the country (Grewal et al 2003, Singh et al 2016). The region is characterised by barren hill slopes, undulating topography and gravely coarse textured soils with low fertility and poor moisture retention capacity, and erratic rainfall pattern. The intermittent and prolonged droughts lead to yield reduction and even crop failures. The increase in temperature coupled with decreased rainfall during the winter and spring period is making current production systems in the region highly unsustainable (Verma et al 2010).

Potentials: The Himalaya is rich in economical and biological resources. The land area covers pockets of fertile lands, extensive grasslands and forests, mineral deposits, easy-to-harness waterpower and biodiversity. The varied and unique climatic conditions offer opportunities for specialized production systems like organic farming, cultivation of medicinal, aromatic and high value crops, and several agriculture-based production systems. Some features of IHR with respect to agriculture sector are briefly discussed below:

Pool of genetic resources*:* Mountains make up around 24 per cent of the world's land area, but harbour nearly 50 per cent of the world's biodiversity hotspots (Rodríguez-Rodríguez et al 2011). Likewise, the IHR is a rich source of biodiversity (Myers et al 2000, Kumar et al 2018). Major genera for which rich diversity exists in IHR are: *Oryza*, *Avena*, *Amaranthus*, *Chenopodium*, *Fagopyrum*, *Allium*, *Hordeum*, *Linum*, *Saccarum*, *Citrus*, *Musa*, *Pyrus*, *Prunus, Rubus*, *Fragaria*, *Sorbus*, *Rosa*, *Lilium*, *Vicia*, *Lepidium*, *Lathyrus*, *Dioscorea*, *Cucumis*, *Solanum* and *Trichosanthes* species with several of their wild relatives. Besides contributing significantly towards food and environment security of the hill people, they serve as gene pool having tremendous breeding value for improving crop species (Rana et al 2012). The rich biodiversity of the IHR, however, presently is threatened by natural and anthropogenic factors (climate change, expansion and intensification of agriculture, excessive mining of biological material etc.) for more and more economic returns. It needs serious thinking, planning, investment and management to conserve gene pool.

Horticulture*:* The fragile undulating terrains in hilly areas are more suited to horticulture than field crops. The wide agro-climatic variation of the IHR provides scope for tropical, sub-tropical and temperate horticulture. A wide range of fruits, vegetables and other cash crops can be successfully and profitably cultivated in the entire Indian Himalayan range. The fruits and vegetables cover around 16 per cent of crop land in the IHR. The proportion of farmlands under fruit crops is much higher in the western Himalayas (20%), than in the central and eastern Himalayan states (5%) (Partap 2011). Unique horticulture-based production/farming systems have evolved in the IHR depending on the regional ecologies and human needs and resources.

The lands which are not suitable for seasonal crops and lying barren and unproductive could be covered with orchards to generate additional income for farmers without causing land degradation. Chinese gooseberry (*Actinida* sp.) and blueberry (*Cyanococcus* sp.) can be grown in the mid-altitudes of the region. In the hills having low elevation and less rainfall, where failure of seasonal crop is a regular feature, guava, Indian gooseberry, pomegranate, mango etc. would be a profitable commodity. Orange (*Citrus* sp.) grown below 1500m is very popular for its excellent quality. Apple (*Malus* sp.) can come-up well around 2500m with proper selection of planting material and disease control. Nowadays, low chilling requirement apple varieties are available which can be planted in suitable areas.

The IHR can be successfully utilised for off-season vegetable production. The popular *rabi* vegetables could be grown successfully at high hills above 2000 m during summer. Himachal Pradesh has successfully tapped the off-season vegetable production. Protected cultivation in polyhouses can further boost off-season vegetable production as well as production of high value crops.

Floriculture also has tremendous potential in many parts of this region. Many regions in IHR from sub-tropical to sub-alpine zone (*viz* Sikkim, Arunachal Pradesh) are famous for orchids. Spices cultivation is another viable option in the IHR. Large cardamom plantation is economically viable and ecologically sustainable agro-forestry system despite low average yield (around 200kg dry capsule/ha) on steeply sloppy lands. Although the soil and climatic conditions in the IHR are highly favorable for several types of horticultural crops and also there is a shifting trend from cultivation of cereal crops to horticulture crops since 1990s, yet the organized horticulture in the IHR in reality is relatively scanty. A major portion of the hill tracts still remains untapped. In order to boost up the horticulture sector in the IHR, the Indian government has launched a scheme called 'Mission for Integrated Development of Horticulture' (MIDH). Various developmental projects have been implemented in hill states with the help of state governments.

Integrated farming system*:* Hill farmers traditionally have been practicing integrated farming, i.e. agroforestry, livestock-based farming, crop production integrated with fish farming, etc. Different components of integrated farming are interdependent, one is an insurance against failure of another component, and help sustain food productivity and ecological conservation. Integration of livestock (cattle, sheep and goat, rabbits, yaks, pigs and poultry) in the farming

systems enhances the income, provides manure for soil health, household nutrition and family labour utilisation. Superior livestock germplasm and better management practices need to be developed to increase the productivity of the system. In economic terms, there is great potential for the development of commercial production of tree and perennial crops (large cardamom, tea, coffee, black pepper etc.) on the slopes of tropical hills for export market. Apiary is another viable option and better integrated with horticulture.

Agroforestry is the most viable component of hill farming. Plenty of grasses are available during the monsoon periods and scarcity only occurs in winter (November to March). The cultivation of fodder crops on agricultural lands is impractical due to constraints of land availability and other inputs. Here a number of natural feed resources (tree leaves, grasses, shrubs and vines) are available. A practical alternative is available to encourage the propagation and planting of fodder tree species and grasses on village waste and marginal lands, community grazing lands, out scrub between and around the farm boundary, etc. under different afforestation programme for their lopping of leaves to meet the feed requirement during lean periods. The leaf of some fodder trees is almost as nutritious as that of leguminous fodder crops and offers an added advantage of producing fuel wood as a by-product. Leguminous fodder trees (*Albizia* sp., *Alnus nepalensis* and others) enrich the site through nitrogen fixation, which helps in effective soil and water conservation.

Diversification*:* Diversification is a viable tool for resilience against climate change. Diversification improves the mobilisation of the diverse resources and production conditions available on the farm while improving the use and productivity of available labour, capital and skills. Diversification empowers small scale farmers, increasing their technical know-how and decision making capacity, and promoting adequate changes in land use, crop rotations, interaction between forestry, livestock systems and cropping systems in support of sustainable development, and an important component of risk management. Thus, diversification is a key component for necessary and sustainable progress of agricultural production in order to meet the growing demand while the size of farms is decreasing regularly with time. It has tremendous scope especially with small and marginal farmers of hills.

Studies have shown highest food insecurity (85%) among farmers doing subsistence farming of cereal based crops, and minimum food insecurity (5%) among farmers cultivating vegetables and horticulture (IMI FAO Report 2019). Farmers now realize it and are slowly shifting their focus from traditional cereal crops (subsistence farming) to high-value cash crops (commercial farming) such as fruits, vegetables, floriculture and also medicinal plants. Farmers in Kullu valley of Himachal Pradesh have partially to completely shifted from food crop farming to vegetable cultivation. It is a good sign of farm economy in future. A recent study in the Lahaul & Spiti districts of Himachal Pradesh revealed significant changes in the cropping pattern with traditional crops like potato, barley and black pea being increasingly replaced by green pea (Sharma and Chauhan 2013). Apple, another cash crop, is gaining popularity in Lahaul and Spiti due to perceptible changes in climatic conditions.

Dhanta and Negi (2018), using the Herfindahl-Hirschman's Index (HHI), studied crop diversification in twelve districts in Himachal Pradesh. The results indicated moderate diversification (HHI=0.150-0.300) in eight districts, *viz.* Shimla, Kullu, Sirmour, Lahaul-Spiti, Mandi, Kangra, Solan and Chamba, and least diversification (HHI=0.300-0.450) in four districts, *viz.* Kinnaur, Bilaspur, Una and Hamirpur. None of the districts in Himachal Pradesh showed high diversification (HHI<0.150) or complete specialisation (HHI>0.450). Sati (2012) observed diversification with the cultivation of cash crops including fruits, off-season vegetables and medicinal plants, replacing traditionally grown cereal crops in Garhwal Himalaya. The factors responsible for such changes include improved road connectivity, better means of transportation, availability of favourable microclimatic niches, availability of new crop inputs like hybrid seeds, chemicals and fertilizers, emerging new markets, etc.

Niche based production systems: There are several niches that can easily be exploited to improve the economic status of hill people. Niches like organic farming, natural farming, cultivation and utilization of local underutilized crops, local land races with special characteristics, cold-water fish (trout) etc. Many Himalayan regions are by default organic, as the use of agrochemicals in those regions is either minimal or totally absent. Many underutilised crops like buckwheat, *Amaranthus* sp. have high nutritive value, and with value addition can fetch a good price for hill farmers. Similarly, there are some landraces of crops that have special characteristics like aroma, taste, nutrition etc. and are becoming extinct. They can be cultivated in hills.

Agri-tourism: The agri-tourism is a particular form of social innovation in agriculture and rural development of mountainous areas, aiming at recomposing the natural and the human dimensions within the framework of a new sustainable way of doing agriculture (Chiodo et al 2019). Agri-tourism in traditional way has tried to integrate agricultural activities with tourism to diversify farmers' incomes. But now, as the diversity of practice has grown and

new values have emerged, the range of farmers' motivations has become much broader. The new motivations include not only economic issues but also social, environmental and cultural ones, and address more comprehensively the idea of community-based sustainable development. Innovative ideas are pre-requisite to utilise, otherwise fragile eco-systems/landscapes in hills for developing agri-tourism to the tourist satisfaction, preserving at the same time the ecology, rich rural cultures, human values, economic prosperity and sustainable livelihood security. The agri-tourism has become a successful example of farm diversification in India (Chatterjee and Prasad 2019). Farm visits, farm stays and trail visits etc. are gradually picking up amongst tourists to experience something different from age-old sightseeing packages of a destination. The IHR offers significant potential for agri-tourism by providing a diverse resource base of great interest to new tourism activities.

Several sensitive and fragile human-environment systems and ecological carrying capacity issues, however, are critically linked with tourism development in hilly areas (NITI Aayog 2018). Specific negative impacts linked to the current form of tourism in the IHR include the replacement of traditional eco-friendly and aesthetic architecture with inappropriate, unscientific construction in the area of high seismic vulnerability, poorly designed roads and associated infrastructure, inadequate solid waste management, air pollution, degradation of watersheds and water sources, and the loss of natural resources, biodiversity and ecosystem services. The prevailing model of tourism in the IHR is viewed as a source of environmental damage and pollution, a threat to socio-cultural heritage, a heavy user of scarce resources, and a potential cause of negative externalities in society. Tourism development and promotion in the IHR should, therefore, be built around the principles of sustainable tourism as opposed to mass tourism. The tourism in IHR must be inclusive (focusing also on marginalised areas and groups) and sustainable (ensuring jobs, promotion of local culture and tourism products) and contributing to achieving the Sustainable Development Goals (SDGs).

On-farm and Off-farm employment: Increasing on-farm and off-farm employment in hill areas through vocational training in different sectors will economically empower local people. Some of the sectors having potential in hilly regions include post-harvest management (value addition, food processing, etc.), mushroom cultivation, protected cultivation, cold-water fishery, beekeeping, dairy farming, poultry farming, organic farming, machinery repair, agri-clinics, marketing etc. Since hill agriculture is women-centric, the women-folk must get priority in imparting skills and their empowerment.

CONCLUSION

The IHR, the youngest and geologically unstable mountain range, inhabiting more than 1.3 million people, occupies a special place in mountain agro-ecosystem. It is a store-house of water for drinking, agriculture and other economic sectors. Agriculture is the primary livelihood option of the Himalayan dwellers. The IHR is characterized by marginality, fragility, complex physiography and lack of adequate infrastructure (irrigation, roads, transport, markets, etc.). In spite of these inherent constraints, agriculture in the IHR has sustained over years providing food and economic security to its people. Presently, hill people are experiencing demographic, environmental and social stresses. Agriculture, which is already of subsistence type, is under tremendous pressure of climate change, shrinking natural resources, rural migration, labour scarcity, continued fragmentation of land holdings making them smaller and smaller and non-viable, increasing cost of production, lack of financial support, lack of adequate infrastructure for training of human resource, etc. Consequently, the sustainability of agriculture sector in the IHR has become a serious issue.

The IHR, in addition to several inherent constraints, is also bestowed with several features which offer tremendous potential for sustaining agriculture and improving socio-economic status of people. It is a richest store-house of biodiversity, bio-resources, minerals and traditional knowledge etc. It has unique niches and specialities which offer tremendous potential for overall development of this region. The region has tremendous scope and opportunities for meeting the food, nutrition and economic security through organic agriculture, natural farming, horticulture, olericulture, floriculture, cultivation of medicinal and aromatic plants, and several agri-based occupations like apiculture, mushroom, fisheries, and piggery etc. Small cottage industries may be developed for processing of perishable agricultural produce and value addition. The region has tremendous scope of animal husbandry and poultry. There are niche areas which are unique to the IHR. They need to be carefully and sensibly identified, and prudently developed and executed. Agri-tourism is one such example which can significantly improve the economy of the region provided due attention is given to check environmental degradation and erosion of social and cultural values of the natives to avoid social and cultural conflicts.

Site-specific policies framed with mountain thinking, investment in infrastructural development and training of people with scientific knowledge and technologies are needed. Long-term strategic planning is required targeting the climate change impacts on hill agriculture. Hill and mountain agriculture need be managed on scientific lines.

Local people have the knowledge about the limitations and potentials of the area. Their involvement in policy planning, execution and risk-profit sharing would increase their confidence in the developmental system and better land-use planning. It is a matter of satisfaction that global community is feeling concerned with the issues of climate change and agricultural sustainability especially for resource constrained hill people. Several international organizations have debated and discussed such issues, *viz.* the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in 1992, the Sendai Framework for Disaster Risk Reduction 2015, the Paris Agreement 2015 of the United Nations Framework Convention on Climate Change, and the Sustainable Development Goals (SDGs) and 2030 Agenda for Sustainable Development. Likewise, NITI Aayog (Government of India) in 2017 has set up five thematic working groups contributing to Sustainable development in the Indian Himalayan Region. All such efforts aim at settling various ethical and social issues underlying these fragile but important agro-ecosystems.

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Analysis of Land Use and Land Cover Dynamics and Forest Disturbance in Western Ghats Region of Maharashtra, India

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Abstract: Human activities have influenced landscapes due to its various development activities, which in turn has led to degradation of environmental quality. In the present study, land use land cover (LULC) dynamics of Western Ghats of Maharashtra were mapped using Landsat and LISS 3 satellite data. Hybrid image classification approach was employed for mapping different land use land cover types and diverse forest ecosystem at 1:50000 scale. Altogether ten vegetation type classes were mapped in the study region for the year 1991, 2000 and 2011. Results reveals that forest types like dry deciduous, moist deciduous, semi-evergreen and evergreen forests have decreased by 0.22% (79.70 km^2), 0.25% (88.80 km^2), 0.26% (94.30 km^2) and 0.11% (37.60 km^2). Other classes like built-up, waterbodies and agriculture have increased by 0.26% (93.1 km^2), 1% (358.7 km^2) and 0.93% (333.9 km^2). Landscape metrices were used in the study area to examine the levels of fragmentation of the forested area and to study the degree of disturbance. Fragmentation analysis reveals increase in edge and perforated areas, 5.9% and 8.3% in 2011.Very high disturbance areas increased from 12.4% in 1991 to 26.2% in 2011. The research finding and analysis will help us to prioritize or develop an approach to conserve tropical forest ecosystems.

Keywords: Western Ghats (WG), LULC dynamics, GIS (Geographical information system), Landscape metrics, Disturbance index

Any region or pattern of Earth's land cover is an outcome of different factors like socio-economic activity, population pressure, natural factors, and their use by men over the period. Many thorough changes in LULC have been induced by human activities which have an implication on climate change (Joshi et al 2006, Dickinson et al 1986, Lean and Warrilow 1989). Anthropogenic impacts on environmental resources leads to illegal cutting of forest trees leading to deforestation which is occurring at an alarming rate (Whitmore 1997). Habitat loss and forest degradation have been recognized as principal risks to ecosystems around the world (Jaybhaye et al 2016, Armenteras et al 2003, Dale and Pearson 1997, Iida and Nakashizuka 1995, Noss 2001). Human encroachment has diminished the total forested land areas of the forested regions and is accountable for vast species destruction which in turn alter biological diversity in many forms like habitat reduction, fragmentation, and creation of ecological alterations inside a particular area between forest and deforested areas (Roy and Joshi 2002). When large continuous patch of forest is divided into smaller patches due to development of roads, agriculture, urbanization, and other developments it leads to forest fragmentation. As a large habitat becomes fragmented, all that is left are disjointed fragments of varying size.

Western Ghats is also one of the biodiversity hotspots in the world, has the highest concentration of biological diversity and are home to many species of flora and fauna which are endemic in these regions. But during the last 50 years these regions has degraded due to destruction and disturbance to biodiversity which are mostly escalated due to human interference (Singh and Das 2013). Change in land use, habitat loss and fragmentation are the outcomes of the destruction of the area. With increasing anthropogenic pressure due to human activities there are different consequences on the land use land cover of WG. Land use change detection allows us to identify the processes and their direct effect on biodiversity. It is important to identify the land use pattern of WG area so that necessary actions and proper conservation management plan can be implemented. Dense forest loss was calculated at an annual rate of 0.53% in the WG region of Maharashtra (Panigrahy et al 2010). One of the researches has shown that the net loss of forest area in the Western Ghats from 1920 to 2013 was 35.3%, also there was no significant deforestation rate in recent years (Reddy et al 2016). Forest cover mapping is one of the important aspects of mapping of natural resource and management for any area (Reddy et al 2016). GIS and remote sensing technologies are potent tools to address the consequences due to deterioration of forests and to monitor the disturbances of forest ecosystem (Jha et al 2000, Singh et al 2002). In the present study Geographical information system (GIS) and remote sensing in association with landscape metrices was

used to understand the spatio-temporal dynamics of the study area WG region of Maharashtra. During recent times anthropogenic activities have disturbed forest area into smaller fragments (Singh et al 2003). These disturbances can be assessed using different indices like degree of fragmentation, porosity, interspersion and juxtaposition, patchiness, Disturbance Index. Fragmentation metrics at different landscape levels were selected for measuring land fragmentation under different land use categories (Wang and Yang 2012). The above landscape metrics were performed in present study using FRAGSTATS 4.2.1 for the Western Ghats area of Maharashtra and then raster datasets were processed in Arc GIS for further use.

MATERIAL AND METHODS

Study area: Western Ghats (WG) is listed as one of the UNESCO world heritage sites and is one of the eight hotspots of biological diversity in the world (Myers et al 2000). Western Ghats of India extends about 1600 km starting in the north from Tapti river and going down to Kanyakumari in south. It passes along the states of Maharashtra, Goa, Karnataka, Gujarat, Tamil Nadu, and Kerala. The study area (Fig. 1) Western Ghats of Maharashtra lie roughly between 72°55' E to 74°57'E longitude and 15°44'N to 21°12'N latitude covering about 35718.7 in sq. kms. Western Ghats also known as Sahyadri Hills in Maharashtra passes through 12 districts, Dhule, Nasik, Thane, Raigad, Pune, Ahmednagar, Satara, Ratnagiri, Sindhudurg, Kolhapur, Sangli and Nandurbar.

Satellite data: Indian remote sensing satellite (IRS) cloud free LISS-III data (October 2011) with spatial resolution 23.5 and LANDSAT 7 & LANDSAT 5 (October and November) spatial resolution 30 m data was used for constructing LULC change map for 2011, 2000, and 1991, respectively, using various analytical method. False colour composite image of the study area is given in Figure 2.

Forest type Hybrid classification using satellite data: Geographical Information System (GIS) and Remote Sensing (RS) methods were adopted for the preparation of several thematic layers to evaluate changes in land use in the current study area. The vegetation-type mapping was carried out using post monsoon data based on the phenology of the vegetation cover. Ground truthing and existing descriptions have been used to delineate vegetation types of ecological significance. A Garmin GPS was used to conduct field surveys to obtain coordinates on vegetation types and land uses. From satellite data, all major forest types identified by (Champion and Seth 1968) were interpreted and mapped. Moist Deciduous Forest, Dry Deciduous Forest, Semi Evergreen Forest, and Evergreen Forests are the forest forms mapped in the research field. Land use land cover categories and their description are given below in (Table 1).

Hybrid classification combines most of the classification methods together and takes advantage of both supervised

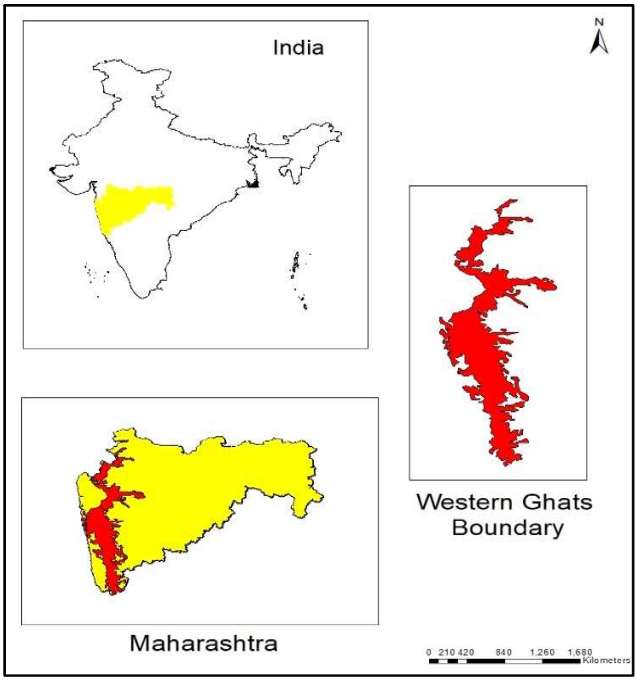


Fig. 1. Location map of the study area

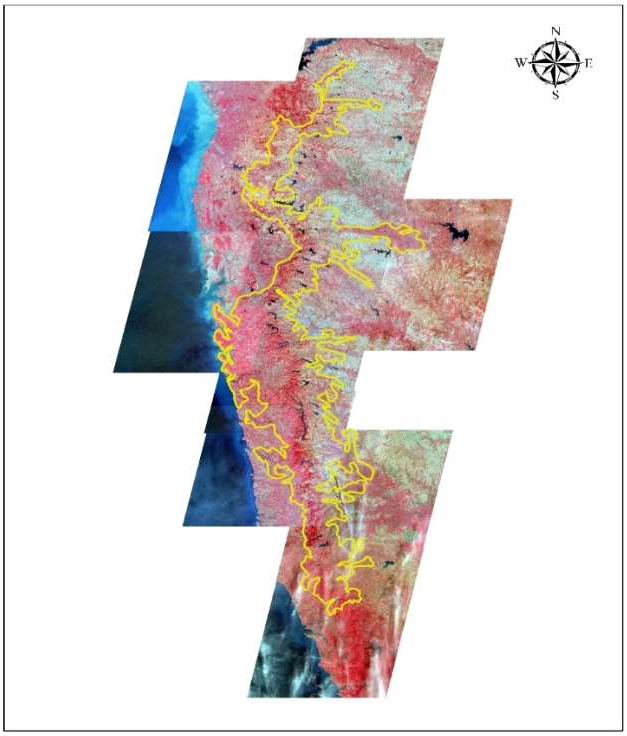


Fig. 2. False colour composite using IRS LISS III data of Western Ghats of Maharashtra and its surroundings

and unsupervised classification and integration of human knowledge from field experience this is how it produces high accuracy classified maps (Singh et al 2013). The first objective of hybrid technique is to map out the pure pixels of all classes. Now for that we had run an unsupervised classification on each image (FCC), 450 unique clusters using ISODATA clustering were identified with pixels of similar spectral characteristics. From the first image, clusters of pixels of different classes with the highest precision were masked out, binary images were obtained were 1 is classified and 0 is not. Will get an image of any one land use class with pure pixels. Another binary image has now been generated where 1 is not classified and 0 is classified, then multiplied by the FCC image. Perform unsupervised classification (for other classes) follow the procedure till no '0' values are available for further classification. The above method was followed for rest of the LULC classes. The procedure was performed on the left-out main image. Multiple images obtained through above different methods were combined and a final LULC image was generated.

Landscape analysis: Landscape functioning mostly focuses on two most fundamental measures of composition and configuration of different ecosystems (Gupta and Singh 2017, Tolessa et al 2016). The features of land cover or ecosystems refer to the structure, while the configuration refers to the spatial characteristics that involve the fragmentation levels of those habitats. The FRAGSTAT, developed to measure fragmentation by McGarigal and Marks (1995), is one of the most used and applied instruments and offers detailed statistical information on a variety of landscape levels. Characteristics of landscape can be explained in terms of porosity, fragmentation, patch density, patchiness, interspersion, juxtaposition, contagion, etc. (Forman and Godron 1986). For the landscape analysis present day approach like Geographic information system and remote sensing are widely used (Pearson 2002, Singh et al 2003, Singh et al 2013). In the present study, different landscape metrics have been studied to assess forest fragmentation patterns using FRAGSTATS and Landscape fragmentation tool.

Fragmentation: Fragmentation is number of patches of forest and non-forest type in per unit area. Vegetation maps of 1991, 2000 and 2011 were used for finding fragmentation and for the analysis of the maps. Landscape fragmentation tool was used in ArcGIS. Forest grid cell are classified into six categories - patch, edge, perforated, small core, medium core, and large core. Core forest is divided into small (less than 250 acres), medium (250-500 acres) and large (greater than 500 acres) categories.

Porosity: Porosity describes the number of patches or density of patches within a particular forest type, regardless of patch size. The analysis for the year 1991, 2000 and 2011 shows how the patches within different forest types are increasing over the years. It also indicates higher the density of patches which leads to more heterogenous and high fragmented habitats.

$$P = \sum_{i=1}^{n} Cpi$$

Where, Cpi is the number of close patches of ith cover class.

Patchiness: "Patchiness is the measure of the density of patches of all types or number of clusters in a given mask". The more the patches in a particular area the lesser the biodiversity. Patchiness also measures the number of polygons over a particular area (Romme 1982).

$$P = \frac{\sum_{i=1}^{N} Di}{N} \times 100$$

Where, N is the number of boundaries between adjacent

Table 1. Different Land use/Land cover categories and description of each classes

LULC classes	Description
Uninterpreted areas/ Hill shadows	Areas which are unidentified in satellite data due to steep slopes.
Built-up land	Areas populated with rural area and urban areas.
Waterbody	Surface water, which is accumulated in the form of rivers, lakes, pond, canals, etc.
Barren/fallow land	Exposed areas which are primarily agriculture but may be fallow.
Open land with scrub	Woody vegetation with a height less than 2 meters.
Agriculture	These are the areas where farming is practiced for different crops in different seasons. These include areas with croplands and commercial plantations.
Dry decidous forest	Forests are highly influenced by the climate
Semi-evergreen forest	Dominants include deciduous species but evergreens predominant
Moist decidous forest	Forests found in areas of moderate rainfall of 100 to 200 cm per annum. Areas of WG surrounding the belt of evergreen forests both on the western and the eastern slopes.
Evergreen forests	Dense tall forests which remain evergreen throughout

cells and Di is the dissimilarity value for the ith boundary between adjacent cells.

Interspersion and Juxtaposition Index (IJI): Interspersion is a count of dissimilar neighbors with respect to central pixel of the spatial intermixing of the vegetation types. Juxtaposition is defined as amount of proximity of the vegetation (Sinha and Sharma 2006). Its analysis mostly includes relative weightages assigned by the importance of the adjacency of two cover types for the species in question. IJI is articulated in % of total edge of landscape.

$$IJI = \frac{-\sum_{i=1}^{m}\sum_{k=i+1}^{m}\left[\left(\frac{eik}{E}\right)In\left(\frac{eik}{E}\right)\right]}{In(0.5[m(M-1)])}\times 100$$

Where, e_{ik} = Total length (m) of edge in landscape between patch types (classes) i and k.

E = Total length (m) of edge in landscape, excluding background.

m = Number of patch types (classes) present in the landscape, along with the landscape border, if present

Disturbance Index (DI): Any kind of disturbance leads to processes like fragmentation of habitats, migration of the species, local and regional extinction. Pickett and White (1985), defined "disturbance as a distinct event in time that alter ecosystem, community or population structure". The landscape disturbance gradient is primarily affected by the size of the patches and their density, which has increased due to fragmented habitat (Sinha and Sharma 2006). The disturbance index was measured using different landscape metrices like fragmentation, porosity, patchiness, interspersion and juxtaposition. Built-up and road distances were the two factors taken into consideration for spatial distribution of disturbance factors. The above factors were generated using the ground control data, land cover maps and ancillary database. Different weightages were assigned to each layer to calculate disturbance index. The forest disturbance was computed by adopting a linear combination of the defined parameters based on probabilistic weightage. Raster calculator tool of spatial analyst extension in Arc GIS was used in computing disturbance index. The formula used for the calculation is as follows.

Disturbance Index = ∫ [Fragmentation, porosity, patchiness, interspersion and juxtaposition, proximity from disturbance sources (built-up and road distances)]

i.e., DI = [(W1* F) + (W2* Po) + (W3*P) + (W4*IJI) + (W5*BU) + (W6*R)]

Where, W = Weightages

RESULTS AND DISCUSSION

Land use land cover dynamics: The obtained LULC layer was classified into 10 classes (Table 1). All the major forest types that are dry deciduous forest, moist deciduous forest, semi evergreen forest, and evergreen forests are classified. Apart from other forest types other LULC classes like water bodies, agriculture, open land with scrub, barren/fallow land, built-up found in the study area was classified. Changes in the LULC cover were mapped for the year 1991, 2000 and 2011. Total of 6 scenes of Landsat-5 satellite images were downloaded. Hybrid classification process was performed on individual scenes of satellite images. Further the classified scenes were mosaicked, and the study area was clipped for further analysis. The total area of Western Ghats of Maharashtra is 35718.7 sq. kms.

WG is one of the biodiversity rich regions, recognition of LULC pattern and delineating the area is more effective for monitoring the environmental heterogeneity and incitement of the current condition. The temporal LULC change during the period 1991, 2000 and 2011 was analysed in the present study. LULC change detection analysis was carry out using the above datasets. Change detection assessment is influenced by different factors like environmental factors and anthropogenic factors but also vary from short term to long term. Considering last few decades, deforestation has been one of the noticeable factors affecting forest cover change. Recent advancement of satellite sensors in spatial and spectral resolution provides high aspect of satellite datasets to describe the land use/cover information.

The major chunk of area is occupied by open land with scrub that is 15100.5 (km^2) that is 42.28% of the total study area (Table 2). Amongst the different forest types of moist deciduous forest constitutes the major area 9601.2 (km^2) and 26.8% of the total forest area. Semi evergreen forest constitutes 5.6 percent of the area. And the remaining dry deciduous forest and evergreen forest 4.7 per cent and 1.9, respectively. Amongst the four different forest types of moist deciduous forest is spread over a larger area (9601.2 km^2) in the year 1991, but the area has decreased to 26.6% for the year 2011 (Fig. 3). Similarly, for the other forest types that is semi-evergreen forest from 5.6% area in 1991 to 5.4% in 2000 and then decrease in the area in 2011 by 5.3%. In dry deciduous forest there is a decrease in area from 1991 to 2000 and from 2000 to 2011 from 4.7% to 4.5%. Similarly, in evergreen forest from 1991 to 2000 there is a decrease in area from 697.9 km^2 to 680.9 km^2 also from 2000 to 2011 the area has decreased by 1.9% to 1.8%. WG has experienced spatial changes over a period of three decades is clearly visible in the above (Fig. 3). The LULC of Western Ghats is mostly dominated by forest, forest dynamics over the three decades is changing continuously due to different factors, conversion of forest land to plantations and agriculture,

chopping down of the trees for fuel wood, fodder, and timber. Many human-led developments have led to disasters like landslides, forest fire etc., ultimately affecting the flora and fauna of WG regions. Built up has increased moderately from the year 2000 to 2011 that is from 257 km^2 in 1991 to 350.1 km^2 in 2011. Built up must have increased at the cost of open land with scrub and forest area. Water bodies has increased continuously from year 1991 to 2011, from 1.9% in year 1991 to 2.2% in year 2000 and to 2.9% in 2011, this can be associated with construction of new dams and other river valley projects. Some of the dams constructed in this time period are temghar dam, tilari dam, nilwande dam, ghatgar dam and many more. Agriculture area has increased significantly from 1991 to 2000 that is 12.8% to 12.9% and again it has increased in 2011 to 13.7%. Barren/fallow land also follows the pattern decrease in year 1991 2.4% to 2.35% in year 2000 and increased to 2.38% in year 2011. During the field work many ground truth data/GCPs were collected which were used for calculating the accuracy of the classified image/map. Accuracy assessment was done for each LULC maps of year 1991, 2000 and 2011. The overall accuracy was 86.92%, 85.77% and 85.00% and the overall kappa statistics were 0.82, 0.80 and 0.81 respectively. Land use land cover maps for the year 1991, 2000 and 2011 are shown below Figure 4.

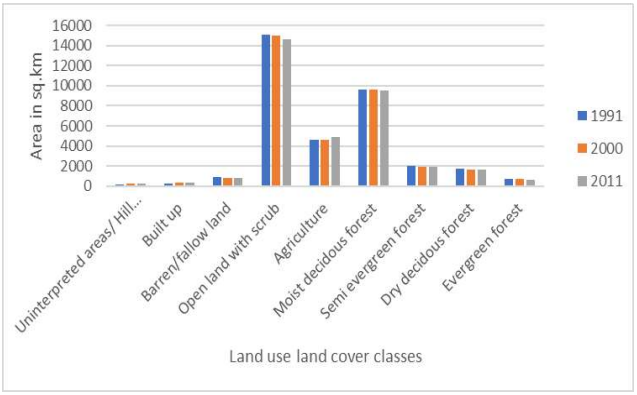


Fig. 3. Area statistics of land use land cover distribution

Landscape metrics dynamics: Landscape pattern indices also mentioned as landscape metrics are used to study the changes in landscape spatial pattern which are induced by anthropogenic and natural disturbances (Gillanders et al 2008). Apparently for forest class, fragmentation is mostly by

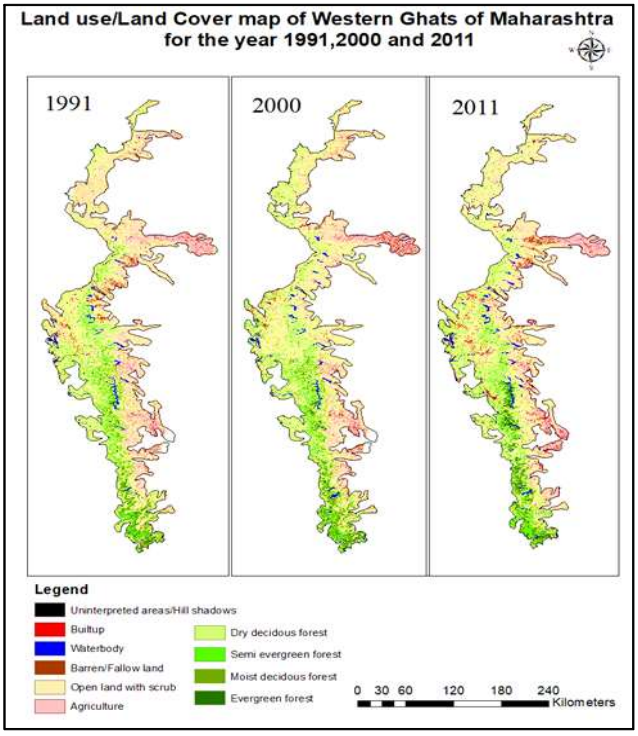


Fig. 4. Land use/land cover maps for the year 1991, 2000 and 2011

Table 2. Statistics of study area Western Ghats of Maharashtra for the year 2011

Land use/ Land cover classes	1991 Area (Sq.km)	Area %	2000 Area (Sq.km)	Area %	2011 Area (Sq.km)	Area %
Uninterpreted areas/ Hill Shadows	205.90	0.58%	207.20	0.58%	207.60	0.58%
Built up	257.00	0.72%	300.00	0.84%	350.10	0.98%
Waterbody	693.90	1.94%	797.70	2.23%	1052.60	2.95%
Barren/fallow land	867.90	2.43%	838.10	2.35%	850.70	2.38%
Open land with scrub	15100.50	42.28%	15040.40	42.11%	14630.70	40.96%
Agriculture	4585.60	12.84%	4630.40	12.96%	4919.50	13.77%
Moist decidous forest	9601.20	26.88%	9588.10	26.84%	9512.40	26.63%
Semi evergreen forest	2001.20	5.60%	1950.00	5.46%	1906.90	5.34%
Dry decidous forest	1707.60	4.78%	1685.90	4.72%	1627.90	4.56%
Evergreen forest	697.90	1.95%	680.90	1.91%	660.30	1.85%
TOTAL AREA IN SQ.KM	35718.7	100.00%	35718.7	100.00%	35718.7	100.00%

anthropogenic sources which are on the higher risk of further removal of forest by fragmentation or by natural causes (Giriraj et al 2011). Results of landscape metrics has also revealed that Western Ghats area is going under high disturbance. In fragmentation analysis small core forest category is increasing from year 1991, 2000 to 2011. The large core area decreased drastically from 12915.0 to 7934.93 and further decreased to 6844.07 km^2. Patch forest area has increased from 532.12 km^2 in 1991 to 987.51 sq. km in year 2000. Increase in forest patch area refers to conversion of forest to non-forest areas. Forest fragmentation increases the number of patches in a particular area. Edge forest area is between the core forest and large non-forested areas. Edge forest formation is increasing 2836.92 km^2 in 1991 to 4074.73 km^2 in 2011. Perforated forest makes up the interior edge of non-forested areas. As the perforation aggravated formation of patch forest increases which is followed by edge forest which is also further fragmented into forest areas. The analysis (Table 3) shows how the extent of fragmentation is increasing over the years in all the forest classes of Western Ghats region of Maharashtra. Fragmentation map of Western Ghats of Maharashtra is shown below in Figure 5.

Techniques like GIS, remote sensing and landscape ecology approaches are now widely used for biodiversity conservation in WG (Menon and Bawa 1997). Accelerated transformation, high rate of deforestation, conversion of forests to agriculture and monoculture plantations has adverse effects on biodiversity of the region. Low levels of porosity indicate that the forest type is homogenous and non-fragmented. High porosity values indicate particular species is scattered in the region (Fig. 7). Majority of the forest types in western ghats region shows increased levels of fragmentation from year 1991 to 2011 (Fig. 6). Number of patches in moist deciduous forest have increased drastically from 1991 to 2011. Also, the patchiness that is the density of patches is on the higher side in all the land use land cover classes from 1991 to 2011(Fig. 8). Major factor for increase in

Table 3. Forest fragmentation analysis of Western Ghats of Maharashtra

Class name	1991 Area (km^2)	2000 Area (km^2)	2011 Area (km^2)
Patch	532.12	987.51	921.68
Edge	2836.92	3202.53	4074.73
Perforated	946.90	1016.82	1292.34
Small core	1214.57	1492.51	1969.23
Medium core	205.66	224.18	376.61
Large core	12915.0	7934.93	6844.07

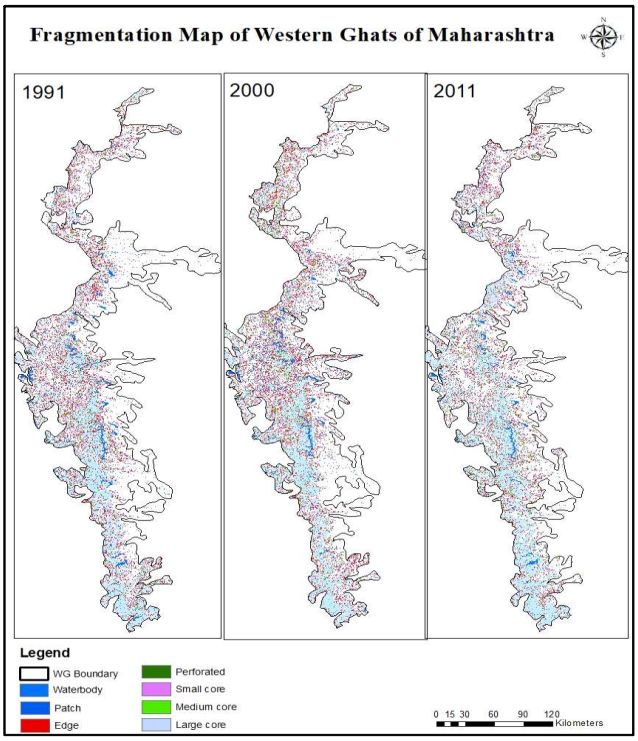


Fig. 5. Fragmentation map for the year 1991,2000 and 2011

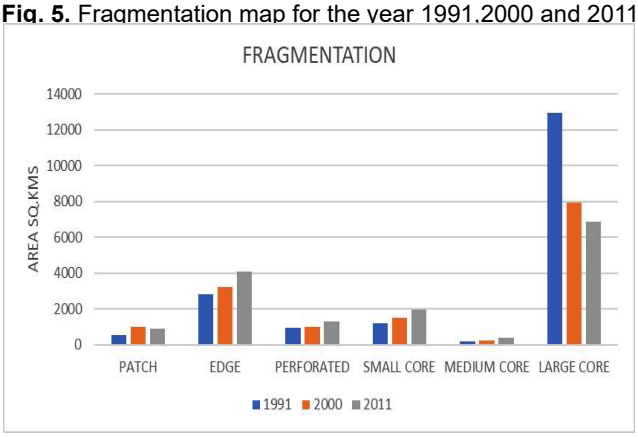


Fig. 6. Area statistics of fragmentation for the year 1991, 2000 and 2011

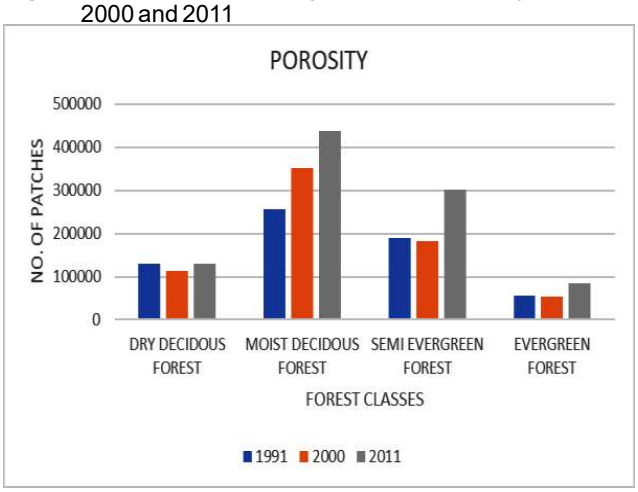


Fig. 7. Porosity for the year 1991, 2000 and 2011

patchiness is clearing of forest for developmental activities.

Different landscape patterns in WG have undergone spatial changes over the period of two decades. Above results signify large scale fragmentation in the forested area. As a result, patches in the forested areas are also on rise. Patch density or porosity in the area in increasing in different forest classes. Higher the patchiness in an area, higher the heterogeneity. IJI gives us the measure of evenness of patches, 100 for even and 0 for uneven. High values of IJI gives clustered and unequal measure of patches whereas low level indicates patches which are evenly adjacent to each other (Fig. 9). According to the above results forest types are more clumped in an area. It is found that fragmented forest led to decrease in species richness of tropical forests (Benitez-Malvido & Martinez-Ramos 2003). It is very important to study the landscape fragmentation process to propose proper management plans for vulnerability studies and assessment of forests.

Mapping of disturbance: Disturbance index map was classified into five categories i.e., least, low, medium, high and very high. The extent of disturbance is highly increasing in western ghats areas from year 1991 to 2011. Forest fragmentation and forest disturbance are extrusive in western ghats region over the few decades. The below Table 5 shows the distribution of disturbance area in different classes. Very high disturbance areas are present in Satara, Ratnagiri, Sindhudurg, Pune, Nashik, Kolhapur and thane districts.

The major change of disturbance is seen in very high category where in year 1991 the area was 1310.57 km^2which

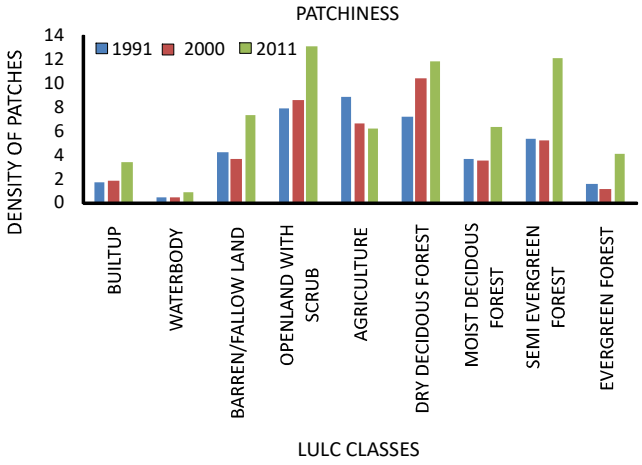


Fig. 8. Patchiness for the year1991, 2000 and 2011

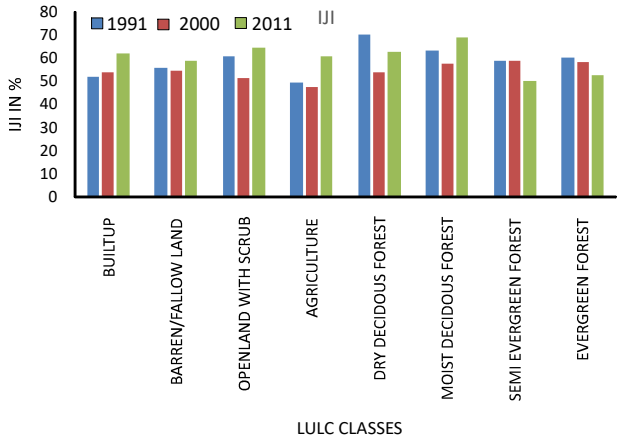


Fig. 9. IJI for the year 1991, 2000 and 2011

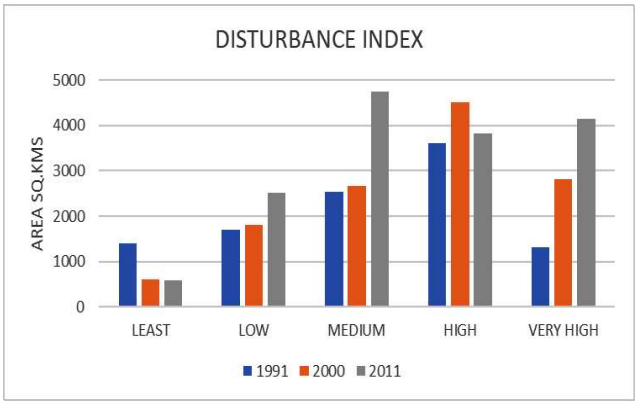


Fig. 10. Area statistics of disturbance index for the year 1991, 2000 and 2011

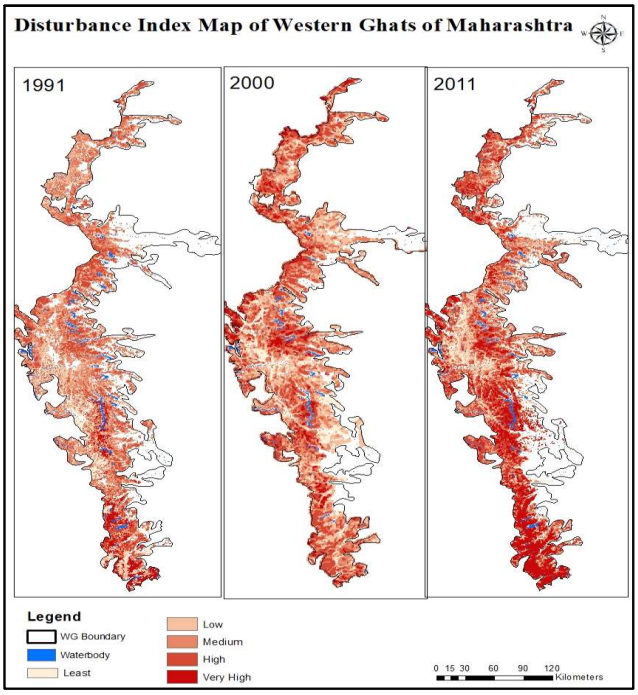


Fig. 11. Disturbance index map for the year 1991, 2000 and 2011

Table 4. Disturbance index of Western Ghats of Maharashtra

Classes	1991 (Area Km^2)	2000 (Area Km^2)	2011 (Area Km^2)
Least	1393.6	603.2	574.36
Low	1699.59	1815.82	2520.6
Medium	2543.24	2673.4	4739.64
High	3615.3	4520.71	3821.49
Very high	1310.57	2814.54	4143.35

increased to 4143.35 km^2 in 2011. Figure 8 shows the disturbance index map of the study area. Low disturbance area is represented by low porosity, low patchiness, low IJI, low fragmentation and at a great distance from human interference of roads and settlements. High disturbance area is characterized by high porosity, high patchiness, high IJI, highly fragmented, and close to human disturbance. Increased human pressure for food and increase in accessibility is one of the reasons for high levels of disturbance in WG. Many external factors like human modified landscape, deforestation and reforestation, plantation, urbanization, agriculture expansions influence the landscape change of the study area. These factors have far-reaching consequences for continuation of the threatened species. There are many protected areas like national parks, sanctuaries, biosphere reserves have been created to save biodiversity, but they are not free from human influence. Therefore, it is important to study these landscape elements they provide us with characterization and configuration of a habitat which gives info for biodiversity distribution pattern.

CONCLUSION

Geospatial is an important technology combined with different statistical tools for mapping land use land cover and landscape metrics studies. The results of our study show how crucial the Western Ghats region are for the people living in that region and for its global impact. Deforestation and soil erosion, flash floods, decline in the yield of food, fodder, fuel, also in many areas intensive human and livestock pressure has led to degradation of the region. Many developmental activities like construction of buildings, roads, dams, large and medium industry, and mining have aggravated environmental problems. Our study has analysed the distribution of forest cover over three decades and its changes over the period. LULC changes identified in the present study has direct association with the landscape metrics which leads to increased disturbance in over the years. Different landscape metrics results have proved the area of this region is more fragmented and have high degree of disturbance. It is crucial to identify the disturbed area in the region so that appropriate measures can be taken for conservation that is the need of the hour. Identification of disturbance zones in the study area will help for sustainable forest management and forest conservation as well as mapping sensitive zones in future. Proper land use policy, afforestation programmes, and other conservation strategies can protect the environment. Conservation of Western Ghats should be the prime agenda due to its high endemicity. As forest is one of the important constituents of landscape because it helps in maintaining biodiversity, regulating climate change, and providing other essential ecological resources it becomes our major duty ensuring sustainable development.

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Space-Time Modeling of Climate Change and Bioclimatic Potential of Steppe Soils

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Abstract: Climate change manifests itself in the intensity, frequency of climate anomalies and extreme weather phenomena at different levels of the hierarchy in space and time. Climate research is a complex interdisciplinary problem covering environmental, economic and social aspects of sustainable development of the world's countries. The study presents the results of space-time modeling and identifying regularities in climate change and also bioclimatic potential of the steppe soils in Ukraine applying specialized methods and GIS-technologies. The past 30 years are the most extreme period by the frequency of climate anomalies with a steady trend-cycle increase in the air temperature by 2°C and a reduction in the annual precipitation by 178 mm. It caused an increase in solar radiation reaching the earth surface by 7.2%, a decline in natural moisture by 66.4% and the hazard of soil washout by 80.5%, a reduction in climate energy expenses for soil formation by 21%, in bio-productivity of plants by 62% and in the potential of humus horizon capacity of steppe soils by 34.5%, that led to deterioration in the conditions of agricultural production, a decrease in crop productivity, self-regenerating and self-regulating functions of steppe soils. The obtained results are the basis for developing and introducing new measures for adaption to climate change at different economic levels.

Keywords: Climate, Air temperature, Precipitation, Bioclimatic potential, Soil formation, Humus horizon, Steppe soils, Modeling, GIS-technologies

Climate change is one of the most important global challenges of the 21st century going beyond the scope of scientific studies being a complex interdisciplinary problem that covers environmental, economic and social aspects of sustainable development of the world's countries. Climate change manifests itself in the intensity, frequency of climate anomalies and extreme weather phenomena at different levels of the hierarchy in space and time. For the past 30 years there has been a considerable increase in the frequency and intensity of dangerous weather phenomena causing a substantial economic loss, threatening steady functioning of landscape and aquatic ecosystems, and also human health and life. According to the predictions of many scientists, there will be a steady trend-cycle climate change (Wang et al 2019, Felice et al 2019, Dikshit et al 2021) causing considerable changes in the functioning of natural and artificial ecosystems, an increase in the frequency of signs of dangerous processes and consequences, degradation in the environment. The world scientists maintain that global climate change is caused by the factors: anthropogenic factors (Zhang et al 2019, Christidis and Stott 2021), an increase in the concentration of carbon dioxide (Paraschiv and Paraschiv 2020), radiative heating of the atmosphere because of absorption of infrared radiation under a dominating impact of convective heat transfer (Sorokhtin 2011), changing currents in the Arctic Ocean (the cold Labrador Current in the in the area of Greenland and the warm Gulfstream), causing periodical disastrous epochs of a steady decline and increase in the temperature regime in the Northern Hemisphere (Chaudhuri et al 2009, Weiser et al 2021). Climate at a regional level forms under the influence of the three most important factors: atmospheric circulation, solar insolation and topography (Lisetskii and Chepelev 2014). Therefore, need to take appropriate preventive measures, extensive implementation of basin management principles in the environment, application of advanced technologies to reduce the amount of carbon dioxide emissions and pollutants in the atmosphere, decreasing the area of arable lands and increasing the area of natural lands, using alternative sources of energy and technologies of energy supply, introduction of adaptive technologies and measures to uncontrolled climate change in different economic areas of the world's countries etc.

An increase in anthropogenic load reduces the resistance of the environment to uncontrolled signs of climate change. Negative signs of anthropogenic climate change are especially evident in the Steppe zone (Lisetskii and Pichura 2016, Dudiak et al 2019). There has been a considerable decline in the supply of water resources and their quality (Pichura et al 2018, 2020), the natural hydro-network of small and medium rivers has been destroyed by 60% (Oti et al 2020, Lisetskii 2021), the frequency of droughts has

increased (Assan et al 2020, Ukrainskiy et al 2020) and the frequency of the signs of erosion processes has risen (Dudiak et al 2019, 2020), the condition of land resources has deteriorated (Breus et al 2019, 2020, Lisetskii et al 2020) and crop productivity has also fallen (Domaratskiy et al 2018). Therefore, in order to farm effectively, substantiate nature conservation measures, regenerate natural resources and use them efficiently, adapt to new farming conditions and ensure sustainable nature management, it is necessary to consider space and time regularities of climate change and bioclimatic potential of territories. Analysis of the available sources shows that the issue of space-time modeling of climate change and evaluation of its impact on the formation of bioclimatic potential of territorial ecosystems aimed at the development and implementation of new adaptation measures at different economic levels is still topical and requires thorough examination. The purpose of the research is to model climate change and determine bioclimatic potential to establish trend-cycle changes in time and heterogeneity in spatial distribution of climate energy in the functioning of steppe soils.

MATERIAL AND METHODS

The study was conducted on the territory of the steppe zone of Ukraine (Fig. 1) (the total area is 167.4 thousand km^2), including the area of agricultural land (132.3 thousand km^2). Agricultural development of the region varies within 20-97%.

Space-time modeling of climate change and bioclimatic potential of steppe soils was performed on the basis of extrapolation of the data of 47 meteorological stations collected in 1990-2019. There are two approaches to determining effective climate energy through heat and moisture supply, proposed by Volobuiev (1974), Rasmussen and Tabor (2007). The previous research (Lisetskii and Pichura 2016) established a close exponential relation between the models of Rasmussen-Tabor (Q_{RT}) and Volobuiev (Q_V): Q_{RI} = 52.065 exp. (0, 001 Q_v); r^2 0, 93 determining the impact of climate energy on soil formation processes. It proves that the proposed approaches are complementary and allow approximation of identical conditions for the direction of climate energy, but the approach proposed by Volobuiev (1974) provides an additional possibility to determine climate impacts on the formation of soil horizon. Therefore, soil and climate studies use the method of bioenergetics research that allows modeling scenarios of climate impacts, given in energy equivalents, on the trends of soil development in time.The raster of spatial differentiation of climate energy expenses for soil formation (Q, MJ m^{-2}) in ArcGIS was calculated by the formula:

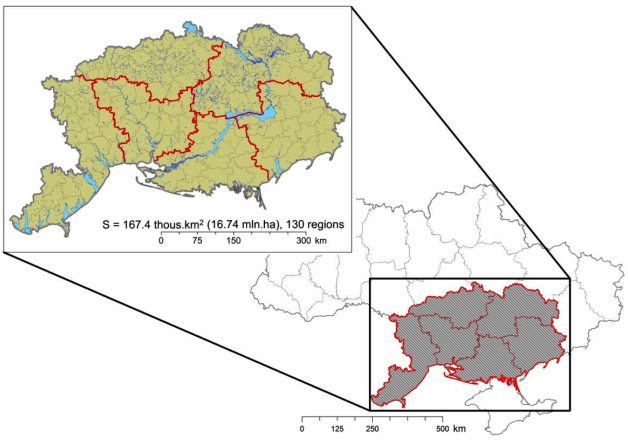


Fig. 1. Spatial characteristic of the territory of the steppe zone of Ukraine

$$Q = 41.868R \cdot e^{(-18.8\frac{R^{0.73}}{P})}$$

where R – the balance of solar radiation, kcal cm^{-2}; P – the raster of the total annual precipitation, mm.

The calculation of spatial differentiation of the balance of solar radiation ®, kcal cm^{-2}) considering surface unevenness was performed by the formula:

$$R = R_0 \frac{\cos(s) \times \sin(h) + \sin(s) \times \cos(h) \times \cos(\psi_s - e)}{\sin(h)}$$

where R_0 – the value of radiation balance of horizontal surface for each month of the year, kcal cm^{-2}; h – the average daily solar altitude for each month, rad; ψ_s – azimuth of the normal projection to the slope on a horizontal plane, rad; s – the raster of slopes, rad; e – the raster of expositions, rad.

The calculation of the raster of spatial distribution of the maximum capacity of soil humus horizons (H_{lim}, mm) depending on Q was performed by the formula:

$$H_{\lim} = \frac{2000}{1 + e^{(5.346 - 0.00523 \cdot Q)}}$$

Space-time differentiation of bio-productivity of plants (the dry weight – F, t ha^{-1}) was calculated depending on climate energy expenses for soil formation by the formula (Pichura 2020):

$$F = 0.3202 \cdot \exp(0.003421 \cdot Q),\ r = 0.96$$

The coefficient of the hazard of soil washout (K_{gm}) for the territory of the Steppe zone of Ukraine was calculated depending on the average multi-year value of the total precipitation in May–September (X_{av}) with a high level of correlation R=0.726 and determination R^2=0.527 by the formula (Svetlichny 2018):

$$\mathrm{K_{gm}} /(2.6 \cdot 10^{-6}) = 0.0174 X_{av}^{2.1}$$

where X_{av} – the average multi-year value of the total precipitation in May–September.

Zoning is performed by the gradation: 1 – the zone of high rainfall activity (K_{gm} > 1500), 2 – the zone of moderate rainfall activity (K_{gm} = 500-1500), 3 – the zone of low rainfall activity (K_{gm} < 500).

An important index for determining the intensity of the signs of dangerous washout and regulating irrigation norms in the Steppe zone is evaluation of changes in general climate moisture by the moisture coefficient of Vysotsky–Ivanov (K_H), measured by the ratio of the total annual precipitation (*Py*) and annual evaporation (*Ey*):

$$K_H = Py/Ey$$

Zoning is performed by the gradation: K_H>1 – the territory (time period) with excessive moisture, K_H is about 1 – with optimal moisture, K_H = 1.0–0.6 – with unsteady moisture, K_H = 0.6–0.3 – with insufficient moisture (Ivanov 1948).

In order to evaluate annual evaporation, we used the method (Kolomyts 2010), implying that evaporation depends on average monthly air temperature of the warmest month (July– t_{max}) with high coefficients of correlation R=0.94 and determination R^2=0.88:

$$Ey = 1384\text{-}161.6t_{max} + 6.245t^2_{max}$$

Modeling and calculation of spatial distribution of the research indexes were performed by means of the software ArcGIS 10.1.

RESULTS AND DISCUSSION

The Steppe zone of Ukraine is referred to the territories of risky agriculture by extreme climate conditions, signs of droughts and wind erosion. The territory is characterized by a high level of agricultural land development, the area of farmlands was 13235.5 thousand hectares (21.92% of the total area of Ukraine) on January, 2019. The area of natural lands is about 14%, including forests and other woodland areas (6.1%), followed by territories covered with surface water (6.91%) and open wetlands 0.97%. A high degree of agricultural land development (77.83%) and arable territories (66.76%) of the Steppe zone causes a low level of ecological stability of the landscapes in terms of soil conservation measures. More that 60% of the irrigated lands of Ukraine are located in the territory of the Steppe zone, without the temporarily occupied territories, making about 1324.1 thousand ha, 461.2 thousand ha (34.8%) of these territories are irrigated. Extensive use of land resources in the Steppe zone caused imbalance in the natural state of soil fertility, its considerable deterioration, ecological imbalance in the environment, a decline in the efficiency and rate of natural soil formation processes, an increase in energy expenses for obtaining steady crop yields. In particular, negative environmental processes intensified by climate change cause large-scale manifestation of wind erosion, salinization and alkalization of steppe soils. It deepens the problem of examining soil condition and soil functioning under high anthropogenic pressure and climate change.

Changes in the air temperature and precipitation: There has been a trend-cycle increase of the average air temperature and a decline in the total annual precipitation in the Steppe zone of Ukraine. The cycle components of the multi-year formation of climate indexes were: air temperature (8 years) and precipitation (11 years). The past 30 years (Fig. 2a) are considered to be the most extreme period by the frequency of climate anomalies that doubled causing an increase in the temperature regime by a cyclic-linear regularity (R=0.72, R^2=0.52) and led to an increase in the average annual temperature by 2°C at the average increase rate of 0.07°C per year. Cyclicity of the changes in precipitation in the Steppe zone is within asynchronous

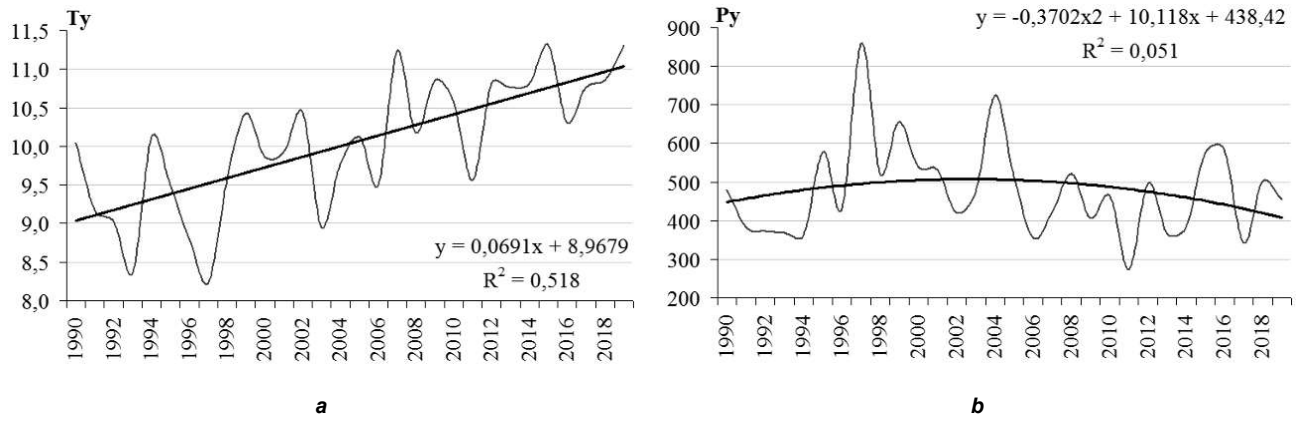
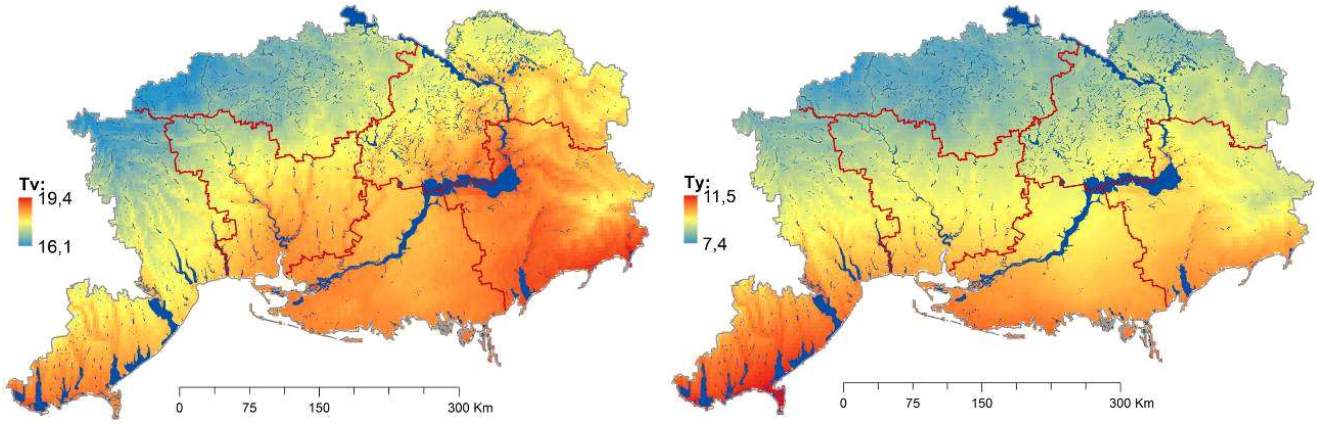


Fig. 2. Dynamics of the average annual air temperature (*a* – *Ty*, °C) and the total precipitation (*b* – *Py*, mm) within the territory of the Steppe zone of Ukraine in 1990-2019

regularity of changes with respect to the temperature regime. In 1990–2019, 35% of years with anomalous amounts of precipitation were registered, in particular (Fig. 2b) 8 years with severe and 4 years with very severe anomalies. Over the past 30 years it has caused a reduction in the total annual precipitation by 178 mm at the reduction rate of 7.12 mm per year.

An increase in the frequency of anomalous high temperatures and a decline in the amount of precipitation have caused deterioration in the conditions of agricultural production, self-regenerating and self-regulating functions of soils, a reduction in the rate of soil regeneration, leading to a decline in their fertility, maintaining a negative tendency to soil degradation, losses in crop yields and deterioration in food security of the country.The results of the spatial modeling allowed establishing zonal regularities of climate preconditions for differentiation of the functioning of steppe soils. The average air temperature in 1990–2019 in the Steppe zone of Ukraine changed from 16.1 to 19.4°C in the direction from the North to the South during the growing season (Fig. 3a), and the average annual was within 7.4–11.5°C (Fig. 3b). The highest value of the air temperature was registered in the southern part of the Steppe zone. Zonal climate changes in the functioning of soils depend on the principle of the limiting factor, i.e. bio-productive potential of soil s, plant growth, the amount and stability of their yields depend on the substance, whose concentration is minimal. Moisture is the limiting factor in the Steppe zone. In particular, background characteristics of the zonal changes in heat and moisture supply explain the specificity and multi-year rhythmicity of the conditions of agricultural production.

Spatial differentiation of precipitation during the growing season in the territory of the Steppe zone of Ukraine in 1990-2019 ranged from 182 mm to 382 mm from the southern part to the northern part (Fig. 4a). Theannual precipitation ranged from 321 mm to 607 mm (Fig. 4b). The highest value of precipitation is registered in the north-western and the north-eastern parts of the Steppe zone.There were considerable variable changes (V = 6-10 %) of the average annual indexes in the growing season, in particular, the air temperature and the total precipitation were within V = 27-32%. Retrospective analysis of the dynamics of the air temperature and precipitation indicates to a steady cyclic increase in the average annual air temperature and a decline in the precipitation. An increase in the precipitation over some periods of time was not productive, because of rainfalls causing flood processes and water erosion. Climate change is characterized by an uncontrolled dynamic process that affects the functioning of all components of ecosystem, including the space-time differentiation of climate energy expenses for soil formation processes and the formation of natural soil fertility. The dependence of soil formation on climate is an unsteady temporal process, characterized by cyclicity and amplitude, and also by a change in the trend of moisture supply (total precipitation) and energy (solar radiation).



a *B*

Spatial function of value distribution *Tv*:

$$Tv = -23,271 - 2,904x - 0,036x^2 + 4,215y - 0,091y^2 + 0,115xy,\ r^2 = 0,79$$

Spatial function of value distribution *Ty:*

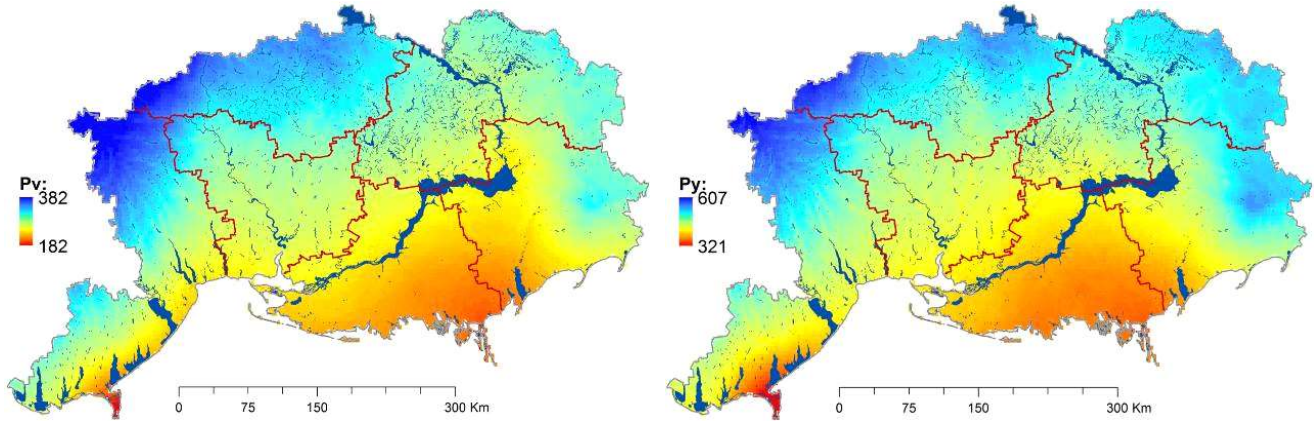
$$Ty = 148,909 - 2,604x - 0,021x^2 - 3,215y - 0,006y^2 + 0,086xy,\ r^2 = 0,91$$

where, x – longitude, decimal degrees, y – latitude, decimal degrees

Fig. 3. Spatial differentiation of the air temperature in the territory of the Steppe zone of Ukraine in 1990–2019: *a* – the average value in the growing season (*Tv,* °C); *b* – the average annual value (*Ty,* °C)

Moisture deficit in the conditions of the Steppe zone and the necessity to obtain high yields have caused the development of irrigated agriculture in these regions. Intensive agriculture in irrigated lands using obsolete machinery and technologies has led to irreversible processes of deterioration in their environmental-reclamation condition (Pichura and Breus 2015, Martsinevskaya et al 2018), flooding, salinization, alkalization and excessive irrigation have caused degradation in soil horizons, excessive and unreasonable exploitation of surface water resources.

Changes in the solar radiation and climate energy expenses for soil formation: Distribution of solar radiation is an important climate component of crop yield formation and an object of modifying agro-landscape microclimate. Space-time differentiation of solar radiation depends on cyclic movement of temperature regime and morphometric characteristics of topography. In particular, the value of radiative balance and moisture coefficient have asynchronous movement. In 1990-2019 the f the balance of solar radiation increased by 7.2% (from 51.5 to 55.2 kcal cm^{-2}) at the average annual increase rate of 0.2 kcal cm^{-2} per year (Fig. 5*a*). The process of evaporation from the surface is more intensive when there is an increase in solar radiation, as a result, it causes a decline in the coefficient of soil moisture and low yields.



A ***b***

Spatial function of value distribution *Pv*

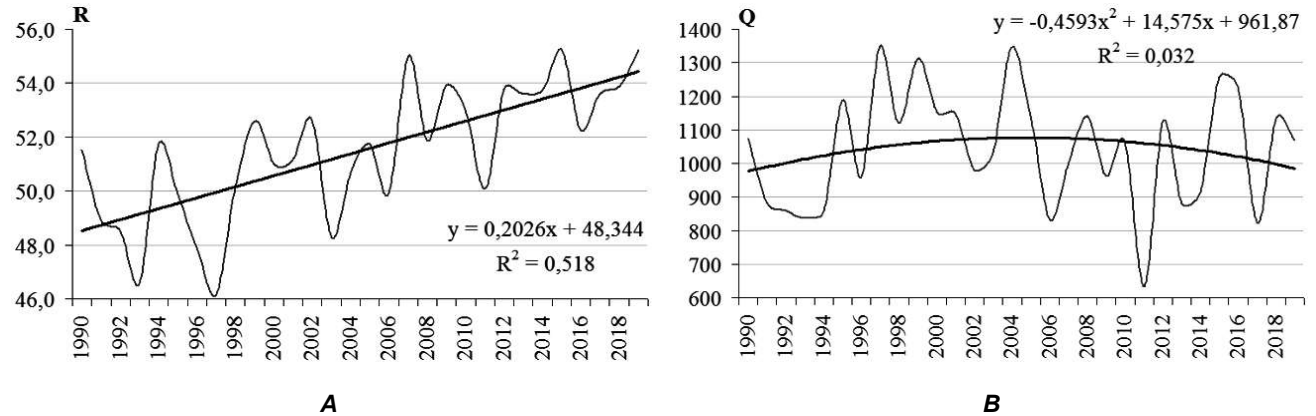
$$Pv = -4218{,}089 - 84{,}729x + 3{,}475x^2 + 221{,}238y - 0{,}875y^2 - 3{,}219xy,\ r^2 = 0{,}78$$

Spatial function of value distribution *Pv*

$$Py = -7728{,}96 - 249{,}927x + 5{,}848x^2 + 473{,}386y - 3{,}429y^2 - 2{,}985xy,\ r^2 = 0{,}85$$

where, x – longitude, decimal degrees, y – latitude, decimal degrees

Fig. 4. Spatial differentiation of precipitation (*P,* mm) in the territory of the Steppe zone of Ukraine in 1990–2019: *a* – the total precipitation in the growing season (*Pv,* мм); *b* – the total annual precipitation (*Py,* mm)



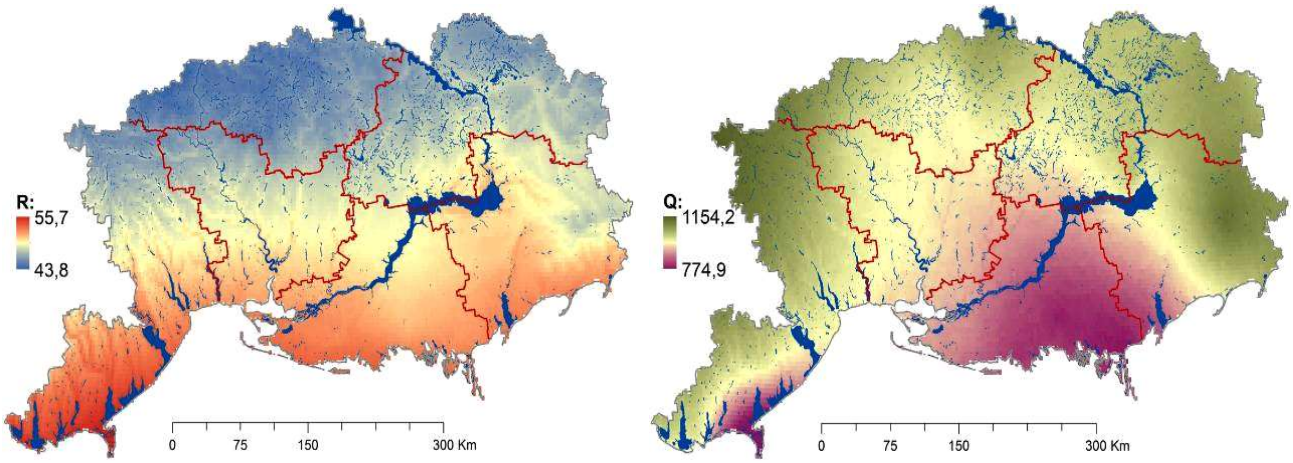
A ***B***

Fig. 5. Dynamics of the balance of solar radiation (*a* – *R*, kcal cm^{-2}) and climate energy expenses for soil formation (*b* – *Q*, MJ m^{-2}) within the territory of the Steppe zone of Ukraine in 1990-2019

Spatial differentiation of the balance of solar energy in the territory of the Steppe zone of Ukraine in 1990–2019 ranged from 43.8 to 55.7 kcal cm^{-2} from the northern part to the southern part (Fig. 6a). The highest value of the balance of solar radiation was registered in the southern part of the Steppe zone.Cyclicity of changes in precipitation and asynchronous movement of solar radiation causes a decline in climate energy expenses for soil formation processes. For instance, the annual climate energy expenses for soil formation (*Q*, MJ m^{-2}) within the territory of the Steppe zone in 1990-2019 ranged from 632.3 to 1350.0 MJ m^{-2} (Fig. 5b), its minimal value was registered in 2011 and its maximum value in 1997. The annual climate energy expenses for soil formation fell by 21% (from 1350 to 1067.6 MJ m^{-2}) at the average annual rate of 9.0 MJ m^{-2} per year in 1997-2019. A negative tendency to a decline in the dependence of soil formation processes on climate leads to a decrease in the rate of natural capability of regenerating soil fertility and an increase in the time necessary for conservation of degraded and low-productive farmlands. The spatial differentiation of climate energy expenses for soil formation in the territory of the Steppe zone of Ukraine in 1990–2019 ranged from 774.9 to 1154.2 MJ m^{-2} from the southern part to the northern part (Fig. 6b). The highest value of climate energy expenses for soil formation was registered in the northern part of the Steppe zone.

Changes in the bioclimatic potential of soils: Spatial heterogeneity of soil cover within the Steppe zone is caused by the interaction of bioclimatic, litholytic, geomorphological and historical-genetic factors. In particular, the temperature regime and the regime of soil and air moisture have determined the zonal differentiation of bioclimatic potential of soils that characterizes the state of the atmosphere as a basic part of the environment and the functioning of soil. Under conditions of continuous climate change, bioclimatic potential allows determining space-time regularities of changes in the potential of crop productivity, the rate of accumulation of organic matter and regeneration of soil fertility. Bioclimatic potential of soils is determined by the value of bio-productivity of plants. The bio-productivity of plants (*F*) varied within 2.8–32.4 t ha^{-1} depending on climate conditions of the Steppe zone of Ukraine in 1990–2019 (Fig. 7*a*), minimal in 2011and maximum in 1997. Climate-dependent bio-productivity of plants fell by 62% (from 32.4 to 12.3 t ha^{-1}) at the average annual rate of 0.45 t ha^{-1} per year in 1997-2019.

The considerable heterogeneity (about 73%) in the differentiation of bio-productivity of plants in the territory of the Steppe zone of Ukraine in 1990-2019 was observed and ranged from 4.5 to 16.7 t ha^{-1} from the southern part to the northern part (Fig. 8*a*). The highest value of bio-productivity of plants was registered in the north-western and the north-



Spatial function of value distribution *R:*

$$R = 485{,}526 - 7{,}633x - 0{,}061x^2 - 9{,}423y - 0{,}016y^2 + 0{,}251xy,\ r^2 = 0{,}88$$

Spatial function of value distribution *Q:*

$$Q = -22066{,}35 - 593{,}60x + 2{,}18x^2 + 1344{,}96y - 14{,}46y^2 + 2{,}18xy,\ r^2 = 0{,}83$$

where, x – longitude, decimal degrees, y – latitude, decimal degrees

Fig. 6. Spatial differentiation of climate energy features in the territory of the Steppe zone of Ukraine in 1990–2019: *a* – radiative balance of the surface (*R*, kcal cm^{-2} per year); *b* – climate energy expenses for soil formation (*Q*, MJ m^{-2})

eastern parts of the Steppe zone.Spatial distribution of the data on climate energy expenses for soil formation (*Q*) allowed determining space-time regularities of the zonal-cyclic changes in the formation of the potential of the capacity of soil humus horizon (H_{lim}, *мм*) in the territory of the Steppe zone. Climate dependence of the change H_{lim} in 1990–2019 ranged from 226.5 to 1684.2 mm (Fig. 7*b*), minimal was in 2011 and maximum in 1997. The H_{lim} fell by 34.5% (from 1684.2 to 1102.4 mm) at the average annual rate of 19.7 mm per year from 1997 to 2019. The spatial differentiation of the potential of soil humus horizon in the territory of the Steppe zone of Ukraine in 1990–2019 ranged from 422.8 to 1321.4 mm from the southern part to the northern part (Fig. 8*b*). The highest average H_{lim}, was registered in the north-western and the north-eastern parts of the Steppe zone. In particular, the development of irrigated reclamation in the Steppe zone has caused a considerable increase (1.5 times) H_{lim} (Lisetskii and Pichura 2016), that leads to systematic manifestation of leaching, transportation of organic substances to lower soil horizons poorly accessible for plants and, as a result, to a decline in agriculture efficiency and top soil fertility.

Changes in the hydro-meteorological conditions of soil washout: Space-time regularities of accelerating degradation of soil cover and unpredicted signs of yield destruction are mainly determined by differentiation of the eroding regime of rainfalls, characterized by the hydro-

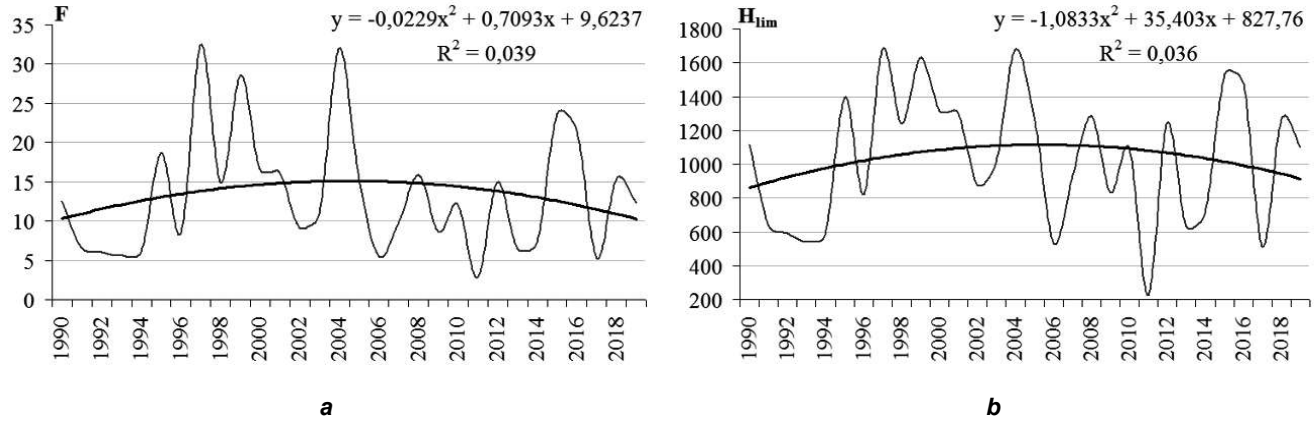
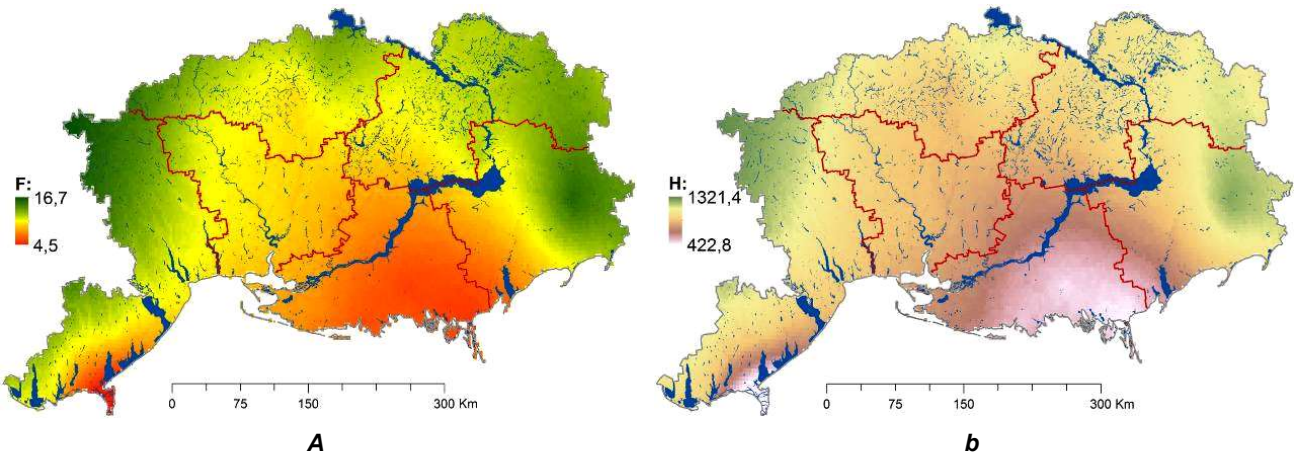


Fig. 7. Dynamics of bio-productivity of plants (*a* – by dry weight – *F,* t/ha) and capacity of soil humus horizon (*b* – H_{lim}, *mm*) within the territory of the Steppe zone of Ukraine in 1990-2019



Spatial function of value distribution *F*

$$F = -764,186 - 21,251x + 0,306x^2 + 45,90y - 0,473y^2 + 0,018xy,\ r^2 = 0,83$$

Spatial function of value distribution *H*

$$H = -57111,06 - 1527,44x + 18,78x^2 + 3405,55y - 36,69y^2 + 5,79xy,\ r^2 = 0,81$$

where, x – longitude, decimal degrees, y – latitude, decimal degrees

Fig. 8. Spatial differentiation of bioclimatic potential in the territory of the Steppe zone of Ukraine in 1990–2019: *a* – plant bio-productivity (F, т га$^{-1}$); *b* – maximum capacity of soil humus horizon (H_{lim}, mm)

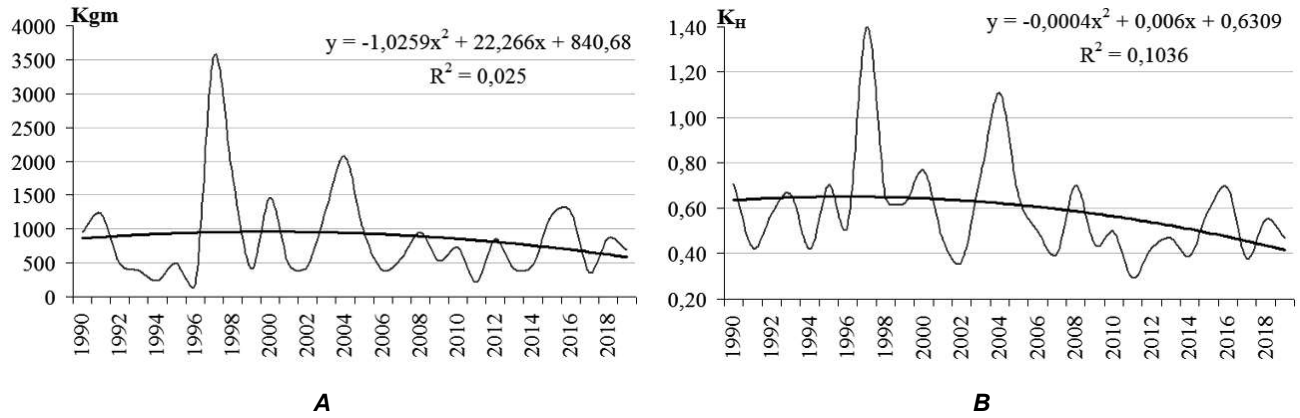


Fig. 9. Dynamics of the hydro-meteorological coefficient of the hazard of soil washout (*a* – K_{gm}) and the moisture coefficient of Vysotsky-Ivanov (*b* – K_H) within the territory of the Steppe zone of Ukraine in 1990-2019

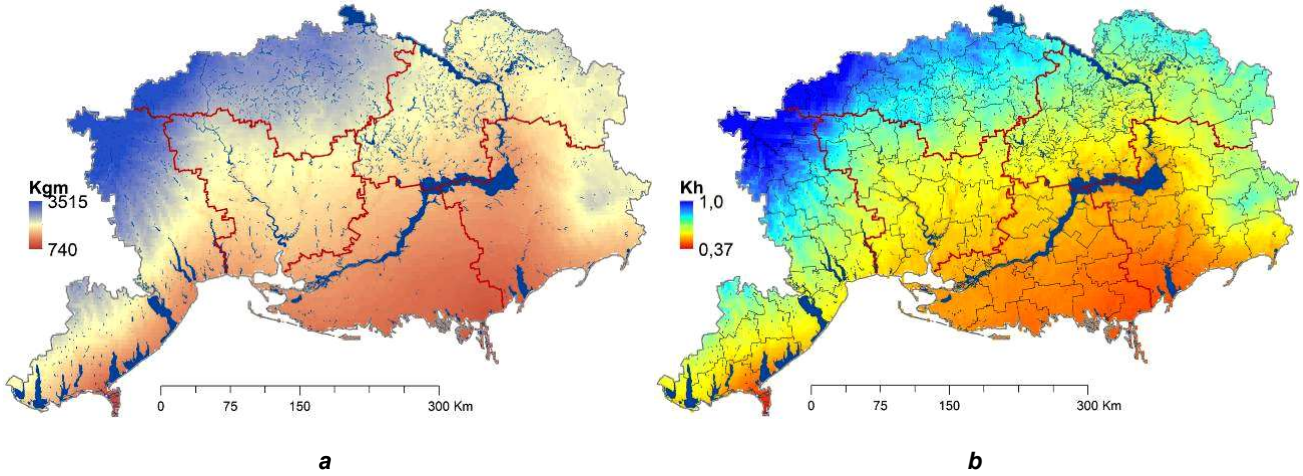


Fig. 10. Spatial differentiation of the hydro-meteorological conditions of soil washout in the territory of the Steppe zone of Ukraine in 1990–2019: *a* – the hydro-meteorological coefficient of the hazard of soil washout (K_{gm}); *b* – the moisture coefficient of Vysotsky-Ivanov (K_H)

meteorological coefficient of the hazard of soil washout (K_{gm}). In the period of 1990-2019 the K_{gm} ranged from 208.9 (2011) to 3552.6 (1997) (Fig. 9*a*). During 1997 to 2019 the hydro-meteorological coefficient fell by 80.5% (from 3552.6 to 691.7) at the average annual rate of 47.7 per year. There were 12% of the years with high rainfall activity, 52% of the years with moderate rainfall activity and 36% of the years with low rainfall activity. The spatial differentiation of K_{gm} in the territory of the Steppe zone of Ukraine in 1990–2019 ranged from 740 to 3515 from the southern part to the northern part (Fig. 10*a*), its highest value was in the south-western part of the Steppe zone. The results of the calculations made it possible to determine that in of 1990-2019 the moisture coefficient (K_H) ranged from 0.29 (2011) to 1.4 (1997) (Fig. 9*b*). In the period of 1997-2019 the moisture coefficient fell by 66.4% (from 1.4 to 0.47) at the average annual rate 0.018 per year. According to the classification, there were 8% of the years with excessive moisture, 44% of the years with unsteady moisture and 48% of the years with insufficient moisture.

The spatial differentiation of the moisture coefficient in the territory of the Steppe zone of Ukraine in 1990–2019 ranges from 0.37 to 1.0 from the southern part to the northern part (Fig. 10*b*). The highest K_H was in the north-western part of the Steppe zone.

CONCLUSIONS

The modeling allowed determining space-time regularities of climate change and bioclimatic potential of steppe soils. The past 30 years are considered to be the most extreme period by the frequency of climate anomalies with a steady trend-cycle increase in the air temperature by 2°C and

a decline in the total annual precipitation by 178 mm. It caused an increase in the solar radiation reaching the soil surface by 7.2% and a decline in climate energy expenses for soil formation by 21% that reduced the rate of natural capability of regenerating soil fertility. In particular, there has been a decline in bio-productivity of plants by 62% and is used to determine bioclimatic potential ranging from 4.5 to 16.7 t ha^{-1} in steppe soils. There has been a reduction in the coefficient of natural moisture by 66.4% and that of the hazard of soil washout by 80.5%. Low values of the corresponding coefficients characterize insufficient moisture content in steppe soils and a low level of rainfall activity. Changes in climate energy expenses for soil formation caused a decline in the potential of humus horizon capacity of steppe soils by 34.5% that led to deterioration in the conditions of agricultural production, a reduction in the yields, self-regenerating and self-regulating functions of steppe soils. The results of space-time modeling of climate change and the examination of its impact on the formation of bioclimatic potential of steppe soils must be a basis for the development and implementation of new measures for adaptation to climate change at different economic levels.

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Forest Fire Monitoring of Wildlife Sanctuary using Geospatial Techniques

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Abstract: Forest fires are the most destructive element in the ecosystem, and it is the critical environmental issue. Geospatial technology provides various techniques for fire monitoring across the globe. The present study uses various indices like dNDVI and dNBR for creating burn severity mapping of Sri Venkateswara Wildlife Sanctuary (SVWS) which can help identify the fire risk zones and monitor vegetation activity for the year 2020. This study collects various Active Fire data products like MODIS and VIIRS to do overlay analysis to compare the Burn severity mapping. The study identifies various high and moderate fire risk zones along the study area which effects the biodiversity in the region.

***Keywords*:** Fire, Geospatial, MODIS, VIIRS

India represents the world's most significant biodiversity area with a wide range of Flora and Fauna. In India, the number of Protected Areas (PA) vulnerable to forest fires increases in states from 33% to 90% (Roy et al 2015). Recently, India displayed a rising forest fire trend relative to Southeast Asia (SEA) countries (Vadrevu et al 2019). Most forest fires in India are anthropogenic (Agarwal et al 2021). However, forest fires depend on various parameters, such as the atmosphere, fuel type, wind, topography, and the country's demography (Giriraj et al 2010). Past observations indicate the increased growth and severity of forest fires, which often causes increasing temperature and decline in precipitation in Asian countries (Meehl 2007). Remote Sensing and GIS system provides the necessary information to develop a forest fire location maps to classifying fire hazard area (Sowmya and Somashekar 2010).Forest Fires are mainly identifying by spectral reflectance properties and burnt scar vegetation. Thermal differences in burning pixels and background layers are also widely used for fire detection (Giglio and Roy 2020). Various wide range of satellite sensors like Moderate Resolution Imaging Spectrometer (MODIS), Landsat 7 Enhanced Thematic Mapper+(ETM+), Indian Remote Sensing Satellite P6 Linear Imaging Self-Scanner (IRS P6 LISS-III), Satellite Pour l' Observation de la Terre (SPOT), Advanced Very High-Resolution Radiometer (AVHRR) will have a wide range of applications in forest fire studies (Manaswini and Sudhakar Reddy 2015). This study's main objective is to produce a forest burnt area map and provide insights for developing policy and planning to prevent larger forest fires in the future, which would help the policymakers in the decision-making process and helps the local community whose livelihood depends upon a forest (Agarwal and Kumar 2020, 2021).

MATERIAL AND METHODS

The study area is in the Eastern Ghats, scatter over the Seshachalam hills of Cuddapah district and Tirumala hills of Chittoor district. It consists of southern tropical dry deciduous forests, dry redsanders forest, and southern dry mixed deciduous forest. The geology of Sri Venkateswara Wildlife Sanctuary(SVWS) is mostly hilly, ranging from 150 m to 1,130 m. The average temperature recorded in the area varies from 12°C to 44°C. The region's maximum rainfall mostly receives from northeast monsoons and south-west monsoons with an average rainfall of 900 mm. The total area of study is 525.97 sq. Km out of this 325 sq. km is under Sri Venkateswara National Park. The vector dataset of the SVWS is obtained from Google Earth with reference to the World Database of Protected Area (WDPA), which is part of the protected-planet-online platform maintained by the UN Environment International Union Conservation of Nature (IUCN). The SVWS falls under category four, according to the WDPA.

This study analyses forest fires in the Sri Venkateswara Wildlife Sanctuary in the Chittoor district, Andhra Pradesh, which is the only PAs in the state. The SVWS contains a wide

range of flora and fauna like Red sanders, *Sterculia urens*, *Ficus religiosa*, *Slender loris*, and Golden gecko. The conditions in the study area indicating the highest Normalized Difference Vegetation Index (NDVI) values attributed to lush green conditions in the monsoon season, whether in summer NDVI values are low attributed to leafless conditions. The climatic conditions in SVWS create specific environments to grow red sanders, which are endangered, and endemic taxon to Andhra Pradesh, India. These are spread across SVWS and creates economic growth in the region. The methodology adopted for the study is shown in Figure 1.

Land use and land cover (LULC) map: Forest GIS layers are extracted from the decadal land use and land cover (LULC) dataset of 2005 with 100 m spatial resolution. This LULC product is derived from Landsat-5 ETM+, IRS-1C, Linear Imaging Self-Scanning system III (LISS-III) of 2004. Widespread ground truth of 12,606 stratified random samples is used to assess 19 LULC classes accuracy. The overall mapping accuracy is obtained up to 94.46% with a kappa accuracy of 0.9445 (Roy et al 2015). Two forest-type are merged to form forest class (Table 1 and Fig.2)

Multispectral data: Multispectral satellite data from Landsat sensors on the GEE platform is acquired to do Burn area mapping. Spectrally sensitive Landsat-8 OLI orthorectified surface reflectance data (Arekhi et al 2019) were used to identify the burn area patches over SVWS. Vegetation Burn scar sensitive short-wave infrared (SWIR), vegetation greenness indicator of Near- Infrared (NIR), and Red bands of Landsat-8 OLI are employed to generate various spectral indices namely, NDVI and NBR.

Table 1. Forest type class of decadal Land use land cover which are merged into one forest class

Class value	Class	Merged class
1	Deciduous broadleaf forest	Forest
4	Mixed forest	

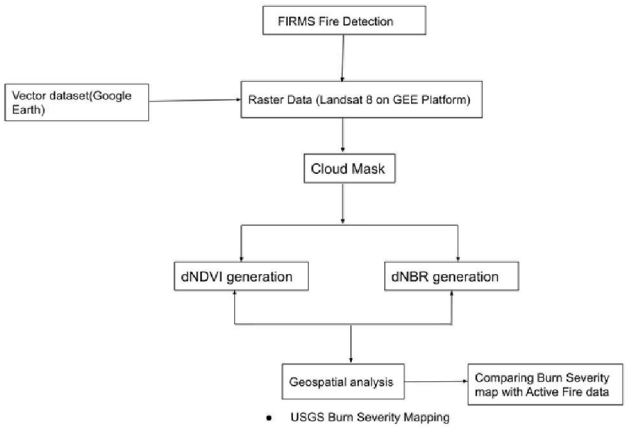


Fig. 1. Flowchart showing methodology used for the study

Forest fire detection: NASA's Fire Information and Resource Management System (FIRMS) is a web-based portal used to detect forest fires worldwide. Sensors like MODIS Terra/Aqua with a spatial resolution of 500m and VIIRS with a spatial resolution of 375m are used to identify the global fire and fire hotspots. The fire is detected in the study area between March to April 2020. Several patches of the study area were affected during the fire. In this analysis, the FIRMS platform is used to detect the extent of forest fires in the region.

Platform overview: Earth Engine is an online cloud-based platform for planetary analysis. It has a multi-petabyte analysis-ready data catalogue used for various societal issues. It is accessed and controlled through an Internet-accessible application programming interface (API) and an associated Web-based interactive development environment (IDE) that enables prototyping and visualization of results. The data catalogue houses an extensive repository of publicly available datasets, including observations from various satellite and aerial imaging systems in optical and non-optical wavelengths, i.e., Landsat-8, Sentinel -2 (Gorelick et al 2017).

Processing: Satellite images with a geographic reference system with WGS84 datum are acquired from Earth Engine. The images are taken before the fire and after fire events in the SVWS, and Both images are cloud masked using Landsat-8 cloud mask algorithms.

Normalized difference vegetation index generation: NDVI is one of the major indices to monitor vegetation health. It is computed from NIR and red band reflectance ratio, as shown in eq.1. Simultaneously, chlorophyll absorbed red wavelength, whereas mesophyll scatters NIR. NDVI ranges from -1 to +1. Negative values indicate the absence of vegetation, whereas a positive value indicates high vegetation (Pettorelli et al 2005).

$$NDVI = \frac{NIR\text{-}RED}{NIR+RED} \qquad (1)$$

After computation of NDVI for both Pre-fire and Post-fire scenes, dNDVI is calculated for identifying the difference between Pre-fire and Post-fire NDVI values as shown in the eq.2

dNDVI=Pre fire NDVI – Post fire NDVI (2)

Normalized burn ration generation: According to the USGS burn severity classification, NBR is used to identify the

burnt areas using satellite imagery. To identify the burnt patches on the ground, NBR uses NIR and SWIR2 (2.107-2.294 µm) bands to calculate pre-fire NBR and Post-fire NBR as per eq.3. The difference between Pre-fire and Post-fire NBR is calculated to identify the vegetation's quantitative change due to the fire event, as shown in eq. 4.

$$NBR = \frac{NIR-SWIR2}{NIR+SWIR2} \quad (3)$$

dNBR = Pre fire NBR – Post fire NBR (4)

Once dNBR is computed it can be interpreted by considering negative values as enhanced regrowth or absence of burn in the vegetation, whereas; positive values are classified as burn severity values from low to high. USGS burn severity threshold mainly uses the classification for burn severity, ranging from -0.5 to +1.3. As per the Fire Monitoring and Inventory System (FIREMONS) (Lutes et al 2006), dNBR values are accurately used to identify the burn area, and dNBR values are duly classified into seven classes as shown in Table 2 based on the FIREMONS study .

Active fire products: The Terra/Aqua combined MCD64A1 Version 6 is a monthly, yearly 500m gridded product containing per pixel burned area information. Compared to the earlier collections 5 and 5.1, collection-6 has reduced uncertainties and false alarms (Louis Giglio et al 2013). The Visible Infrared Imaging Radiometer Suite (VIIRS) is a 375 m (VNP14IMGTDL_NRT) fire data point that provides a more significant response of fires over relatively small areas and improved night time performance (Oliva and Schroeder 2015). In this study, the burn severity map is compared with MODIS and VIIRS fire products.

RESULTS AND DISCUSSIONS

Spatial analysis: NDVI maps are computed using Landsat-8 OLI Surface reflectance data for Pre-fire and post-fire images. Figure 4 show a significant decline in vegetation compared to Figure 3 due to fire events in the study area. The overall NDVI analysis of SVWS states that some areas are severely affected by the fire.All the negative values of NDVI represent unburnt areas because the study area has present water bodies that represent negative values. The higher dNDVI values indicate a higher impact of forest fires in the study area. Based on dNBR analysis, fire-affected regions are observed (Fig. 5, 6) and USGS burn classification is applied to the dNBR image to know the high severity zones in the region.The various high severity, and moderate-high severity zones along the SVWS region are identified (Fig. 7).

Table 2. Burn severity classification with FIREMONS with dNBR ranges for high severity classes

Severity level	dNBR value range
Enhanced regrowth, high (post-fire)	-0.500 to -0.251
Enhanced regrowth, low (post-fire)	-0.250 to -0.101
Unburned	-0.100 to +0.099
Low severity	+0.100 to +0.269
Moderate – low severity	+0.270 to +0.439
Moderate – high severity	+0.440 to 0.639
High severity	+0.640 to +1.300

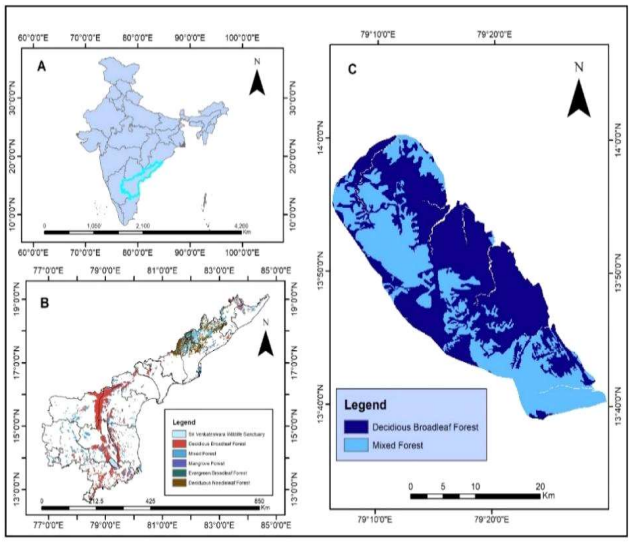


Fig. 2. Forest type map of SVWS extracted from decadal LULC-2005

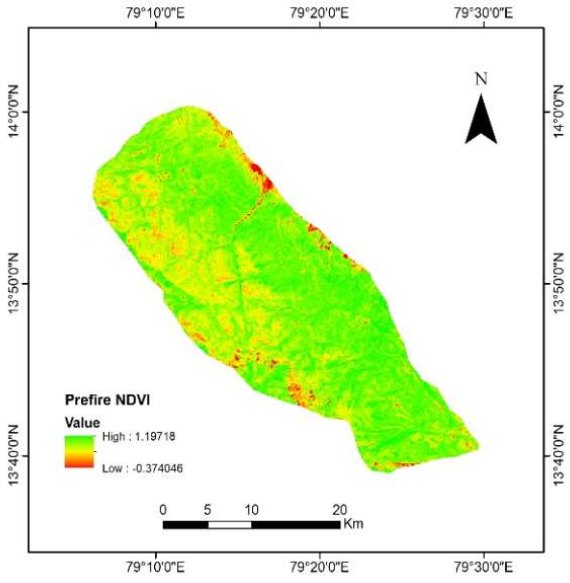


Fig. 3. Pre-fire NDVI

The fires are due to natural fire agents and anthropogenic activity, which causes fires and affecting the ecosystem.

Burn area mapping and active fire data: The overlay is one of the traditional approaches in GIS used in this study to know the relation between two features. The Burn severity map of SVWS is overlayed with various active fire data products like MODIS and VIIRS. The fire points are exactly overlayed on high severity and moderate-high severity zones of SVWS (Fig. 8). Based on the spatial correspondence burn severity map of SVWS is performed according to active fire data of MODIS and VIIRS.

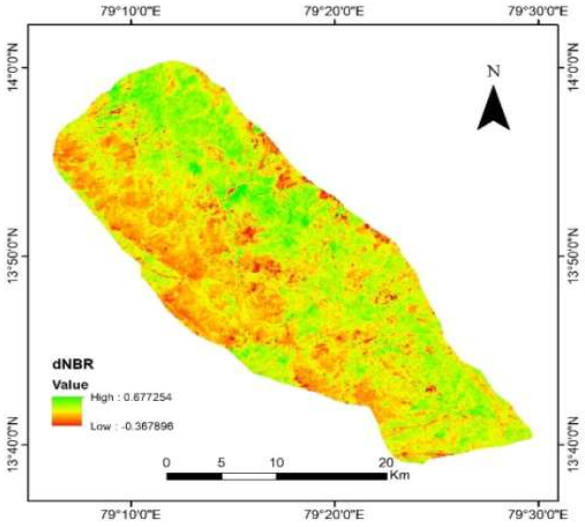


Fig. 4. Post-fire NDVI

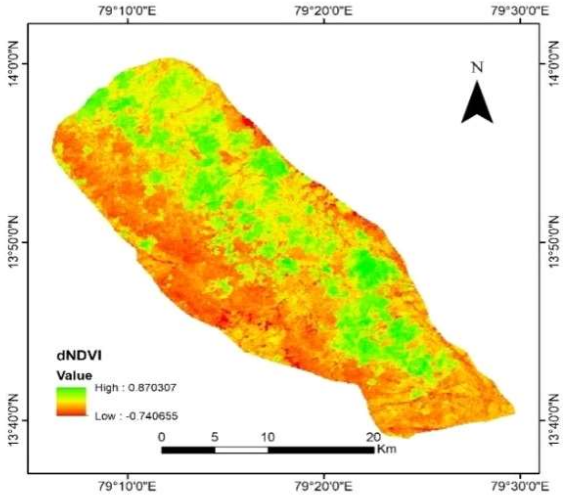


Fig. 5. dNDVI (Difference image of pre fire NDVI and Postfire NDVI imagery of SVWS)

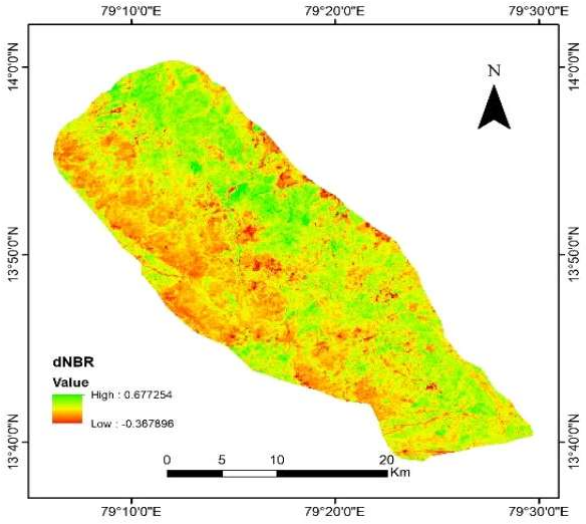


Fig. 6. dNBR (Difference image of Prefire and Post-fire normalized burn ratio)

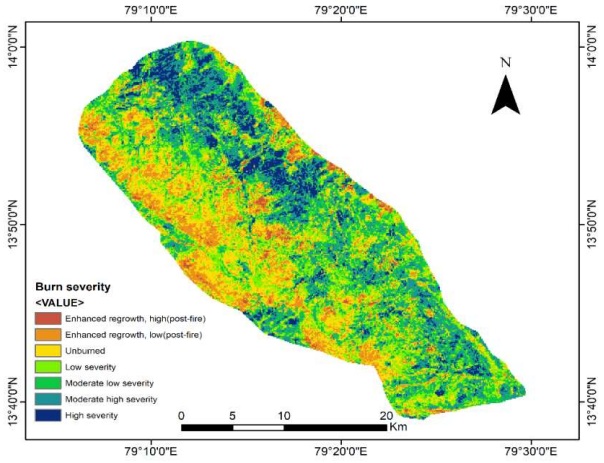


Fig. 7. Burn severity map of SVWS based on dNBR

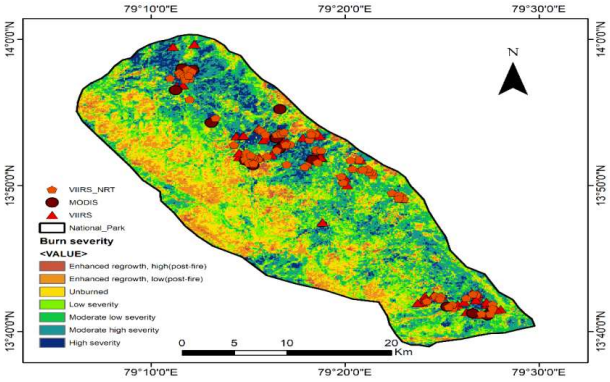


Fig. 8. Active fire data products overlay on burn severity map of SVWS

CONCLUSIONS

This study identifies the potential fire severity zones of the SVWS using Landsat-8 OLI satellite imagery, and the burn severity map produced by the indices are compared with Active Fire data products like MODIS and VIIRS. The indices used in the study can give a better estimation of the impact zones in the region. There also some limitations while using satellite imagery, especially in terms of satellite resolution. The use of drone imagery and multi spectral sensors of forest fires to better map burn severity zones is recommended. It would also be easier to estimate the forest products in the Sanctuary and nearby areas, creating a better action plan for policy makers shortly.

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Analysis of Vegetation and Similarity in the Nature Tourism Forest of Gunung Meja, West Papua, Indonesia

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***Abstract*:** This study aims are to determine the importance value index (IVI) and the similarity of vegetation types in the Manggoapi and Brawijaya area. Data were obtained by continuous strip sampling. A total of 40 plots or 1.74% Ha of the natural forest mountain area was used in this study. The square size of each plot was 100 m X 20 m. Plant inventory activities were conducted in the Manggoapi and Brawijaya areas. There were 126 species from 38 families with 1334 individuals. *Pometia coreacea* was the highest IVI value of 21.98%. The highest and lowest similarity indexes were 47.1% and 0.9%, respectively. A total of 137 species was found in 33 families with 738 individuals from Brawijaya area. *Pometia coreacea* had the highest IVI value of 28.05%, with the highest similarity index of 50%. Moreover, the lowest species similarity was 3.9%. The similarity index values between Manggoapi and Brawijaya areas were low. There was no combination of observations with a similarity index value > 75%.

Keywords: Vegetation, Importance value index, Similarity index, Tree, Nature park

The number of human populations in the world will increase rapidly to 9 billion by 2050 according to the world's population (US Census Bureau 2013). An increase in population causes land use to change ecosystem needs, food, wood, and clean water also increased (European Commission 2009). Biodiversity is particularly dangerous related to socio-economic, climate, and land use (Keenan et al 2015). The plant diversity index is sensitive to change (Faggi and Dadon 2011). The concept of naturalness relates to the extent to which the natural state has been degraded (Winter 2012). Rapid development must be balanced with the maintenance of biodiversity and an emphasis on ecotourism (Brandt et al 2012). Many studies have shown that human activity causes habitat destruction (Kardol and Wardle 2010), changes the plant species distribution (Dawson et al 2011), and triggers the extinction of species (Vetaas et al 2012). Secondary plant communities are increasingly dominant because most primary forests have been depleted (Tang et al 2010), but over time it will lead to natural native vegetation (Fukushima et al 2008, Tang et al 2010). Based on data from the center of World Conservation and Monitoring, more than 10.000 plant species are in danger of extinction in the world. Biodiversity is facing increasing pressures from human activities, including habitat fragmentation, climate change, pollution, habitat conversion, and degradation. Global assessments show that the risk of species extinction. Many ecosystem functions and services rely on biodiversity for the long term (Newbold et al 2015). The diversity of species on earth from simple to complex levels is a common phenomenon. Biodiversity can be measured at various biological levels, from genetic diversity within a species to diverse ecosystems on earth (Guruprasad and Padmaja 2016). In addition, understanding the level of species association and species similarity, there are several treatments mathematically form a similarity index. When two or more assemblies or communities' species compositions are compared, the similarity or inequality index provides a quantitative assessment (Srivastava and Shukla 2016).

The nature park tourism in Gunung Meja is the forest and conservation area located in the middle of Manokwari City, West Papua. It was originally designated as a protected forest with a hydro-orological function (water control). However, the further development of this area was designated as a nature tourism park due to a historical heritage site. This area is designated as nature tourism parks based on the Minister of Agriculture Degree No. 19/Kpts/Um/I/1980 (Lekitoo 2004, Leppe and Tokede 2006). The nature tourism park of Gunung Meja has located at coordinates 134˚03'17" to 134˚04'05" East Longitude and 0˚51'29" to 0˚52'29" South latitude with an area of 460.25 Ha. The north coast of Manokwari is the north border. In the south, it is bordered by Manokwari City. Furthermore, Ayambori Village is the east border, while Papua University Campus is the west border. Calcium (Ca), Sodium/Natrium (Na), Potassium/Kalium (K), and Magnesium (Mg) content impact plant diversities and are low-moderate (Lekitoo 2004, Leppe and Tokede 2006). The development of Manokwari city is accompanied by rapid population growth. The nature

park forest of Gunung Meja has been changed in vegetation. It impacts on hydro-orological function in the nature park forest of Gunung Meja (Lekitoo 2004, Leppe and Tokede 2006). There are 23 water sources and two caves in the nature park forest of Gunung Meja . This water source is also used by the community around the nature park forest of Gunung Meja. The surrounding community actively uses the water sources of Manggoapi and Brawijaya. However, the vegetation condition is not yet known, especially the vegetation of woody plant groups. The catchment area is the primary ecosystem that regulates the water system. The study aims are to determine the importance value index (IVI) and similarity of types (IS) of plant vegetation levels in the Brawijaya and Manggoapi areas.

MATERIAL AND METHODS

Study area: This study was undertaken in the natural park forest of Gunung Meja, especially in the Manggoapi and Brawijaya areas. The types of tree vegetation at the plant vegetation level were observed.

Procedures: The descriptive and observation method were used in this study. The descriptive method was intended to describe the condition of woody plant vegetation in catchments and water sources. Data were obtained from the path method and the continuous strip sampling method. The plot was made continuously. Therefore, there was no distance between one plot and the next, with a plot size of 100 m x 20 m. The descriptive and observation method were used in this study. The descriptive method was intended to describe the condition of tree plant vegetation in catchments and water sources. Data were obtained from the path method and the continuous strip sampling method. The plot was made continuously. Therefore, there was no distance between one plot and the next, with a plot size of 100 m x 20 m. A total of 20 sample plots in each Manggoapi and Brawijaya area.

Vegetation analysis: Vegetation analysis was conducted by the calculation of important value index to determine plant density, species distribution, species control, and species role (Mueller - Dombois and Ellenbeg 1974). Importance value index (IVI) was calculated by following formula:

$$\text{Density} = \frac{\text{Number of individuals}}{\text{Plot area}}$$

$$\text{Relative density} = \frac{\text{Type of a density}}{\text{All density}} \times 100$$

$$\text{Frequency} = \frac{\text{The number of discovery plots}}{\text{The number of the entire plot}}$$

$$\text{Relative frequency} = \frac{\text{The frequency of type}}{\text{The frequency of the entire plot}} \times 100$$

$$\text{Domination} = \frac{\text{The area of type base}}{\text{Plot area}} \times 100$$

$$\text{Relative domination} = \frac{\text{Domination type}}{\text{All domination}} \times 100$$

Importance value index (IVI) = Relative domination + Relative density + relative frequency

Similarity index: The level of similarity between the two communities has been calculated based on the frequency of similarity index between two communities by Sorenson (1948).

$$IS = \frac{2C}{A+B} \times 100$$

ID = 100 – IS

C = Sum of common species between two communities

A = Sum of all the species in community A

B = Sum of all the species in community B

RESULTS AND DISCUSSION

Plant vegetation in the Manggoapi area: There were 126 species from 38 families and an average of 66.7 individuals for each observation plot. *Pometia coreacea* was an important species in the composition in the Manggoapi area and was followed by woody plant species such as *Intsia bijuga, Palaquium amboinensis, Pimelodendron amboinicum, Horsfieldia sylvestris, Intsia palembanica Lepiniopsis lanceolatus, Spathiostemon javensis, Pometia pinnata, and Haplolobus lanceolatus* (Table 1).

Pometia coreacea had the highest IVI of 21.98%. This species was a primary plant-level species in the forest area of the Manggoapi area due to it had a large number of individuals. It revealed with the high relative density value of 13.278%. *Palaquium amboinensis* had a second rank with an IVI value of 13.65%. It had a high relative density value of 7.607%. Meanwhile, *Pimelodendron amboinicum* was the third rank with an IVI value of 13.266% and the high relative density value of 6.501%. Different forest types cause different IVI values (Chauhan et al 2020). A total of 38 families was in the Mangoapi area, with the largest percentage of the *Moraceae* family (11.2%) (Fig. 1).

Plant Vegetation in Brawijaya area: There were 137 species from 33 families with an average plot of 36 individuals. *Pometia coreacea* was an essential population and followed by woody plant species such as *Pometia pinnata, Alstonia scholaris, Pterygota horsfieldia,*

Haplolobus lanceolata, Pimeleodendron amboinicum, Flindersia amboinensis, Koordersiodendron pinnatum, Dysoxyllum alliaceum, and Artocarpus incius in the Brawijaya area (Table 2).

Pometia coreacea had the highest IVI of 28.05% and was a major species in the Brawijaya area. It demonstrated with a large number of individual with a density value of 8.943% and good average diameter growth. *Pometia pinnata* was the second important plant type with an IVI value of 15.501% and density value of 8.672%. Meanwhile, *Alstonia scholaris* had the third rank with an IVI value of 11.439%. It had a high relative density value of 4.336% and a better average diameter growth. A total of 33 families was in the Brawijaya area with the largest percentage of the Moraceae family (12.4%) (Fig. 2).

Vegetation analysis in the two catchments of Manggoapi and Brawijaya shows that the dominant species is *Pometia coreacea.* This type is dominant; one of the factors is the lack of utilization so that it is from a large frequency and high diameter size and results in a density level. The cause of Pometia is dominant because of the lack of utility (Daniel and Hegde 2007). The biotic and abiotic environment greatly influences the composition of the plant structure. External factors significantly affect the disturbance of vegetation

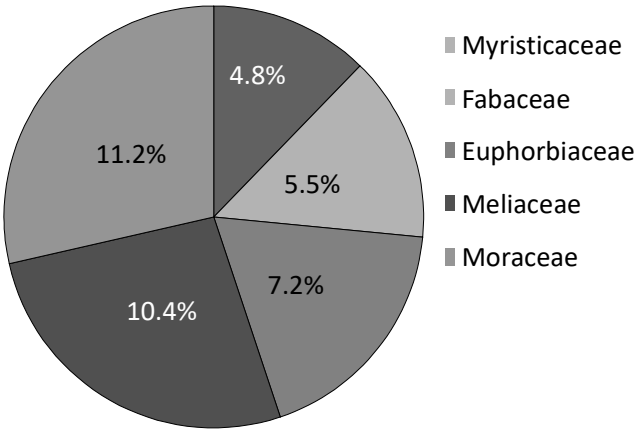


Fig. 1. Percentage of five dominant families in the Manggoapi area

Table 1. Primary plant types in the Manggoapi area

Scientific name	Family	RD[1]	RF	DR[2]	IVI
Pometia coreacea	Sapindaceae	13.278	8.688	0.009	21.98
Palaquium amboinensis	Sapotaceae	7.607	6.028	0.018	13.65
Pimelodendron amboinicum	Euphorbiaceae	6.501	6.738	0.028	13.27
Intsia bijuga	Fabaceae	7.469	5.142	0.021	12.63
Spathiostemon javaensis	Euphorbiaceae	6.086	4.965	0.039	11.09
Pometia pinnata	Sapindaceae	4.564	4.255	0.042	8.86
Haplolobus lanceolatus	Burseraceae	2.766	3.014	0.066	5.85
Lepiniopsis ternatensis	Apocynaceae	2.351	2.660	0,077	5.12
Intsia palembanica	Fabaceae	2.351	2.305	0.060	4.72
Horsfieldia sylvestris	Myristicaceae	2.075	2.482	0.082	4.64

Table 2. Primary plant types in the Brawijaya area

Scientific name	Family	RD[1]	RF	DR[2]	IVI
Pometia coreacea	Sapindaceae	8,943	1,33	17,78	28,05
Pometia pinnata	Sapindaceae	8,672	1,37	5,455	15,50
Alstonia scholaris	Apocynaceae	4,336	1,31	5,789	11,44
Pterygota horsfieldia	Sterculiaceae	1,762	1,02	4,697	7,481
Haplolobus lanceolata	Burseaceae	3,794	1,26	2,329	7,383
Pimeleodendron amboinicum	Euphorbiaceae	3,794	1,1	2,108	7,004
Flindersia amboinensis	Meliaceae	2,168	1,26	1,891	5,318
Artocarpus incises	Moraceae	1,22	1,7	2,088	5,007
Dysoxyllum alliaceum	Meliaceae	1,762	1,12	2,101	4,978
Koordersiodendron pinnatum	Anacardiaceae	1,897	1,1	1,816	4,814

damage from time to time. So that changes in vegetation in a certain location are compared to natural vegetation that is still original or potential, so there is a special method to determine which vegetation is truly native so that species associated with their habitat are studied (Bhatt and Khanal 2010). The plant phenology, dispersal, and birth control influence variation in composition and structure in the plant community. Differences in fecundity and fertility in each plant species often affect the birth of a new individual. The important value index determines the parameter of a plant species role in a community. IVI below 0.5 indicates their fragility (Sunil et al 2016). The existence of a tree species in a location reveals adaptability and resistance towards environmental conditions. Adaptable species will survive and dominate an area.

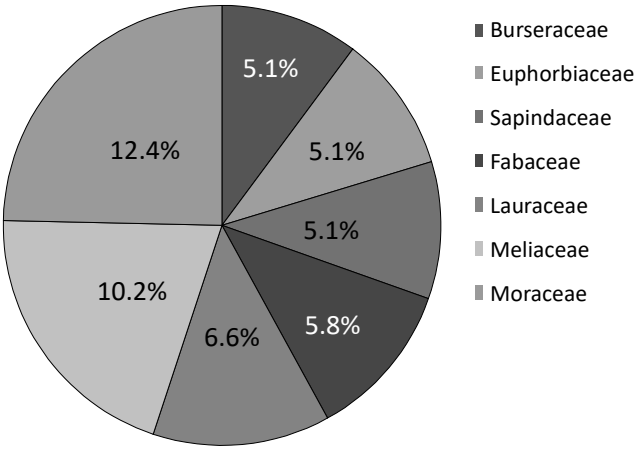


Fig. 2. Percentage of dominant families in the Brawijaya area

Similarity index: The similarity and inequality of each plant vegetation in the Brawijaya and Manggoapi area are presented in Tables 3 and 4. The highest species similarity was in the plot ratio of 9 to 16 (47.1%). In addition, the lowest similarity was in the plot of 1 to 12 (0.9%) - a total of 20 observation plots in the Manggoapi area. The similarity was below 65%. It indicated that there was no similarity among species in the Manggoapi area.

A total of 20 species had a similarity in the Brawijaya area. The highest species similarity was in the plot ratio of 3 to 7 (50%). In addition, the lowest similarity was in the plot of 5 to 17 (3.9%). There were 20 observation plots in the Brawijaya area. The similarity was below 65%. It indicated that there was no similarity among species in the Brawijaya area. This type of inequality is due to the fact that both locations have experienced damage due to the many community activities in the area due to economic factors as motivation resulting in

Table 3. Similarity and inequality index values of plant level in the Manggoapi area

IS/ID	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1		13.5	14.7	22.1	18.0	15.0	16.1	12.9	4.6	2.5	1.4	0.9	4.7	2.8	6.1	7.9	2.9	1.4	3.7	3.2
2	86.5		25.6	20.0	27.9	26.6	26.9	30.4	20.4	11.5	6.8	3.4	17.6	15.2	15.2	26.1	12.0	10.6	19.8	16.8
3	85.3	74.4		38.0	39.4	20.5	36.5	41.7	21.8	8.5	6.6	3.4	14.9	10.5	21.1	33.7	11.6	6.2	12.8	16.3
4	77.9	80.0	62.0		29.9	18.8	38.4	29.3	19.1	9.0	6.3	7.8	10.9	9.2	16.9	26.2	9.9	4.5	18.6	7.5
5	82.0	72.1	60.6	70.1		38.7	38.3	40.3	19.0	9.6	8.4	3.3	22.4	18.2	28.3	28.3	17.8	7.9	20.4	15.7
6	85.0	73.4	79.5	81.2	61.3		27.1	22.6	10.1	6.3	9.2	2.9	10.7	15.9	23.0	12.4	5.8	7.0	7.1	13.8
7	83.9	73.1	63.5	61.6	61.7	72.9		41.9	21.8	13.2	14.0	7.8	15.5	13.5	28.8	28.8	14.7	11.3	17.5	20.6
8	87.1	69.6	58.3	70.7	59.7	77.4	58.1		27.3	17.1	12.8	5.7	29.6	22.0	31.7	34.1	16.4	16.7	19.8	25.9
9	95.4	79.6	78.2	80.9	81.0	89.9	78.2	72.7		20.9	12.5	8.7	17.9	20.6	23.5	47.1	20.3	22.9	20.9	16.9
10	97.5	88.5	91.5	91.0	90.4	93.8	86.8	82.9	79.1		11.4	15.0	18.5	23.9	16.5	27.5	10.0	16.2	29.6	26.8
11	98.6	93.2	93.4	93.7	91.6	90.8	86.0	87.2	87.5	88.6		12.2	21.1	13.8	10.3	13.8	16.3	20.0	24.6	16.4
12	99.1	96.6	96.6	92.2	91.6	97.1	92.2	94.3	91.3	85.0	87.8		18.8	18.6	18.6	18.6	16.3	15.9	25.9	22.5
13	95.3	82.4	85.1	89.1	77.6	89.3	84.5	70.4	82.1	81.5	78.9	81.2		36.1	16.4	26.2	16.3	15.9	36.7	25.0
14	97.2	84.8	89.5	90.8	81.8	84.1	86.5	78.0	79.4	76.1	86.2	81.4	63.9		25.8	25.8	16.3	25.0	29.5	36.9
15	93.9	84.8	78.9	83.1	71.7	77.0	71.2	68.3	76.5	83.5	89.7	81.4	83.6	74.2		29.0	16.3	25.0	13.1	30.8
16	92.1	73.9	66.3	73.8	71.7	87.6	71.2	65.9	52.9	72.5	86.2	81.4	73.8	74.2	71.0		16.3	18.8	29.5	24.6
17	97.1	88.0	88.4	90.1	82.2	94.2	85.3	83.6	79.7	90.0	83.7	83.7	83.7	83.7	83.7	83.7		18.2	30.8	21.4
18	98.6	89.4	93.8	95.5	92.1	93.0	88.7	83.3	77.1	83.8	80.0	84.1	84.1	75.0	75.0	81.3	81.8		31.7	26.9
19	96.3	80.2	87.2	81.4	79.6	92.9	82.5	80.2	79.1	70.4	75.4	74.1	63.3	70.5	86.9	70.5	69.2	68.3		31.3
20	96.8	83.2	83.7	92.5	84.3	86.2	79.4	74.1	83.1	73.2	83.6	77.5	75.0	63.1	69.2	75.4	78.6	73.1	68.8	

Table 4. Similarity and inequality index values of plant level in the Brawijaya area

IS/ID	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1		22,7	21,6	26,3	22,6	27,3	26,3	41,6	36,1	39,5	16,2	16,9	14,8	19,8	39,4	35,6	25,4	27,0	19,7	14,9
2	77,3		38,6	36,4	28,9	37,5	33,3	33,0	25,6	37,8	27,3	19,0	34,0	23,4	12,5	13,8	18,2	22,7	32,9	39,5
3	78,4	61,4		44,7	19,4	36,4	50,0	39,0	26,1	34,2	35,1	25,4	34,6	30,0	24,2	19,2	41,3	29,7	22,5	26,9
4	73,7	63,6	55,3		21,9	23,5	23,1	32,9	29,7	23,1	31,6	21,9	31,7	36,6	17,6	21,3	24,6	23,1	32,9	33,3
5	77,4	71,1	80,6	78,1		29,6	15,6	27,7	20,0	34,4	19,4	10,2	17,6	23,5	14,8	9,8	3,9	6,3	13,6	25,5
6	72,7	62,5	63,6	76,5	70,4		32,4	31,9	28,1	32,4	12,1	19,0	25,0	30,6	13,8	18,5	21,8	24,2	28,6	13,6
7	73,7	66,7	50,0	76,9	84,4	67,6		35,4	24,3	33,3	21,1	16,4	34,1	22,0	14,7	21,3	21,3	15,8	19,2	14,5
8	58,4	67,0	61,0	67,1	72,3	68,1	64,6		37,3	40,5	31,2	27,0	33,7	31,3	29,0	34,2	27,3	28,6	21,6	17,1
9	63,9	74,4	73,9	70,3	80,0	71,9	75,7	62,7		35,1	22,2	23,2	25,6	35,9	40,6	36,6	32,8	25,0	26,1	9,2
10	60,5	62,2	65,8	76,9	65,6	67,6	66,7	59,5	64,9		39,5	19,2	39,0	34,1	26,5	26,7	21,3	31,6	30,1	23,2
11	83,8	72,7	64,9	68,4	80,6	87,9	78,9	68,8	77,8	60,5		14,1	32,5	30,0	15,2	19,2	19,0	32,4	31,0	14,9
12	83,1	81,0	74,6	78,1	80,6	81,0	83,6	73,0	76,8	80,8	85,9		26,0	26,0	22,2	17,1	26,7	22,5	29,4	18,8
13	85,2	66,0	65,4	68,3	82,4	75,0	65,9	66,3	74,4	61,0	67,5	74,0		39,5	19,4	22,8	20,3	32,5	26,0	19,2
14	80,2	76,6	70,0	63,4	76,5	69,4	78,0	68,7	64,1	65,9	70,0	74,0	60,5		25,0	17,7	26,1	25,0	13,0	13,7
15	60,6	87,5	75,8	82,4	85,2	86,2	85,3	71,0	59,4	73,5	84,8	77,8	80,6	75,0		49,2	36,4	27,3	22,2	10,2
16	87,5	86,2	80,8	78,7	90,2	81,5	78,7	65,8	63,4	73,3	80,8	82,9	77,2	82,3	50,8		25,8	27,4	22,9	9,1
17	75,8	81,8	58,7	75,4	96,1	78,2	78,7	72,7	67,2	78,7	81,0	73,3	79,7	73,9	63,6	74,2		25,4	16,7	7,1
18	82,4	77,3	70,3	76,9	93,8	75,8	84,2	71,4	75,0	68,4	67,6	77,5	67,5	75,0	72,7	72,6	74,6		33,8	26,9
19	85,2	67,1	77,5	67,1	86,4	71,4	80,8	78,4	73,9	69,9	69,0	70,6	74,0	87,0	77,8	77,1	83,3	66,2		34,4
20	86,2	60,5	73,1	66,7	74,5	86,4	85,5	82,9	90,8	76,8	85,1	81,3	80,8	86,3	89,8	90,9	92,9	73,1	65,6	

the clearing of small-scale agricultural land. Vegetation analysis is a method to determine the composition or composition of vegetation in a plant community based on the vegetation structure. Plant communities have a heterogeneous structure and species composition (Tang et al 2010). Therefore, the analysis of the similarity index is needed as the basic data of each observation plot. The highest similarity was 50% in the Brawijaya area, while the highest similarity in the Manggoapi was 47.1%. It revealed that these two regions have different types in plant-level.

In a present study, the species composition shows low similarity. The smaller similarity index value causes a lower similarity level. It is due to variations in environmental conditions and interactions between species. This phenomenon will be different if the environmental conditions are relatively homogeneous. The condition indicates that the presence of different species at different altitudes indicates different environmental conditions. Altitude is one of the factors influencing species differences (Barman et al 2021, Jazib 2020). In addition, other factors also determine plant species, such as groundwater content, plant properties, climate variables, human disturbances, and humidity (Fousseni et al 2010, Luo et al 2016, Yadav et al 2020, Zegeye et al 2006). Therefore, plant species can be used as an environmental indicator. Further research can examine environmental factors and human disturbances that affect vegetation and the similarity index of plants in these two areas.

CONCLUSION

The research concludes that the number of individuals, species, and families in the Manggoapi and Brawijaya areas were different. The Manggoapi area had 126 plant species. Meanwhile, 137 species were found in the Brawijaya area. *Pometia coreacea* is essential species in both areas. The similarity index values in the Manggoapi and Brawijaya area were low. It indicated by similarity index values below 65%.

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Assessing Shea Nut Access in the Savannah and Northern Regions of Ghana

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Abstract: The various customary and political paths through which natural resources are accessed have become topical. These issues attract more attention if they relate to access by women to support livelihoods. This paper uses qualitative approaches to describe the nature of access to shea nuts in Ghana. Sourcing information from 300 shea collectors in 15 communities in the Northern Region of Ghana indicated that majority of shea collectors relied on family fields as their main source of nuts instead of communal fields. On the political front it was revealed that shea resources are customarily managed and predominantly controlled by males. Shea trees on communal lands are under the control of traditional leaders while those on cultivated lands are controlled by family heads. The main challenge that collectors faced regarding access to shea nuts was ageing/diminishing shea population which has caused irregular and reduced fruiting.

Keywords: Shea access, Informal relations, Northern Ghana, Communal fields

Shea is one of the main cash crops indigenous to the Northern part of Ghana. It has many uses but its most important asset is its nut which is used globally in the cosmetic, pharmaceutics and chocolate formulations (Bup et al 2014). Shea has been part of the top 10 prominent non-traditional export products from Ghana for several decades. Within the agriculture sub-sector for example, shea nut was the second highest export earner with US$34 million behind cashew nuts in 2015 (GEPA 2016). The export earnings from shea butter products in 2015 was US$64 million, up from US$52 million in 2014, a 23 % growth. In Africa, approximately 16 million rural women contribute to livelihoods and support their family and education of their children by collecting, processing, and selling shea kernels and butter (Pouliot 2012). About 900,000 of these women are believed to come from Ghana.

Specific policy interventions to ensure that shea remains an important livelihood option for local women and their households are inadequate. There is the indiscriminate burning of trees by honey tappers and cutting down of trees for local building materials and artisanship (Boffa 2015). There are also concerns of tree productivity and long gestation period which question the sustainability of shea nuts. These are likely to affect livelihood outcomes of shea collectors. The tree productivity concerns have been linked to factors such as erratic weather and destructive human activities (like deforestation and improper farming methods) gradually constraining nut access and making nut supply uncertain (Kent and Bakaweri 2010). Since shea collection in Ghana is the preserve of women, uncertainty in nut production affects their ability to access enough nuts thereby reducing their capacity to support their livelihoods (Jakpa et al 2018). In the view of Buyinza and Okullo (2015) access to shea in the wild is constrained and daunting as collectors sometimes set off as early as 3am to search for nuts thereby becoming exposed to several risks including snake bites and human attacks. Factors like land commercialisation and urbanisation have caused collectors to walk long distances before accessing shea nuts. Ayanda and Salawu (2017) argue that nearly 48% of shea nuts remain uncollected in the wild as a result of the distance phenomenon. There are other structural and institutional relations which are shaped by demographic and socio-political factors. These relations enhance or hinder access to enough shea nuts based on collectors' household and individual characteristics. These are the main drivers that govern and control shea access (Lyatuu and Urassa 2014).

In view of this background, this paper determines the nature of shea nut access and describes other important considerations affecting shea nut access in Ghana. The

study aims to strengthen our comprehension of the dynamic articulation between political and ecological processes within the contexts of human–environmental interactions. An analyses of the constantly shifting relationships between nature and society require an integrated understanding of the interconnections between political struggles over environmental resources, cultural meanings attached to the environment, and the ecological dynamics of environmental change.

MATERIAL AND METHODS

Data source and sampling: Multistage sampling approach was used for this study which was conducted in the Northern and Savannah Regions of Ghana because at the time of the study in 2017, the former Northern (which was the original focus before the administrative division into Northern, Savannah and North East Region) was the biggest across Ghana's shea belt with about 70% of the shea belt (Lovett 2010). Fifteen communities were selected from five districts in the regions. Each district was represented by three communities. Using the lottery approach, twenty respondents were randomly selected from each community making a total of 300 respondents for the study as presented in Table 1. Information regarding location, processes, challenges and strategies for accessing shea nuts were sourced from the respondents through a pretested questionnaire and interview guide. Focus group discussion were also held among shea collectors.

Table 1. Selected districts and communities for the study

District	Selected communities
East Gonja	Dashei, Worlanyili, Janton
Central Gonja	Aliyili, Zanzugu, Galinzengu
Yendi	Adiboo, Kanimo, Puriya
Tolon	Gbarimani, Kasuliyili, Waribogu
Savelugu/Nanton	Nakpazuu, Tibali, Zorgu
Total	

Sample size: 20 per community

Data analysis: The study adopted qualitative data analysis techniques to explore and describe the major issues relating to shea access in the study area. SPSS and Microsoft Excel software were used to analyse the field data and the results presented in tables. Access to shea resources is defined as the ability of collectors to benefit from shea trees and nuts in their community. This study adopted the Access Framework by Ribot and Peluso (2003). Four major themes were explored to answer the following questions:

1. Where is the resource located?
2. Who is the main beneficiary of the resource?
3. How is benefit derived from the resource? and
4. When is benefit derived from the resource?

Relative responses to further questions generated from these themes were used to describe the nature of access to shea nuts in the study area.

RESULTS AND DISCUSSION

Main source of nuts and beneficiary: The results on responses to “where is the resource? and “who benefits from the resource?” showed that shea tree access can be gained at several locations. Majority (50%) of shea collectors' source nuts from trees on family lands (Table 2). Communal land and neighbour's land followed with 44 and 6% respectively. Family land is categorised to include father's land, husband's

Table 2. Nature of access to shea

Theme	Source of access		
	Family	Communal	Neighbour
Where is the resource (Main source of nuts)?	50.33 %	43.67 %	6.00 %
Who benefits from the resource?	Beneficiaries are mainly collectors from the family but access rights can be given to collectors from other families	Access is open to all interested collectors in the community irrespective of family affiliation	Collectors who have been granted entry and access rights to collect nut on neighbours' field
How is benefit derived? (Who controls the resource)	Access is derived through permission from family head or trustee.	Through permission from traditional leaders after the annual ritual has been performed. This is virtually by default	Access is gained through permission from neighbours' family head, trustee or eldest woman in the family.
When is benefit derived? (Time of access)	Collectors who access nuts mainly from family and communal fields can do that anytime during the day but usually collect early in the morning	Nuts are usually accessed in the afternoon after neighbour has finished picking. Can also pick alongside neighbour in the morning	

land or in some rare cases brother's land. The observation suggests that collectors do not ordinarily allow other collectors to pick from their family fields. The communal fields become the only source of nuts for collectors without enough shea trees on their fields. This result is in line with the trend reported by Laube (2015) in the Northern Region where communal and family fields accounted for about 49% apiece of collectors' main source of nuts with neighbours' fields recording only 2%. This finding contradicts the situation among the Bamana in Mali where Naughton (2016) observed that women were at liberty to pick shea nuts from anywhere being family or neighbour's fields. This point notwithstanding, the study was quick to add that the situation could be different in other shea locations in Mali.

A few (19%) of the women complained about the tree ownership arrangement in the area (Table 7). Their inability to pick shea from fields of non-family members without permission especially in the event of returning from communal fields with little harvest can be very frustrating. Many (92%) of the shea collectors believe access to nuts have reduced (Table 3).

Table 3. Perception of limited access to shea nuts

Response	Frequency	Per cent
Yes	276	92.00
No	19	6.33
Don't know	5	1.67

Shea collectors agreed to the reduced reliance on communal fields as main source of nuts. Community dwellers are more likely to fell shea trees on communal fields for fuel, charcoal burning and building materials for houses compared to family fields. Communal forests are also more prone to fires since hunting and honey searching are usually done there. Naughton (2016), again observed in Mali that shea trees on cultivated fields are trimmed and light pruned resulting in better nut yield than trees on uncultivated communal fields. This practice could be a contributory factor to the reliance on family fields for nuts compared to communal fields. Just about 9% of the respondents linked reduce access to the challenge of long maturity and gestation period of the shea trees (Table 7).

Distance to main source of shea nuts: The average distances from collectors home to their main source of nuts was 7.82 kilometres to collect from their main nut sources. They cover half of this distance carrying collected shea fruits on their heads. Travelling these distances have meant that collectors sometimes have to leave some of their harvest in the wild since carrying enough nuts on their heads back home is daunting. The study found that respondents who collect shea nuts mainly from communal fields on the average trek longer distances (3.92km) compared to those who pick from family fields (3.77km). However, the observed differences were statistically insignificant at a level of 1% (Table 4).

Table 4. Test of means between distance to nuts from family and communal fields

Main source of shea nuts	Mean distance km^{-1}	Std. dev.	Sig. (2-tailed)
Family	3.77	1.00	0.347
Communal	3.92	1.45	

There is also the challenge of poor access routes, which was supported by about 17% of shea collectors. Considering the fact that the shea season coincides with the rainy season, collectors have to meander through tall grass vegetation in an effort to reach nuts especially from communal fields. Directly related to the challenge of poor access routes to shea fields is attacks from animals like snakes and scorpions. This becomes exacerbated by the lack of appropriate clothing like overalls, boots and gloves. Some respondents recounted personal experiences where they have shunned picking from particular zones notorious for such attacks.

Reasons for limited access to shea nuts: The reasons attributed to limited access of shea trees and nuts are shown in Table 5. Chief amongst them was reduced rainfall which was agreed by about 40% of the respondents. This was followed closely by ageing tree population (38%) and cutting of trees for fuel wood and charcoal production (35%). The phenomenon of cutting productive down trees for fuel wood, timber and other purposes has also been reported in India by Chittapur and Kammar (2020) who observed that farmers do this to in an effort to become self-reliant and meet basic needs. Other factors agreed to a lesser extent were population growth (22%) and bushfires (19%). These findings affirm the claims by Adam and Abdulai (2014). In a later study, CILSS (2016) enumerated rural population growth and intensification of land use as the main factors that

Table 5. Reason for limited access to shea nuts

Reason for limited access	Frequency	Per cent
Reduced rainfall	119	39.67
Ageing tree population	113	37.67
Cutting trees for fuel wood and charcoal	105	35.00
Population growth	67	22.33
Bushfire	57	19.00

could impact women's access to shea trees in the Sudanian and Sudano-Sahelian regions of West Africa.

Quantity of nut picked from main source: The mean quantity of nuts collected in the study was 375kg. This figure is higher than the 250kg reported by Awo and Anaman (2015) in the Northern Region of Ghana. Collecting mainly from family field leads to having more nuts compared to collecting mainly from communal fields (Table 6). This is an indication that since communal fields are open access, respondents who collected mainly from family field had the added advantage of supplementing their collection from communal fields leading to higher volumes.

Table 6. Test of means between volumes of nuts collected from family and communal fields

Main source	Mean collected kg^{-1}	Std. dev.	Sig. (2-tailed)
Family	387.11	97.90	0.236
Communal	372.08	110.43	
Overall	375.23	105.46	

Source: Survey data (2017)

Control over shea resources: Control over shea resources depend on the location of the shea tree. Trees on communal lands were found to be under the control of 'earth priests' who are males (Table 2). Collectors freely pick from communal fields once rituals are performed to “officially” open the shea season. This is a conservation practice by traditional authorities to ensure the sustainability of communal resources. This finding agrees with Kharumnuid and Bharucha (2020) who observed this as an effective strategy to manage community conserved areas in Meghalaya, India. However, once any part of these fields are cultivated following the permission of the earth priests, shea trees on that boundary are controlled by the male leader of the family that cleared the space. Trees on all agricultural lands in the study area are controlled by the land owners who are males and grant collectors access to them. In extended family and polygamous households, each collector first has the exclusive rights to pick from their respective farmlands while nuts on the husband's main farmland is usually open to all wives; priority access may be granted the first wife.

The custom is that shea fruits are not harvested from the tree in the study area. They are allowed to fall by themselves before collection. This observation was also reported by Laube (2015). This practice is to prevent conflict in situations where access to the shea tree is shared. The rules for sharing collected fruits vary between households and families. Collectors could collect individually or together and nuts shared according a pre-agreed arrangement. Although collectors enjoy total control over all proceeds of shea irrespective of the source (Poudyal 2011), it is common practice for some women to give part of shea earnings to their husbands. This situation usually occurred when the husbands, especially those in monogamous homes, help in the gathering of shea nut after the days farm work on their fields. This finding corroborates Awo and Anaman (2015) report that about 7% of shea collectors in the Northern Region of Ghana are supported by their husbands in the process of collection. Another form of support is through transportation of harvested nuts in situations where husbands own appropriate means of transport. The current study further deviates from Kent (2017) who found that about 50% of married shea collectors make joint spending decisions for shea income largely because of their husbands' involvement in nut production. Control of shea income seem to deviate across West Africa. Rousseau et al (2017) report of situations in Burkina Faso where men are obtaining increasing proportion of shea income from their female relatives.

Time of accessing shea nuts: The results on response to “when is benefit derived?” showed that timing is of great essence (Table 2). Collectors recounted that they mostly leave home in the early hours of the day in search of nuts that had fallen the evening and night prior. Access is on first come first served basis. The time of collection is partly a function of the main source of nuts and the type of right collectors have to trees. Collectors seeking nuts from communal fields usually set off at dawn in groups. Although those picking from own or family fields also mostly set off at dawn, they have the luxury of leaving home later in the morning or afternoon especially if they have exclusive rights to trees and nuts. The minority group of people who collect nuts from their neighbours' fields can also pick at dawn/morning with permission or have to wait till the afternoon when original access holders are done picking for the day.

As a result of competition on communal lands, collectors concentrate on collecting from the communal lands before family lands. This scenario may be different for collectors from polygamous or large families. This is because competition may exist for nuts on family or farm lands among wives or extended family members. In such situations, nuts may be sourced from family fields before communal fields. This observation supports the finding of Ingram et al (2015) who reported that competition on family lands may even be direr for senior wives or elderly women among collectors in Ghana and Burkina Faso.

Table 7. Challenges in accessing shea nuts

Challenge	Frequency	Per cent
Ageing/diminishing shea population	65	21.67
Tree ownership issues	57	19.00
Long maturity period of shea trees	28	9.33
Long distance to shea fields	64	21.33
Snake/scorpion attacks	36	12.00
Poor access routes	50	16.67

CONCLUSIONS

Shea collectors rely mostly on family lands compared to communal or private compared to public. Shea resources are controlled by males and access to nuts is determined by relationship and social interaction between shea collectors and controllers of land and shea trees. Shea tree productivity is reducing due to indiscriminate felling and distant location of collector's homes from the trees. There is therefore the need to encourage positive gender relations that will allow women to have easy access to shea resources. Owing to the customary and informal nature of shea nut access, such initiatives should bring together chiefs and traditional leaders, family heads, leadership of shea collector groups as well as the appropriate government agencies and the private sector to achieve buy-in and consensus that will guide nut access. The appropriate authorities should work with community watch dog committees to monitor the incident of indiscriminate tree felling and improve tree productivity. These committees must be fairly constituted and compensated to prevent rent seeking behaviours from culprits. Efforts at further improvement in tree productivity could be through community-based plantation establishment supported by intensive research and extension drive on early maturing and high yielding shea trees.

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Development of Biomass and Volume Models of *Melia dubia* Cav. for Early Establishment

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Abstract: The present study was carried out in Navsari Agricultural University, Navsari to develop linear regression models for industrially important *M. dubia* during 2015 to 2020. In this study destructive approach has been used for measurement of required variables, *i.e.* diameter at breast height (DBH), tree height, end-diameters of tree logs and fresh tree biomass. Comparison of various tested fresh biomass models relationship on the basis of adjusted R^2 values showed that the linear functions $B=0.0299(HD^2)$ ($R^2 = 0.960$) as best fit. Similarly, linear regression equation developed using linear function $V=0.003 + 0.00003\ HD^2$ ($R^2 = 0.935$), considering tree volume as an dependent variable and height and DBH as an independent variable, with highest adjusted R^2 value was found best fit for all height and DBH classes. Hence, these linear regression equations were selected for development of height and diameter class wise biomass and volume models. The allometric models developed in this study can be used for estimation of *M, dubia* standing tree biomass and over bark volume.

Keywords: *Melia dubia*, Biomass, Volume, Allometry, Regression models

Direct and indirect quantitative estimation of biomass, volume and carbon stocks of natural and manmade forests at any growth stage is important to academicians, forester, natural resource managers, farmers and timber merchants (Luna et al 2014, Gao et al 2016) in several contexts like applications from the management, ecology, commercial exploitation of timber to global carbon cycle (Giri et al 2019) and for studies on the energy and nutrients flows in ecosystems (Zianis et al 2005). If empirically equations are not available, alternative to estimate the volume of logs is to use formulae like a cylinder, a cone, a paraboloid or a neiloid. However, this is somewhat wise approach when researchers are concerned for the bole alone. However, when other parts of the tree are of interest, and empirical data are available, statistical estimation of volume tables or functions invariably preferable (Hofstad 2005).

In India, biomass and volume tables based on empirical models are in vogue for many commercial tree species (Sandeep et al 2014) and estimates for standing crops can easily be computed. With the advancement in tree improvement new species are being advocated for commercial plantation and are used by wood based industries. *Melia dubia* Cav., is an important short rotation multipurpose tree, suitable for pulp and plywood industries, high-quality timber for various purposes (Parthiban et al 2009, Sinha et al 2019, Sukhadiya et al 2021). Due to non-allelopathic effect (Kumar et al 2017b, Parmar et al 2020), this species is considered as an excellent tree component for agroforestry system (Thakur et al 2018, Mohanty et al 2019). Therefore, *M. dubia* has become popular among the farmers and large scale plantations are being done as the industry has started utilizing the species for paper pulp and plywood (Vagh 2021). It is against this background that this study aimed to develop local biomass and volume empirical equations for estimating total tree fresh biomass and over bark volume.

MATERIAL AND METHODS

Twenty trees from *M. dubia* plantation raised at main campus of Navsari Agricultural University, Navsari (20.95°N latitude, 75.90°E longitude, at an altitude of 10 m above the mean sea level) Gujarat, were felled each year (1 to 5 year). The data on diameter at breast height (DBH) and tree height was recorded. Branches were separated from the main stem and fresh biomass was recorded immediately. Main stem was cut into logs of 1 meter length and total log fresh weight was recorded. The total over bark tree volume (all tree logs of each tree) was computed using Smalian's formula (Jayaraman 1999): $V = (S1 + S2)/2*L$ with V referred as the volume of a log of tree trunk, S1 and S2 as two areas of the small and large ends of the section and L as the log length. To develop allometric regression equations for fresh tree biomass (log+branch) and over bark tree volume, at 5th year, the all sampled trees (100), were considered. Ten trees in each DBH (4 to 17 cm) and height (4 to 11 m) classes were taken in to account.

Model development: The preliminary data pertaining to height and DBH of standing trees up to 5 year age with respective biomass of logs (actual) were subjected to regression equation (linear) using Microsoft Excel data analysis tool with model $Y = a + b\ HD^2$, where Y is fresh biomass (in kg) or volume (m^3) and HD^2 is the factor derived out of height (H) and DBH (D).

RESULTS AND DISCUSSION

Annual growth, fresh biomass and volume (over bark) production: The data in Table 1 indicated that *M. dubia* attained 4.76, 6.73, 8.24, 9.23 and 10.42 m in 1st, 2nd, 3rd, 4th and 5thyear, respectively, whereas, at 1st, 2nd,3rd, 4th and 5thyear age DBH 5.13, 8.46, 10.52, 11.88 and 13.92 cm, respectively. Perusal of data in table 1 expressed that there was 7.90, 13.73, 25.75, 34.83 and 50.76 kg $tree^{-1}$ log biomass at 1st, 2nd, 3rd, 4th and 5th year, respectively. The branch biomass was 2.96, 9.37, 11.73, 15.04, 18.00 kg $tree^{-1}$ at 1st, 2nd,3rd, 4th and 5th year, respectively. The total tree biomass production at 1st, 2nd, 3rd, 4th and 5th year was 10.86, 23.10, 37.48, 49.88 and 68.76 kg $tree^{-1}$, respectively. Similarly, over bark volume of 0.011, 0.017, 0.031, 0.042 and 0.058 $m^3 tree^{-1}$ was attained at 1st, 2nd, 3rd, 4th and 5th year, respectively.

Fresh biomass and volume models: The generated data were used for estimation of biomass and volume (independent variables) using tree height and DBH factors as dependent variables. Different models linear and polynomial regression equations were worked out and the best fit to the total tree biomass and over bark log volume models developed.

Fresh biomass and volume (over bark) models: For trees having height range of 4-5 m and DBH range of 4-7 cm, the biomass equation is

$B=0.0299(HD^2)+7.48$ ($R^2 = 0.960$) (Table 2 and Fig. 1a)

Where, B =Total tree fresh biomass, H=Height of the tree and D= DBH, HD^2= Factor calculated using height and DBH.

The above allometric models were found best fit based on values of coefficients of determination (R^2) compared to other linear and polynomial regression equations. The estimated biomass using above models for all height and diameter classes are presented in table 3. Models based on two variables i.e. height and DBH or DBH squared have been advocated easy to compute and with higher values of coefficients of determination (Thakur et al 2008, Luna et al 2014).

Over bark volume models: $V=0.003 + 0.00003\ HD^2$ ($R^2 = 0.935$) (Table 2 and Fig. 1b)

Where V=Log volume (Over bark) and H=Height of the tree and D= DBH, HD^2= Factor calculate using height and DBH. The estimated over bark volume for all height and diameter classes are present in Table 4.

Based on higher values of coefficients of determination,

Table 1. Actual average annual (per tree; n=20) growth, biomass (fresh) and volume of *Melia dubia* calculated through destructive method from 1 to 5 year age

Age (year)	Tree height (m)	DBH (cm)	Fresh biomass (Kg $tree^{-1}$)			Over bark log volume (m^3 $tree^{-1}$)
			Log	Branch	Total	
1	4.76 (±0.37)	5.13 (±0.68)	7.90 (±4.26)	2.96 (±0.71)	10.86 (±4.45)	0.011 (±0.01)
2	6.73 (±0.54)	8.46 (±1.02)	13.73 (±3.45)	9.37 (±4.61)	23.10 (±5.77)	0.017 (±0.004)
3	8.24 (±0.62)	10.52 (±1.21)	25.75 (±6.18)	11.73 (±4.08)	37.48 (±7.84)	0.031 (±0.01)
4	9.23 (±1.05)	11.88 (±0.77)	34.83 (±7.50)	15.04 (±4.57)	49.88 (±11.05)	0.042 (±0.01)
5	10.42 (±1.28)	13.92 (±1.33)	50.76 (±10.93)	18.00 (±5.59)	68.76 (±12.83)	0.058 (±0.01)

DBH=Diameter at breast height (1.37 m above ground); values in parenthesis are standard deviation

Table 2. Tree fresh biomass and volume model estimated using HD^2 and statistical parameters in *M. dubia*

Model form	Height and diameter range	Regression constant (a)	Regression coefficients (b)	Multiple R	R^2	Adjusted R^2	Standard error	F value	Significance level
Fresh biomass									
$Y=a+b\ HD^2$	H=4-11 m; D= 4-17 cm	0.0299	7.48	0.980	0.960	0.959	4.29	44.00	< 0.001
Volume (over bark)									
$Y=a+b\ HD^2$	H=4-11 m; D= 4-17 cm	0.0038	0.00003	0.967	0.935	0.933	0.005	602.18	< 0.001

H= Height, D=DBH

Table 3. Estimated *M. dubia* fresh biomass (kg tree^{-1}) based on regression equation (Y=0.0299HD^2+7.48)

Tree height (m)	DBH (cm)													
	4	5	6	7	8	9	10	11	12	13	14	15	16	17
4	9.39	10.47	11.79	13.34										
5	9.87	11.22	12.86	14.80										
6				16.27	18.96	22.01	25.42	29.18						
7				17.73	20.87	24.43	28.40	32.80	37.61					
8					22.78	26.85	31.39	36.41	41.91	47.89	54.35			
9					24.70	29.27	34.38	40.03	46.22	52.94	60.21	68.01		
10							37.37	43.65	50.52	57.99	66.06	74.73	84.00	
11									54.83	63.05	71.92	81.46	91.65	102.50

Table 4. Estimated *M. dubia* over bark volume (m^3 tree^{-1}) based on regression equation (Y= 0.003 + 0.00003HD^2)

Tree height (m)	DBH (cm)													
	4	5	6	7	8	9	10	11	12	13	14	15	16	17
4	0.005	0.006	0.007	0.009										
5	0.005	0.007	0.008	0.010										
6				0.012	0.015	0.018	0.021	0.025						
7				0.013	0.016	0.020	0.024	0.028	0.033					
8					0.018	0.022	0.027	0.032	0.038	0.044	0.050			
9					0.020	0.025	0.030	0.036	0.042	0.049	0.056	0.064		
10							0.033	0.039	0.046	0.054	0.062	0.071	0.080	
11									0.051	0.059	0.068	0.077	0.088	0.098

DBH= Diameter at breast height

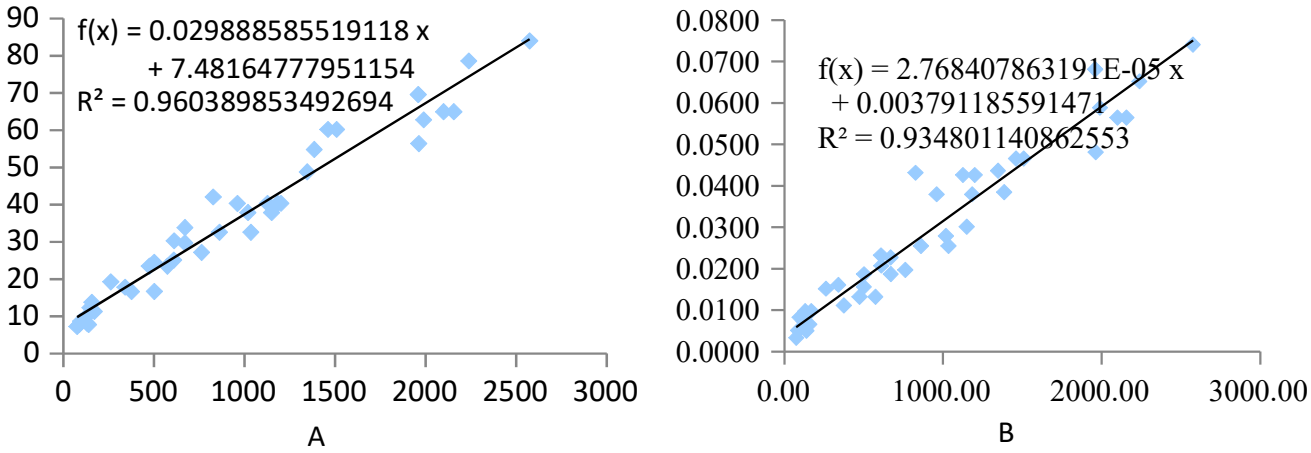


Fig. 1. Best fit (highest R^2 values) fresh biomass allometric equation (a) and b) over bark volume estimation of for *M. dubia*, where X=HD^2

compared to other tested regression equations, above models was found best fit for over bark volume prediction. Tree height and DBH as independent variables are suggested to be easy for computational work. Over bark volume prediction models based on tree height and diameter squared for many commercial species have been developed and are advocated to be reliable (Dogra and Sharma 2003, Thakur et al 2008, Luna et al 2014). In *M. dubia*, biomass and volume prediction models are not available. Recently, Kumar et al (2017a) used under bark total volume model: Volume=0.00045+(0.000026*D^{2}H) developed for *M. dubia*. A comparative analysis of estimated over bark volume using

present model and under bark volume using former model suggested that present developed models estimated slightly higher volume. This is clearly attributed to the fact that our models are for over bark tree volume.

CONCLUSION

The regression analysis revealed that fresh standing tree biomass and over brak tree log volume of different height and DBH classes can be estimated following regression models: $B=0.0299(HD^2)+7.48$ and $V=0.003 + 0.00003HD^2$, respectively. Therefore, farmers, foresters, wood based industry and researchers can utilize these allometric equations for estimation of fresh biomass and volume as well as biomass and volume tables for standing trees *M. dubia* up to 11 m height and 17 cm DBH.

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Floristic Composition of Tree Diversity in Mixed Broad - Needle Leaf Forest Communities in Bidoup-Nuiba National Park, Lamdong Province, Vietnam

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Abstract: This study investigated six types of mixed broad - needle leaf forest communities, which had domination on %IV of the conifers (including: *Pinus. krempfii*, *Pinus dalatensis*, *Fokienia hodginsii*, *Keteleeria evelyniana)* in Bidoup - Nuiba National Park, Lamdong province, Vietnam. Structural, regenerational characteristics and floristic composition of tree diversity were in twelve representative 50 x 50 m plots, each stand was two plots. The study enumerated total of 145 high tree species (diameter at breast height - dbh ≥ 10 cm), belonging to 86 genera, 45 families. The mean density was 894 trees ha^{-1}, Shanon-Wiener index ($He^{'}$) ranged from 3.42 to 3.92. The conifers were dominance species in high trees, with composition coefficient up to 25.4%, but not in regenerated trees. The conifers' regeneration ability in the sites were poor, the mean density of small regeneration trees (about 1.2%) was much lower when compared to whole communities. Sorensen's similarity index (SI) between tree classes ranged from 0.38 to 0.67. Species richness, density and basal area of the communities decreased with increasing dbh class and contributed mainly about in <30 cm dbh class.

Keywords: Bidoup-Nuiba, Composition, Diversity, Mixed broad- needle leaf forest communities

Database on floral composition, diversity and structure rules are essential in understanding the natural forest ecosystem dynamics, conservation and sustainable management (Con et al 2015). In Vietnam, compared to other tropical forests, the quantitative studies on the silviculture characteristics of the subtropical closed evergreen mixed broad - needle leaf forests are poor. Although, the forests are the most exploited and endangered among other forest types because the forest types have special floral composition with many rare needle leaf species (Luu and Thomas 2004, Nghia 2006). Under the core zone of the Langbiang Biosphere Reserve International (in the Central Highlands area), Bidoup - Nuiba National Park was rated as one of the centers of biodiversity in Vietnam, where the preserved area of the large primary forest. Forest types of closed evergreen mixed broad-needle leaf in Bidoup - Nuiba, including forest plant communities of mixed between broadleaf trees to rare conifers species were always considered as natural heritage of the region, with outstanding values of landscape ecology and conservation science. There, the conifers had a role to form groups dominant plant ecology, was the main ingredient to make up dominant layers, dominant unit layers of forest types. The forest types been assessed to be of high biodiversity not only with woody plants that herbaceous plants, plant exchange floors, few the results of research on structure and natural regeneration characteristics of the mixed forest communities are available (Nam 2010, Hoi and Kunetsov 2011, Truong 2014, Binh 2015). However, the database on these have been still limited, the rare species conservation and development have been difficult. To improve the effectiveness of conservation measures for the rare conifers, it is very necessary to have database on structural and natural regeneration characteristics of the communities in which they are distributed. The knowledge on characteristics of floristics composition, dominance, natural regeneration and stand structure is a basis to select silvicultural treatments for promotion of natural regeneration. The study on floristics composition of tree diversity was undertaken within a twelve 2500 m^2 plots in mixed broad-needle leaf forest communities of Bidoup - Nuiba national park, Lamdong province, Vietnam.

MATERIAL AND METHODS

Study area: Bidoup - Nuiba national park area is about 70038 hectares, mostly located in the territory of Lacduong district, a small part of Damrong district, Lamdong province. North of the national park borders on the Krongbong district of Daklak province, the East borders on the Khanhvinh

district, Khanhhoa province and Bac Ai district of Ninhthuan province, the West and the South border on the by administrative units of Lamdong province (Fig. 1). The study site is from 1400 - 2100 m. The climate is divided into two clear seasons (wet and dry seasons), the mean annual rainfall reaches 2200 - 2800 mm, mainly from April to October. The average annual temperature is from 15 - 18°C.

Phytosociological data were collected in six types of mixed broad - needle leaf forest communities, as follow: (1) The mixed forest communities with the participation of *F. hodginsii* (F); (2) The mixed forest communities with the participation of *P. krempfii* (Pk); (3) The mixed forest communities with the participation of *P. dalatensis (*Pd*); (4)* The mixed forest communities with the participation of *F. hodginsii* and *P. krempfii* (F + Pk); (5) The mixed forest communities with the participation of *P. krempfii* and *P. dalatensis* (Pk+ Pd); (6) The mixed forest communities with the participation of *K. evelyniana* (K). Processing survey based on biodiversity research methods of Con et al (2015) and Thin (2007)

Field sampling : The field sampling was carried out from 2016 to 2019. A total of 2 grade A plots (50 x 50 m) x 6 types of the mixed forest communities =12 grade A plots were established in the subzones 89, 90, 91, 125, 127B, 128 belong to the Southeast of the park. The difference in distance between each plot were from 500 m (Fig. 1a, 1b). Each plot was systematically surveyed for all high trees (which have dbh ≥ 10 cm). There were four grade B subplots (25 x 2.5 m) in the center of each grade A plot to survey for the sapling layer or advantage generational trees with total height (H) > 2m and dbh ≤ 10 cm. For the seedling layer or small generational trees (which have 0.3m ≤ H ≤ 2 m) were surveyed in five grade C quadrats of each grade A plot. The sampling plots were designed into 3 grades (Fig. 2). Based on documents Plant of Vietnam (Ho 1999), authors of plant names (Brummitt and Powell 1992), the plant species were identified.

Data analysis: The data were quantitatively analysed by statistical methods in forestry (Tuat and Binh 2005). Besides, the Importance Value (IV) of each high trees species was determined as the sum of relative density (%) and relative dominance (%) to divide by two. For high trees species with IV ≥ 5% is really ecological significant and dominant species which participates in the composition formula of the communities. If a group of less than 10 species has IV index ≥ 40%, they are considered the dominant species group (Trung 1999)

$$IV_i\% = \frac{Ni\% + Gi\%}{2}$$

In which, Ni% - relative density

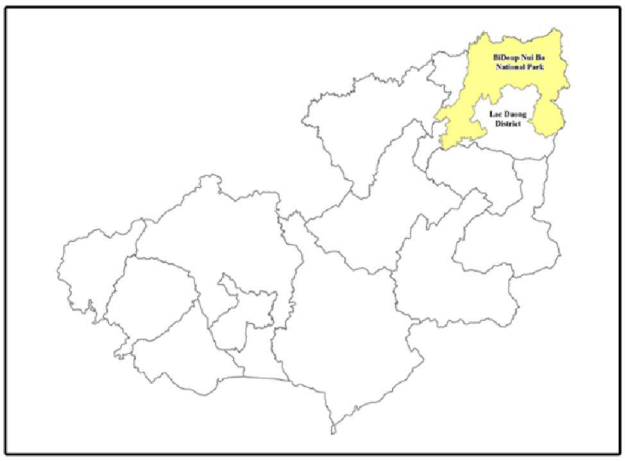


Fig. 1a. The diagram showing the study area



Fig. 1b. Location diagram of plots

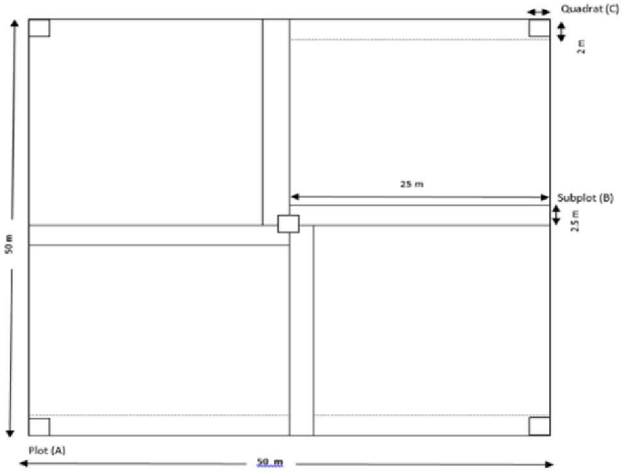


Fig. 2. Diagram of a plot

Ni% = No. of individuals of i species /total individuals of all species in a plot x 100

Gi - basal area (m^2) – Area occupied at breast height (1.3 m) = p x $(dbh/2)^2$

Gi%: Total basal area of i species/total basal area of all species in a plot x 100

Shannon-Weiner Index was used for species diversity of each typical forest communities type (Shannon and Weiner 1949). Similarity between high trees and layers of regeneration trees was analysed by Sorensen's similarity index (Sorensen 1948).

SI = 2K/(M+N)

In which, K - No. of species occurs in both tree layers, No. of species occurs in layer of M trees, N - No. of species occurs in layer of N trees.

RESULTS AND DISCUSSION

Floristics composition and natural regeneration: Research results showed that, with the 12 plots (2500 m^2 area each plot), there were 145 high tree species, representing 86 genera in 45 families. F was the richest species of 80, F + Pk had the lowest number of 54 species. The mixed broad - needle leaf forest communities were rather diverse, the He' index ranged from 3.42 to 3.92. The highest He' index was the two F and K with 3.92. The forest communities with the participation of *P. krempfii* (Pk, F + Pk, Pk + Pd) had lower He' index from 3.42-3.71 (Table 1). The result is similar to the study result on the He' index of the mixed broad - needle leaf forest type where *P. krempfii* is distributed in Bidoup - Nuiba National Park with 3.68 (Ngoc 2015). The mean stand density of high trees of 894 trees ha^{-1}, ranged from 676 to 1004 trees ha^{-1} was higher than that of the other the Central Highland sites, such as: Chuyangsin, Konkakinh (Nam et al 2020). In Bidoup - Nuiba National Park, the capable natural regeneration of the mixed broad - needle leaf forest communities were relatively good. Density regeneration ranged from 22500 to 38530 trees ha^{-1}, include: the small regeneration trees reached from 41.1-60.9%, the advanced regenerating trees accounted for from 6.2-20.1%, corresponding to the 2000-5740 trees ha^{-1}. There was an order of density difference between abundance in plots and stands. For seedlings, total abundance in Pk + Pd stand (Plot 5, Plot 6) was the biggest (33750 trees ha^{-1}). However, Pd (Plot 9, Plot 10) had the biggest total abundance of saplings compared to the other stands (Table 1). In the twelve plots in the communities, there were 3 to 9 dominant species

Table 1. Detail of species inventory in 12 plots of 6 types of the communities

Description	Communities						Total (12 plots)
	F+Pk (Two plots)	F (Two plots)	Pk+Pd (Two plots)	Pk (Two plots)	Pd (Two plots)	K (Two plots)	
High trees							
No. of species	54	80	56	58	72	76	145
No. of genera	40	53	45	47	49	46	86
No. of families	26	33	29	29	31	28	45
Density (stems ha^{-1})	920	988	844	1,004	932	676	
Species diversity index (H_e')	3.42	3.92	3.71	3.62	3.69	3.92	
Natural regeneration							
Advantaged regeneration							
No. of species	43	43	49	58	65	65	122
No. of genera	32	35	41	45	45	46	77
No. of families	23	25	24	26	31	31	41
Density (stems ha^{-1})	2000	3500	4780	5740	6560	3340	
Species diversity index (H_e')	3.46	3.26	3.20	3.57	3.52	3.91	
Small regeneration							
No. of species	28	32	34	31	45	47	107
No. of genera	24	23	30	28	34	34	71
No. of families	19	18	20	22	23	24	38
Density (stems ha^{-1})	30250	19000	33750	22750	26250	25000	
Species diversity index (H_e')	2.81	3.30	3.23	2.80	3.49	3.59	

participated in high trees composition formula, formed 9 plant dominions by total composition coefficient of the most important species, IV > 40% (Trung 1999). *P.krempfii, P.dalatensis, Fokienia hodginsii, Keteleeria evelyniana* were species or groups of species with the highest compassion coefficient in the plots that the IV value reached up to 25.4% expressed their importance in the mixed broad-needle leaf forest communities in Bidoup - Nui Ba National Park. Besides, the species of broadleaf high trees mainly belonged to genera such as: *Castanopsis, Lithocarpus, Craibiodendron, Cinamomum, Litsea, Syzygium,* etc. (Table 2). The study supported the fact that Fagaceae, Lauraceae, Myrtaceae, etc. are the dominant families in closed-evergreen forest types (Ngoc 2015, Trien 2015, Con et al 2015, Cuong et al 2020).

This study also shown that, the species composition of high trees tends to change from tropical species, such as: *Cinnamomum ovatum, Cinnamomum kunstleri,* etc. to the species of subtropical low mountain, medium mountain, such as: *Rhododendron irroratum*, *Camellia kissi,* etc. The result also was consistent with the distribution characteristics of species in the altitudes (Hoa 2017). The altitude 1500-1700 m had the highest concentration of species. The proportion of species only appeared in the altitude occupies to 21.4% (Fig. 3). There was transition between two adjacent altitudes, with many species appearing at the same time, such as: 23 species, occupies to 15.9% of the total of species appeared simultaneously in both 1500-1700 m and > 1700 m. At altitudes 1500-1700 m and < 1500 m, there were 26 species appeared simultaneously, accounting for 17.9% of the total of species recorded. However, there were only 3 species appeared simultaneously at altitudes < 1500 m and > 1700 m. The 42 species (accounting for 29.7% of the surveyed species) had wide ecological amplitude, appeared at 3 elevations, the mainly species of the families: Lauraceae, Fagaceae.

Composition between tree classes: The study shown that, the species composition between high trees and regeneration trees classes was similar. There only were 7 dominant species, including: *Craibiodendron bidoupensis*, *Polyosma nhatrangensis*, *Castanopsis wilsonii*, *Keteleeria*

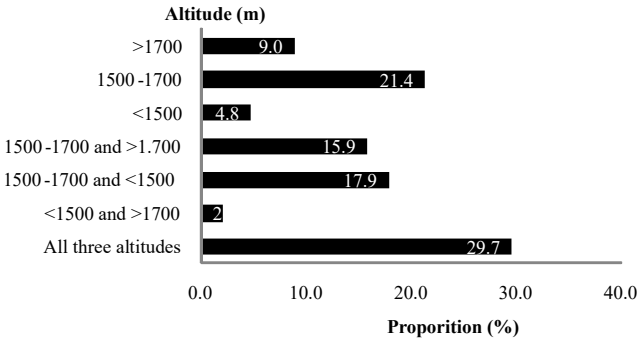


Fig. 3. Altitude distribution of proportion of species (dbh≥10 cm)

Table 2. High trees composition formula

Communities	Composition formula
F+ Pk	17.4 *Pinuskrempfii*+ 8.3 *Syzygium zeylanicum* + 8.0 *Fokienia hodginsii* + 7.2 *Quercus augustinii* + 6.9 *Lithocarpus campylotropis* + 6.1 *Exbucklandia populnea* + 46.1 Other species
	19.8 *Castanopsiswilsonii*+ 13.1 *Pinus krempfii*+ 11.1 *Syzygium zeylanicum*+ 6.3 *Calophyllum rugosum* + 6.1 *Illicium cambodianum* + 5.0 *Fokienia hodginsii*+ 38.6 Other species
F	11.5 *Fokienia hodginsii*+ 8.2 *Litsea lancifolia* + 8.0 *Craibiodendron bidoupensis* + 7.2 *Castanopsischinensis* + 65.1 Other species
	12.4 *Fokienia hodginsii*+ 9.9 *Litsea cubeba* + 8.4 *Lithocarpus stenopus* + 5.6 *Schima supebar* + 5.2 *Cinamomum afftsoi* + 58.4 Other species
Pk+Pd	14.2 *Pinus dalatensis*+ 11.9 *Engelhardia roxburghiana* + 6.9 *Dacrydium elatum* + 5.3 *Pinus krempfii* + 5.2 *Schima supebar* +56.5 Other species
	10.5 *Craibiodendron bidoupensis*+ 9.5 *Quercus augustinii*+ 8.8 *Eriobotrya acuminatissima*+ 7.4 *Elaeocarpus harmandii* + 7.2 *Syzygium zeylanicum*+ 6.9 *Dacrydium elatum* + 6.0 *Pinus dalatensis*+ 5.5 *Rhodoleia championii* + 5.4 *Pinuskrempfii* + 32.8 Other species
Pk	19.9 *Pinuskrempfii* + 9.5 *Castanopsis echidnocarpa* + 8.2 *Syzygium zeylanicum* + 8.1 *Vaccinium sprengelii* + 6.5 *Pentaphylax euryoides* + 6.0 *Craibiodendron bidoupensis* + 5.5 *Engelhardia roxburghiana* + 36.3 Other species
	15.9 *Pinuskrempfii* + 7.9 *Craibiodendron bidoupensis* + 6.7 *Castanopsis pseudoserrata* + 5.4 *Polyosma nhatrangensis* + 64.1 Other species
Pd	16.7*Pinus dalatensis* +16.1*Craibiodendron bidoupensis* + 10.9*Dacrydium elatum* + 56.3Other species
	18.4 *Pinus dalatensis*+ 9.0*Quercus augustinii* + 8.7 *Syzygium zeylanicum* + 7.4 *Syzygium wightianum* + 6.0*Rhodoleia championii* + 5.2 *Engelhardia roxburghiana* + 45.3 Other species
K	22.4 *Keteleeria evelyniana* + 9.1 *Castanopsis echidnocarpa* + 6.5 *Craibiodendron bidoupensis* + 5.5*Cinamomum aff tsoi* + 56.5 Other species
	18.4 *Keteleeria evelyniana*+ 12.7 *Castanopsis wilsonii* + 6.2 *Rhodoleia championii*+ 62.7 Other species

evelyniana, Illicium cambodianum, *Castanopsis echidrocarpa*, *Syzygium wightianum*, *Syzygium zeylanicum*, that appeared in all three classes of trees. Many dominant species of high trees were not dominant species of regeneration trees, especially needle-leaf, such as: *Fokienia hodginsii, Pinus krempfii, Pinus dalatensis.* In addition to it mean density of needle-leaf regeneration trees was very low, occupied 2-4.6% of the stand regeneration density, 1.208 trees ha^{-1} in small regeneration trees and 87 trees ha^{-1} in advanced regeneration trees (Table 3).

SI index between tree classes ranged from 0.38 to 0.67, $SI_{M\&N1}$ were the highest (0.62) in Pk, Pd, K and the lowest (0.38) in F + Pk, $SI_{M\&N2}$ was the highest (0.67) in Pk + Pd and Pd (Table 4). This study has shown that the process of regeneration under the canopy of the mixed broad - needle leaf forest communities occurred randomly at the time of the study. The relationship between species composition of high trees to species composition of regeneration layers were moderate (SI<0.75). The result was similar to the SI index of evergreen broad-leaf forest stands in Xuanson National Park, Phutho province (Trien 2015), in Konhanung, Gialai province (Con et al 2015).

Stand structure: The distribution of the total species, individuals and basal area for all high trees (dbh ≥ 10 cm) in 12 plots decreased with increasing dbh from 10 to more than 150 cm. Species richness contributed mainly about 99.3% in <30 cm dbh class. The girth class also had the greatest proportion of individuals (about 78.1%) (Table 5). The distribution followed an inverted J-curve shape. This distribution shape is popular in other tropical forest stands, such as: Evergreen broad-leaf forest in Konhahung, Gialai province (Con et al 2015) and evergreen dipterocarp forest in Southern Vietnam (Dong et al 2014). However, the distribution of total basal area was not too different between the diameter classes from <30 cm to ≥ 90 cm (Fig. 4). It was not the same as broadleaf group, the basal area of needle-leaf group did not follow the decreasing with increasing dbh. Girth class having <30 cm dbh contributed to about 1% of basal area poorness. The highest proportion of basal area were about 14.7% in the high dbh classes (≥ 90 cm), although the proportion of trees only had about 0.9% in the girth classes (Figs. 4 and 5). The study results showed that the number of trees of needle-leaf group only occupied 8.7% of the total of trees, but the basal area contributed to about 36.6% of the stands (data not shown).

Table 3. Composition between layers of trees

Criteria	High trees - M (1)	Advanced regeneration trees -N1 (2)	Small regeneration trees - N2 (3)
Mean density (trees ha^{-1}) (Needle-leaf/Broad-leaf/Total)	78/816/894	87/4.233/4.320	1.208/24.959/26.167
No. of dominant species participated in composition formula	29	33	50
High dominant trees participated in composition formula of regeneration tree classes	*Litsea glutinosa* (1, 2); *Litsea lancifolia* (1); *Craibiodendron bidoupensis* (1, 2, 3); *Exbucklandia populnea* (1); *Engelhardia roxburghiana* (1, 3); *Elaeocarpus harmandii* (1, 3);*Calophyllum rugosum* (1, 3); *Polyosma nhatrangensis* (1, 2, 3); *Lithocarpus campylotropis* (1); *Lythocarpus stenopus* (1, 3); *Castanopsis wilsonii* (1, 2, 3); *Castanopsis chinensis* (1, 3); *Keteleeria evelyniana* (1, 2, 3); *Illicium cambodianum* (1, 2, 3); *Rhodoleia championii* (1); *Dacrydium elatum* (1); *Castanopsis pseudoserrata* (1); *Castanopsis echidnocarpa* (1, 2, 3); *Pentaphylax euryoides* (1); *Fokienia hodginsii* (1); *Cinnamomum tsoi* (1, 3); *Quercus augustinii* (1, 3); *Eriobotrya acuminatissima* (1, 3); *Vaccinium sprengelii* (1); *Pinus dalatensis* (1); *Pinus krempfii* (1); *Syzygium wightianum* (1, 2, 3); *Syzygium zeylanicum* (1, 2, 3); *Schima superba* (1).		

Table 4. Similarity index betweenlayers of trees

Communities	Species			Species homologous		Similarity index (SI)	
	M	N1	N2	M&N1	M&N2	$SI_{M\&N1}$	$SI_{M\&N2}$
F + Pk	54	42	29	18	23	0.38	0.55
F	80	44	32	34	28	0.55	0.50
Pk + Pd	56	50	34	32	30	0.60	0.67
Pk	68	58	31	39	22	0.62	0.44
Pd	73	65	44	43	39	0.62	0.67
K	76	65	47	44	31	0.62	0.50

Table 5. Diameter distribution on species, individuals and basal area of trees

Dbh class (cm)	Species		Individuals		Basal area	
	Total	Percent of total	Total (trees)	Percent of total (%)	Total (m^2)	Percent of total
<30	144	99.3	2,092	78.1	55.0	31.5
30-50	80	55.2	435	16.2	49.2	28.2
50-70	33	22.8	89	3.3	24.2	13.9
70-90	9	6.2	35	1.3	17.4	10.0
90-110	8	5.5	15	0.6	11.3	6.5
110-130	4	2.8	5	0.2	5.4	3.1
130-150	3	2.1	5	0.2	7.5	4.3
>150	2	1.4	2	0.1	4.5	2.6
	145		2,678	100	174.5	100

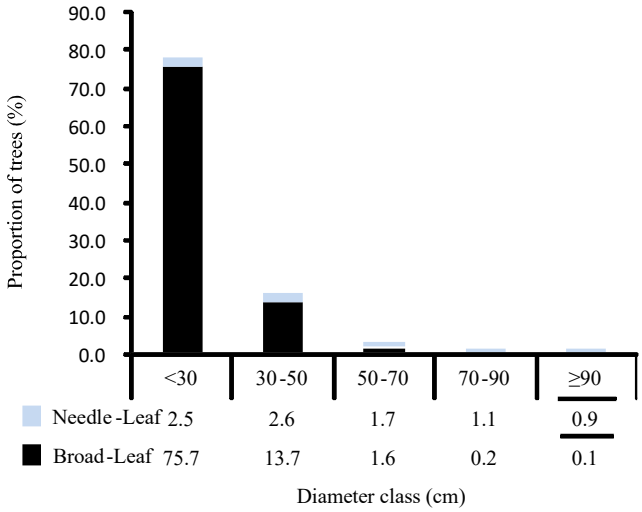


Fig. 3. Diameter distribution of proportion of broad-leaf and needle - leaf trees

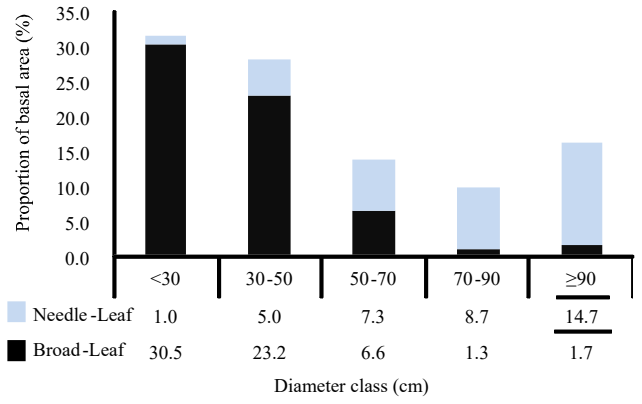


Fig. 4. Diameter distribution of proportion of broad-leaf and needle-leaf basal area

CONCLUSIONS

The mixed broad - needle leaf forest communities were rich in high tree species diversity, with He's index, mean density were rather high. Species diversity and tree density decreased with increasing dbh class, highest in <30 cm dbh class. The value of IV% in the composition formulas showes the important ecological role of the conifers in the mixed broad - needle leaf forest communities. The communities had good natural regeneration ability. For small regeneration density, there were ranged from 19000 to 33750 trees ha^{-1} and 2000-6560 trees ha^{-1} in advanced regeneration trees. However, natural regeneration means density of the conifers including: *Keteleeria evelyniana, P. krempfii, Fokienia hodginsii, P. dalatensis* were about 1208 trees ha^{-1} and decreased rapidly with advanced regeneration trees (87 trees ha^{-1}). The study indicated that the current condition of the mixed broad - needle leaf forest communities was not favorable for regeneration trees of the conifers. Hence, it is very necessary for the conifers to take natural regeneration promotion solutions in the site. This was as a primary input towards studying on forest dynamic, succession monitoring and conservation of the rare conifers of the closed evergreen mixed broad, needle leaf forests in the Central Highlands area of Vietnam.

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Review on Ethno-medicinal Plants Used for Healing Skin Ailments in Madhya Pradesh, India

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***Abstract*:** Skin diseases are common among the rural population due to inadequate sanitary conditions, insufficient hygiene, and contaminated water. Traditional herbal medicines are effective in curing many skin diseases which are used by several local communities. Plants are also an important source of the world's pharmaceuticals medicine, which are widely used in the treatment of various skin diseases. Ethno-botany is the study of the direct relationship between humans and plants. In Madhya Pradesh, tribes and forest dwellers make up a significant portion of the population. A large number of indigenous peoples live in the most remote and inaccessible parts of the forests. The majority of these tribal groups rely primarily on plant species to treat their diseases. The aim of this paper is to enumerate the plants used to treat skin diseases in Madhya Pradesh based on reported ethnobotanical data from various districts for future studies, as well as to identify areas where similar studies have not yet been conducted.

***Keywords*:** Ethnobotany, Traditional medicines, Skin diseases, Tribal community, Madhya Pradesh

India has a long tradition of using medicinal plants and herbal medicines to cure human illnesses. For the majority of our population in rural and tribal areas, medicinal plants are the only readily accessible health care option. Tribal life, tradition, and culture have remained nearly unchanged for hundreds of years. The tribal's experience acquired over decades reflects an in-depth understanding of forest resources (Choudhary et al 2011). Ethno-botany is the study of direct relationship between man & plants, plants continue to be a major source of world pharmaceuticals and folk-lore medicines, which are widely used to treat a number of skin diseases. Due to poor sanitary conditions, insufficient sanitation, and polluted water, skin diseases are widespread among the rural population. Traditional herbal medicines, which are used by various cultures, are effective in treating certain skin diseases. They are safe, reliable, and accessible, and in many situations, they are the only choice for care (Buragohain and Konwar 2007). Tribes and forest dwellers make up a significant portion of the population in Madhya Pradesh. A significant number of tribal peoples live in the forests' most isolated and inaccessible areas. The majority of these tribal groups depend on plant species to treat their ailments. These tribal's have gained special information about the use of wild flora as a result of their near proximity to nature. According to Census of India 2011, the population of Scheduled Tribal's (ST) is 21.1% of the state population, major tribal's communities in Madhya Pradesh are Bhil, Gond, Kol, Korku, Sahariya ,Baiga followed by Pradhan, Saur, Bharia, Majhi, Mewasi, Panika (Census of India 2011). Approximately 34% of occupational skin disorders are treated with conventional herbal medicines used by various communities (Kadam and Sharma 2013). The aim of this paper is to enumerate the plants used to treat skin diseases in Madhya Pradesh based on reported ethnobotanical data from various districts for future studies, as well as to identify areas where similar studies have not yet been conducted.

Common skin diseases: Skin diseases are a widespread ailment that affects people of all ages, from newborns to the elderly, and can affect them in a variety of ways. There are thousands of disorders that can affect the skin, but the majority of them can be classified into nine groups (Marks et al 2006).

Rashes: A rash is a red, inflamed patch of skin or a series of individual spots. Irritation, allergy, infection, an underlying disorder, as well as structural defects such as pores or malfunctioning oil glands, can cause these. Acne, dermatitis, eczema, hives, pityriasis, and psoriasis are examples of rashes.

Viral infections: These occur when a virus penetrates the stratum corneum and infects the inner layers of the skin. Examples of viral skin infections are herpes simplex, shingales, and warts. Some systemic viral infections such as chicken pox and measles, may also affect the skin. Viral infections cannot be cured by antibiotics.

Bacterial infections: Such infections are caused by a

variety of bacteria, the most common types being Staphylococci and Streptococci. Bacteria may infect the topmost layer of the skin, the follicles, or the deeper layers of skin. Bacterial infections are better treated with antibiotics.

Fungal infections: Harmless fungi are always present on surface the skin. Infections occur when these organisms enter into the body. These infections are usually superficial, affecting the skin, hair, nails and include athlete's foot, lock itch and ring worm.

Parasitic infections: These infections occur after exposure to parasites such as lice and scabies.

Pigmentation disorders: The amount of pigment in the skin is determined by the amount of melanin being produced by the body. Loss of pigment (hypo pigmentation) can be caused by absence of melanocytes, malfunctioning of cells, exposure to cold or chemical, or some type of infection. An increase in pigment (hyper-pigmentation) may be caused by skin irritation, hormonal changes, aging, metabolic disorders etc.

Tumors and cancer: Skin cells replicate at a higher rate than normal, resulting in these growths. Not all skin tumours are cancerous. Some tumors are non-cancerous and do not spread.

Trauma: Trauma describes an injury to the skin caused by a blow, a cut, or a burn. Whenever the surface of the skin is broken, the body becomes more susceptible to infections and disease.

Others conditions: Wrinkles, rosacea, spider veins and varicose veins are among those conditions that cannot be neatly categorized.

Studies Already Done

For the present review, information regarding ethnomedicinal plants and their uses for skin diseases was gathered via searching books and scientific databases including Pubmed, Elsevier, Google Scholar, Springer, etc. These searches were exclusively on ethnobotanical published data from Madhya Pradesh only. A scrutiny of literature reveals that several research papers on ethnomedicinal plants to treat skin ailments of various regions and districts of Madhya Pradesh have been published (Anis et al 2000, Kumar & Khanna 2000, Sahu & Sahu 2004, Jadhav 2006, Vijendra & Kumar 2010, Choudhary et al 2011, Kapale 2012, Srivastava et al 2012, Jitin Rahul and Singh 2013, Kadam and Sharma 2013, Jeetendra and Sudip 2014, Quamar and Bera 2014, Wagh and Jain 2014, Sandiya and Sandiya 2015, Singh 2015, Das et al 2016, Ks et al 2016, Rai 2016, Ahirwar 2017, Kumhar et al 2017, Singhal et al 2017, Jaiswal and Jain, 2018, Ahirwar 2020, Shrivastava et al 2020).

The aforesaid literature reveals that still there are many more districts in Madhya Pradesh where the studies on ethnomedicinal plants and their uses have not done yet. But enumeration of these published data will be helpful for future perspective.

Enumeration: The plants used as ethnomedicine for healing skin diseases in Madhya Pradesh, here enumerated from published data alphabetically by scientific name, followed by common name, family, parts used, skin diseases and methods of preparation are given below in (Table 1). It is found that local of Madhya Pradesh are using approximately 97plants species belonging to 50 families for their skin ailments. They can be classified according to their habit. A graphical representation for this has been presented (Fig. 1). It is found that according to habit those plant species are used in skin ailments herbs are 41, trees are 27, shrubs are 19 followed by climbing shrub 4, climbing herb 3, creeping herb 2 and epiphytic herb 1 in number.

CONCLUSIONS

While recent ethnobotanical studies have identified these medicinal as well as ethnomedicinal values of plants, not all of them have been tested, and many species used by Madhya Pradesh tribes for skin diseases have yet to be investigated for their ethnomedicinal value and to isolate the active principle constituents. The rate with which skin diseases like eczema, wart, psoriasis, chicken pox, tumor, ring worms etc., are progressing it appears to have an immediate and reliable solution for ensuring the human population's safety in the face of such diseases. As a result, there is a strong need to investigate plants that have therapeutic efficacy against such diseases. As a result, an attempt has been made to enumerate plants with such uses, but their claimed activities must still be investigated.

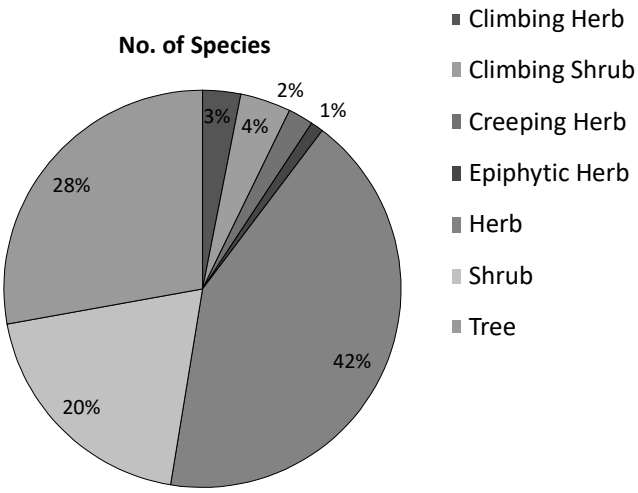


Fig. 1. Graphical representation of habit of ethnomedicinal plants

Table 1. List of ethnomedicinal plants used as skin ailments

Scientific name	Common name	Family	Habit	Parts used	Skin diseases	Methods of preparation
Abelmoschus moschatus Medik.	Kasturi Bhindi	Malvaceae	Herb	Leaf, seeds	Cuts, Wounds	A paste of leaves is applied on the cuts,wounds and sprains. Seeds are also used for same purpose.
Abrus precatorius L.	Ratti	Fabaceae	Climbing shrub	Root	Ringworm Spot	The juice of root, mixed with the half the amount of the juice of *Allium sativum* is applied on ringworm spot.
Acacia sinuata (Lour.) Merr.	Satala	Mimosaceae	Shrub	Pods	Ringworm Spot and Wound	The pods along with *Emblica officinalis, Curcuma longa* and *Rubia cordifolia* are recommended for skin ring worm and wound.
Acanthospermum hispidum DC.	Gokharu	Asteraceae	Herb	Whole Plant	Skin infections, wounds etc.	Paste of whole plants is used to treat skin disease.
Achyranthes aspera L.	Chirchita	Amaranthaceae	Herb	Leaf	Skin infections	Leaf juice with a pinch of salt is applied to cure skin infection
Adiantum philippense Linn.	Hansraj	Adiantaceae	Herb	Rhizome	Dog bites, snake bites	Powder of rhizome applied on area of snake bites and dog bites.
Ailanthus excelsa Roxb.	Adu, Mahaneem	Simaroubaceae	Tree	Leaf	Skin infections	The leaf powdermixed with whole plant of *Solanum xanthocarpum* is used for skin infection
Allium sativum L.	Lahsun	Amaryllidaceae	Herb	Leaf, Roots, Bulb	Wounds ,Bacterial, Viral or on fungal infections leisons.	Boil garlic in mustard oil than apply in affected lesion. Garlic in treating wounds. Antiviral, antibacterial, antifungal,antiparasitic.
Allium tuberosum Roxb.	Ban lahsun	Amaryllidaceae	Herb	Leaf and bulb	Insect bites , wounds etc.	The leaves and bulbs are applied to insect bites, cuts, and wounds.
Aloe vera (L.) Burm.f.	Gwarpatha	Liliaceae	Herb	Leaf	Dry skin, Rash etc.	Leaf pulp is used as a moisturizer
Alternanthera sessilis (Linn.) R.Br. Ex DC.	Gudari shak	Amaranthaceae	Herb	Whole Plant	Burning sensation	The whole plant is used for burning sensation and other skin diseases.
Alternenthera pungens Kunth.	Katua sak	Amaranthaceae	Herb	Leaf	Gonorrhea	Decoction of its leaves is taken to treat gonorrhea.
Amaranthus spinosus Linn.	Chaulai	Amaranthaceae	Herb	Leaf	Scorpion stings and snake bites	Traditionally, leaves are used to treat scorpion sting and snake bite.
Andrographis paniculata (Burm. fil.) Nees	Kalmegha, kirayat	Acanthaceae	Herb	Leaf	Tineacruris,Cut etc.	Leaf juice mixed with cow milk is taken orally twice a day for six to eight days to cure tinea cruris.
Antidesma zeylanicum Lam.	Amti	Euphorbiaceae	Shrub	Leaf	Snake bites	Leaves are used as an antidote for snake bite.
Antigonon leptopus Hook. & Arn.	Antigonum	Polygonaceae	Climbing shrub	Leaf	External skin infections.	Paste of fresh leaves applied externally in skin disorders.
Argemone mexicana L.	Satynasi	Papavaraceae	Herb	Whole Plant	All kinds of skin diseases	Pounded seed along with rhizome of Curcuma aromatica made in to paste are applied on all kinds of skin diseases twice a day till recovery.
Argyreia nervosa (Burm. fil.) Bojer.	Vidhara	Convolvulaceae	Herb	Leaf	Wound	Leaf paste is applied topically on wounds.
Azadirachta indica A. Juss.	Neem	Meliaceae	Tree	Leaf,Bark, young stem.	Wounds, Cuts, Ringworms, Scabies etc.	1 spoon of powder mixed with water/orally thrice in a day/3 days.Effective against skin diseases like ringworms,scabies,wounds.
Bacopa monnieri (L.) Pennell	Brahmi	Plantaginaceae	Herb	Whole Plant	Psoriasis, Eczema etc.	Whole plant juice taken orally to reduce such problems.
Bambusa bambos (L.) Voss	Bans	Poaceae	Shrub	Stem	Wounds	Paste of stem applied on wounds.
Butea monosperma (Lam.)Taub.	Palas	Fabaceae	Tree	Seeds	General wounds and infections.	Seed paste is used to cure skin diseases.
Calotropis procera (Aiton) R. Br.	Arka, Mudar	Asclepiadaceae	Shrub	Root, Latex, Flower, Leaves	Boils, Wounds etc.	The leaves and flower are crushed together, made in to pest and applied tropically on boils.
Carica papaya L.	Papita, Papaya	Caricaceae	Tree	Fruits	Dull skin	Clean and attractive fresh in skin

Cont...

Table 1. List of ethnomedicinal plants used as skin ailments

Scientific name	Common name	Family	Habit	Parts used	Skin diseases	Methods of preparation
Cascabela thevetia (L.) H. Lippold	Kaner	Apocynaceae	Shrub	Leaf, Root	Skin ailments and Ring worm	Oil is used externally for skin ailments, and ring worm treatment.
Cassia alata L.	Dadukapatta	Fabaceae	Shrub	Leaf	External skin infections.	Leaf paste mixed with seed oil of *Pongamia pinnata* applied externally on skin diseases.
Cassia fistula L.	Amaltas	Fabaceae	Tree	Bark	Fungal skin problems.	Bark is used for fungal diseases.
Cassia tora L.	Charota	Fabaceae	Shrub	Leaf	External skin infections.	Paste of leaf is applied over skin to cure infections.
Centella asiatica (L.) Urb.	Brahmi,Thankuni	Apiaceae	Creeping Herb	whole Plant	Wound, UV damage.	Treatment of wound, and protection of skin ageing damage,UV damage.
Cicer arietinum L.	Gram, Chana	Fabaceae	Herb	Fruits, Roots.	Skin freshener, Ring worms.	Powder paste is applied for skin fresheners and also for cure ring worm.
Clerodendrum infortunatum L.	Pumiyau, Bhant	Verbenaceae	Shrub	Leaf	Common Skin Diseases	The paste of leaf is applied in all types of skin diseases.
Coccinia grandis (L.) Voigt	Kunduru	Cucurbitaceae	Herb	Leaf	Bacterial infections and ring worm.	The leaf paste is used as antibacterial and in treatment of ring worm.
Commiphora wightii (Arn.) Bhandari	Gugul	Burseraceae	Tree	Gum, Leaf	Wrinkles, wound,colour improvement	The paste used in wrinkles and aged skin, skin colour improvement, Wound treatment.
Crotalaria retusa L.	Khunkuniyan, Devil bean	Fabaceae	Shrub	Root, leaf, Seed	Hairfall, external skin problems.	Seed oil is used to treat hair problems, leaf and root paste applied to external skin problems.
Cucumis sativus L.	Khira	Cucurbitaceae	Climbing Herb	Fruits	Skin fresh	Fruits are used as skin fresh.
Curcuma aromatica Salisb.	Van haldi	Zingiberaceae	Herb	Rhizome	Eczema	The Paste of the rhizome with a 50% of Neem leaves powder is applied on the skin against eczema.
Curcuma caesia Roxb.	Kali haldi	Zingiberaceae	Herb	Rhizome	Wounds, Cuts, Ringworm	Grind fresh Rhizomes and put on affected area. Paste is mixed with Neem oil is applied Ring worms control.
Curcuma longa L.	Haldi, Turmeric	Zingiberaceae	Herb	Whole Plant	Stimulation, expectorant, ring worm	Used as stimulative, expectorant, face cream in ring worm etc.
Cuscuta reflexa Roxb.	Amarbel	Convolvulaceae	Herb	Whole Plant	Common skin problems	Paste is applied on affected area.
Dalbergia sissoo DC.	Sheesham	Fabaceae	Tree	Wood, Leaf	Skin diseases	Decoction of bark and heartwood are useful in Skin diseases.
Datura metel L.	Dhatura	Solanaceae	Shrub	Whole Plant	Swelling of gums, Swelling base of ear	Leaf juice is mixed with a little opium and applied to the affected area to reduce swelling of gums or base of ears.
Diplocyclos palmatus (L). C. jeffrey	Shivlingi	Cucurbitaceae	Climbing herb	Whole Plant	Skin Diseases	The seed oil and coconut oil in equal preparation is applied on body in skin disease.
Dryopteris cochleata (D. Don) C. Chr.	Jatashankari	Dryopteridaceae	Herb	Rhizome	Leprosy, Fungal infections, Insect bites etc.	Rhizomes are used as antifungal and antidotes to insect bites. It is also used in epilepsy, leprosy, wounds etc.
Eclipta prostrata (L.) L.	Bhringraj	Asteraceae	Herb	Whole Plant	Eczema, Hair problem	Leaf juice is given in eczema and as hair tonic.
Euphorbia hirta L.	Dudhi	Euphorbiaceae	Herb	Whole Plant	Wound, eczema, ring worm	The latex of the plant is applied topically on wounds. Latex is also applied on eczema. The pest of whole plant applied topically on
Ficus hispida L. f.	Gobla	Moraceae	Tree	Leaf, fruits	Leucoderma	Fresh leaf juice is applied externally for skin disorders like Leucoderma and fruit juice is given internally for 3 days.
Ficus racemosa L.	Gullor	Moraceae	Tree	Latex	Boils	The latex is applied topically on boils.
Ficus religiosa L.	Peepal	Moraceae	Tree	Bark	Skin Diseases	Paste of powdered bark is good for skin diseases
Hedyotis corymbosa L.	Davnapatta	Rubiaceae	Herb	Whole plant	Ring worm	Leaf paste used on ring worm.

Cont...

Table 1. List of ethnomedicinal plants used as skin ailments

Scientific name	Common name	Family	Habit	Parts used	Skin diseases	Methods of preparation
Hemidesmus indicus (L.) R. Br.	Anantmool	Apocynaceae	Climbing shrub	Root	Gout, syphilis, wound	Skin diseases gout, syphilis and non- healing wound, soft skin.
Hordeum vulgare L.	Jow	Poaceae	Herb	Grain	External skin infections.	Apply floor of barley with linseed oil & butter milk.
Ipomoea carnea Jacq.	Beshram	Convolvulaceae	Herb	Leaf	Cuts, Wounds	The leaves are fried in mustard oil and tied topically on cuts and wound.
Jasminum angustifolium (L.) Willd.	Chameli, Jasmin	Oleaceae	Herb	Root, Leaf	Dry skin, Rash etc.	The oil used help moisture in the skin to naturally reduce dryness.
Jatropha gossypiifolia L.	Lal ratanjot	Euphorbiaceae	Shrub	Latex	Burn	Latex of plant is applied on burn part of body.
Kalanchoe pinnata (Lam.) Pers.	Patharchata	Crassulaceae	Herb	Leaf	Boils, Insect bites, Wounds etc.	Tender leaves are crushed and mix with wheat husk,coconut oil to apply on the affected part.
Lablab purpureus (L.)Sweet	Semi, Sem	Fabaceae	Herb	Leaf	Dull skin	Leaves paste used bleaching cream, and skin cool.
Lantana camara L.	Machhimudhi	Verbenaceae	Shrub	Leaf	Wounds, Cuts	Leaf paste is an externally applied to wounds and cuts.
Lawsonia inermis L.	Mehendi	Lythraceae	Shrub	Whole Plant	Dry skin, Mud infections	The leaf paste is applied on cracked heels in rainy season due to mud infection.
Leea macrophylla Roxb. ex Hornem.	Hathikana	Vitaceae	Shrub	Root	Cuts, Swelling	Root paste is applied topically on cuts and swelling.
Lens culinaris Medik.	Masoor, Lentil	Fabaceae	Herb	Whole Plant	Skin Diseases	Seed pest is known to cure skin diseases.
Linum usitatissimum L.	Alsi	Fabaceae	Herb	Whole Plant	Wounds	The paste of whole plant is applied topically on wounds.
Madhuca indica J.F.Gmel.	Mahua	Sapotaceae	Tree	Leaf	Wounds	Leaves paste is used topically on wounds.
Mallotus philippensis (Lam.) Müll.Arg.	Kamala, Sindoori	Euphorbiaceae	Tree	Whole Plant	Parasitic infection, wounds	All parts are used in treat parasitic infection of the skin. Wounds treatment.
Mangifera indica L.	Aam	Anacardiaceae	Tree	Gum	Scorpion stings	The gum of the plant is mixed with salt thoroughly and the formed paste is applied on bitten area in scorpion bite.
Melia azedarach L.	Bakayan	Meliaceae	Tree	Leaf	Boils, Eczema, Wounds	Paste of leaves is applied on Boils,Eczema and Wounds.
Moringa oleifera Lam.	Munga, Sahajan	Moringaceae	Tree	Leaf	Skin Diseases	Plant powder is taken internally to treat skin diseases.
Murraya koenigii (L.) Spreng.	Meethi neem, Kadipatta	Rutaceae	Tree	Root	Wounds	Roots are used to curing of wound.
Musa paradisiaca L.	Banana, Kela	Musaceae	Shrub	Fruits	Skin diseases, smooth muscle	Fruits wall used to treat skin diseases and smooth muscle.
Ocimum tenuiflorum L.	Tulsi	Lamiaceae	Herb	Leaf	Skin infections, Insect bites	Leaf juice is applied topically on the affected area.
Origanum vulgare L.	Sathhra, Dounpatti	Lamiaceae	Herb	Whole Plant	Fungal and bacterial skin problems	Whole plant is used as antibacterial and antifungal.
Oxalis corniculata L.	Amrit sak, Amrul	Oxalidaceae	Creeping Herb	Whole Plant	Allergy	The juice of the whole plant is gently rubbed on the skin against allergies for 2-5 days.
Phyllanthus acidus (L.) Skeels	Shri Amla, Harfaauri	Phyllanthaceae	Tree	Bark	Skin diseases	Bark is heated with coconut oil skin diseases treatment.
Phyllanthus emblica L.	Amla, Amlaki	Phyllanthaceae	Tree	Fruits , Leaf	Skin infections	Fruits juice, leaf powder, with Neem leaf and honey is taken for skin infection.
Piper nigrum L.	Kalimirch, Ushan	Piperaceae	Climbing herb	Seeds	Wounds	Seeds are used in wound healing.
Plumbago zeylanica L.	Chitrak, Chita	Plumbaginaceae	Herb	Root	Fungal and bacterial skin problems	Root paste is used as antibacterial and antifungal.

Cont...

Table 1. List of ethnomedicinal plants used as skin ailments

Scientific name	Common name	Family	Habit	Parts used	Skin diseases	Methods of preparation
Psidium guajava L.	Amrood, Guava	Myrtaceae	Tree	Fruits , Leaf	Skin complaints, Ring worm, Wounds	The leaves and bark is taken externally as a lotion for skin complaints, ring worm, wound.
Ricinus communis L.	Arandi	Euphorbiaceae	Shrub	Seeds	Inflammatory skin disorder	Seed pest to the skin as a poultice for inflammatory skin disorders.
Saraca asoca (Roxb.)Willd.	Ashok, Sita Ashok	Fabaceae	Tree	Bark	Skin problems	Powder on skin problem by making paste.
Semecarpus anacardium L. f.	Bhilwa, Gheru	Anacardiaceae	Tree	Seeds, Fruits	Face ring worm	Boil the fruit in Rar oil & apply on face ring worm.
Sesamum indicum L.	Til, Safed til	Pedaliaceae	Herb	Seeds	Leprosy, Boils	The oil of seed is applied topically in leprosy. Seed paste is applied on boils.
Smilax fluminensis Steud.	Chobchini	Smilacaceae	Climbing Shrub	Tuber	Skin problems	Powders mixed with coconut oil and apply.
Solanum lycopersicum L.	Tomato, tomator, Bilayti	Solanaceae	Herb	Fruits	Ring worm	Fruit pulp is applied on the area of infection.
Solanum nigrum L.	Makoi	Solanaceae	Herb	Leaf	Skin diseases	Leaves are used as poultice for skin diseases.
Solanum tuberosum L.	Alu, Potato	Solanaceae	Herb	Tuber	Ring worm, Blackish skin	Tuber paste applied topically on ring worm, black skin.
Soymida febrifuga (Roxb.) Juss.	Rohni	Meliaceae	Tree	Bark	Wound	The paste of bark is used for wounds.
Sphaeranthus indicus L.	Murmuriya, Bhuikadam	Asteraceae	Herb	Whole Plant	Common Skin Diseases	Plant powder is taken internally to skin disease.
Strychnos nux-vomica L.	Kuchila, Bilewa	Loganiaceae	Tree	Leaf	Common Skin Diseases	Leaf paste is applied on common skin diseases.
Tephrosia purpurea (L.)Pers.	Meghapati, Sarpankha	Fabaceae	Shrub	Aerial part	Burn wound	Paste of aerial part used to treat burn wound.
Terminalia arjuna (Roxb.) Wight & Arn.	Kahuwa, Arjun	Combretaceae	Tree	Bark, Leaf	Wound	Leaves are used to wound healing.
Terminalia chebula Retz.	Harra, Hartaki	Combretaceae	Tree	Fruits	Boils	Fruits of Harra along with mustard oils are applied on affected area.
Vanda tessellata (Roxb.) Hook. ex G. Don	Mai ki bagia, Rashna, Venda	Orchidaceae	Epiphytic herb	Root, Leaf	Inflammation, Cuts, Wounds	Leaf paste is applied on the affected area for immediate relief.
Vernonia cinerea (L.) Less.	Sahadevi, Sadodi	Asteraceae	Herb	Whole Plant	Eczema, Ringworm, Tumer	Leaf juice is useful for amobiasis, eczema, ring worm and other skin tumors.
Withania somnifera (L.) Dunal.	Aswagandha	Solanaceae	Shrub	Whole Plant	Common skin problems	Small pieces of plant are mixed with cow's urine and applied on the affected skin.
Woodfordia Fruticosa (L.) Kurz.	Dhawa	Lythraceae	Tree	Stem, Leaf	Scabies, Common skin diseases	Stems are pounded, mixed with curds and applied to scabies. Leaf paste are used many other skin diseases.
Xanthium indicum Koen.	Gokharoo	Asteraceae	Shrub	Fruits	Common skin problems	Fruit oil is applied externally on skin diseases for three days.
Zingiber officinale Roscoe.	Adrak, Ada	Zingiberaceae	Herb	Rhizome	Swollen skin	Rhizomes are ground into a fine paste and applied on the skin.
Ziziphus nummularia (Burm. f.) Wight & Walk.-Arn.	Jharbery	Rhamnaceae	Tree	Leaf	Boils, Wound, Cut	Leaf paste is applied on boils, wounds and cuts.

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Impact of Essential Oils of Lamiaceae Family Against *Tylenchulus semipenetrans*

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Abstract: The nematode of citrus *Tylenchulus semipenetrans* Cobb 1913, is an important parasitic nematode of plants, very widespread in citrus growing regions of the world, and it is responsible of slow decline of citrus fruits. The aim of the present study focuses on the molecular docking approach to inhibition of the "Acetyl CoA Carboxylase" enzyme responsible for fatty acid synthesis in *Tylenchulus semipenetrans* and alteration disrupting the synthesis of the surface layer, this inhibitory action is based on essential oils of aromatic plants, taking as an example the Lamiaceae family, using four species *Lavandula multifida, Lavandula stoechas, Rosmarinus officinalis,* and *Thymus ciliatus*. This study revealed that Cavacrol from *Lavandula multifida* gives the best docking scores compared to Biotine, the co-crystallized inhibitor of the Acetyl CoA Carboxylase, to spirotetramat as chemical insecticide already used against citrus nematode, and to the other complexes. Molecular Dynamics Simulation study showed a good result for the carvacrol- Acetyl CoA Carboxylase docked complex, for that can consider that carvacrol extracted from *Lavandula multifida's* essential oil as a functional inhibitor of Acetyl CoA Carboxylase activities and it can be used as good Bio-nematicides against *Tylenchulus semipenetrans* for the protection of the human health and environment.

Keywords**:** Nematode, *Tylenchulus semipentrans*, Molecular docking, Bio-nematicides, Lamiaceae, Molecular dynamics simulation

Tylenchulus semipenetrans (citrus root nematode) is a species of plant pathogenic nematodes and the causal agent of slow decline of citrus. This pest causes damage most citrus production areas and diverse soil textures worldwide. Their feeding strategy is semi-endoparasitic and has a very narrow host range among commonly grown crops. These nematodes are considered as major plant-parasitic nematode because they can cause 10-30% losses (Verdejo-Lucas, and Mckenry 2004). The fight against nematodes often involves the use of chemical nematicides such as spirotetramat. The latter presents a danger to ecosystems (Brück et al 2009) and new control strategies are therefore urgently needed. For this, bio-nematicides is option to improve the production and quality of citrus fruits in the world which can be made by certain plant parts and extracts possess nematicidal properties. The application of the plant parts or extracts to nematode infested soil affects nematode directly and stimulates soil microbes that reduce nematode populations (Ahmad et al 2004). The present consists in studying the inhibition of Acetyl CoA carboxylase, the enzyme responsible for the synthesis of fatty acids in *Tylenchulus semipenetrans* and its alteration disrupts the synthesis of the surface layer. This inhibitory action is done by ligands derived from four plants from the Lamiaceae family *Lavandula multifida, L. stoechas, Rosmarinus officinalis,* and *Thymus ciliatus*, to produce a bio-nematicide. The essential oils of these plants, growing spontaneously in Algeria, was isolated from the aerial parts of the plant (leaves and flowers), the major component being carvacrol (57.9%) for *L. multifida* (Laghchimi et al 2014), thymol (44.2%) in *Thymus ciliatus*. (Bousmaha et al 2007), α-pinène is one of the major components in *Rosmarinus officinalis* (19.6%) (Bousmaha et al 2007), and fenchone (68.2%) in *Lavandula stoechas.* (Bouzouita et al 2005). The *in scilico* experiments in order to find the most coherent (Enzyme-Ligand) complex (s) to lead to the best inhibitors of acetyl CoA carboxylase in *Tylenchulus semipenetrans* nematode. The main purpose of molecular docking is to predict the most favorable conformation (position and relative orientation) of the ligand within its receptor.

MATERIAL AND METHODS

Ligands and protein preparation: The active ingredient of essential oils of each plant was considered. The three-dimensional (3D) structures of compounds are downloaded from Pub Chem Project in SDF format (sequentially) from PubChem (www.pubchem.ncbi.nlm.nih.gov) and ligands were drawn from the software "Chemdraw" version

12.0.2.1076; (Fig. 1) and saved in format Mol. These ligands were pre-optimized by means of the Molecular Mechanics Force Field (MM+). Thereafter, the resulted minimized structures were further refined using the semi-empirical AM1 (Stewart 2007) with the Polak-Ribiere conjugate gradient algorithm of 0.01 kcal/(Åmol). All methods are implemented in "Hyperchem" "version 8.0.10 and saved in "Mol" format, for molecular docking with the Molecular Operating Environment" MOE "software 2013.

After that, downloaded Acetyl CoA Carboxylase enzyme with 1BDO code from "RCSB" or "PDB" (Protein Data Bank) (Fig.2) with a resolution of 1.80 A. This is selected for modeling studies; the energy of the proteins structures is minimized using the Energy minimization algorithm of MOE tool. These energies of proteins are calculated by MOE using Amber10: EHT force field with conjugant gradient method.

Molecular docking protocol: The method is based on molecular modeling. Docking basically consists of two steps: molecular docking is the step of the selection which consists of placing the ligand in the active site of the protein and sampling the positions, conformations and orientation (poses) possible to have the most stable complex .and scoring is the ranking step, which consists in evaluating the affinity between the ligand and the protein and giving a score to poses obtained during the docking phase. This score helps us to remember the best pose among all that proposed (Boucherit 2012). Docking calculations were carried out using standard default parameter settings in the MOE software package (Molecular Operating Environment -MOE 2013). In this molecular docking program, the proteins are considered as a rigid structure and the ligands are considered as flexible compounds (Abdelli et al 2020). The best conformations of the ligands were analyzed for their binding interactions and were evaluated by the binding free energies and bonds interactions between ligand atom and active site residues.

Molecular dynamics simulation: The molecular dynamics simulation study was carried out for the ligand that was declared as the best among the selected molecules. The molecular dynamics simulation study was performed by iMODS. It is a fast, user-friendly and effective molecular dynamics simulation tool that can be used efficiently to investigate the structural dynamics of the protein complexes. It provides the values of deformability, B-factor (mobility profiles), eigenvalues, variance, co-varience map and elastic network. For a complex or protein, the deformability depends on the ability to deform at each of its amino acid residues. The eigenvalue has relation with the energy that is required to deform the given structure and the lower the eigenvalue, the easier the deformability of the complex. Moreover, the eigenvalue also represents the motion stiffness of the protein complex. IMODS is a fast and easy server for determining and measuring the protein flexibility (López-Blanco et al 2014, Prabhakar et al 2016, Awan et al 2017).

RESULTS AND DISCUSSION

Molecular docking simulation: The results calculations docking details received after dock all ligands with Acetyl CoA Carboxylase 1BDO target are listed in the Table 1. The molecules that had the lowest binding energy of docking score were considered the best molecule and inhibiting the target receptor as the lower binding energy corresponds to higher binding affinity (Simon et al 2017). The 1BDO-ligands complexes formed are shown in (Figs. 3-8).

The best score obtained after docking is that of Spirotetramat a chemical nematicides with a score of -4.9816

Table 1. Docking (binding energy) of all ligands and the controls along their respective number of hydrogen bonds as well as interacting amino acids

Names of ligands	SP Docking Score (Binding Energy) (Kcal/mol)	Interacting residues of the target	Types of bonds	Distance (Å)	Energies (kcal-mol)
Spirotetramat	-4.9816	/	/	/	/
Biotine	-4.6061	O -ILE 138	H-donor	2.97	-3.8
		N -SER 142	H-accepteur	2.95	-4.7
		NH1-ARG 93	H-accepteur	3.05	-4.7
		N -SER 142	H-accepteur	3.32	-1.2
		NH1-ARG 93	ionic	3.05	-4.1
Carvacrol	-4.2349	OG1-THR94	H-donneur	3.06	-1.2
		6-ring-TYR92	pi-pi	3.80	-0.0
Fenchone	-4.0341	/	/	/	/
Thymol	-4.0278	O1- VAL 140	H-donor	2.86	-1.9
		6-ring- GLU 141	pi-H	3.78	-0.8
α-pinène	-3.2004	/	/	/	/

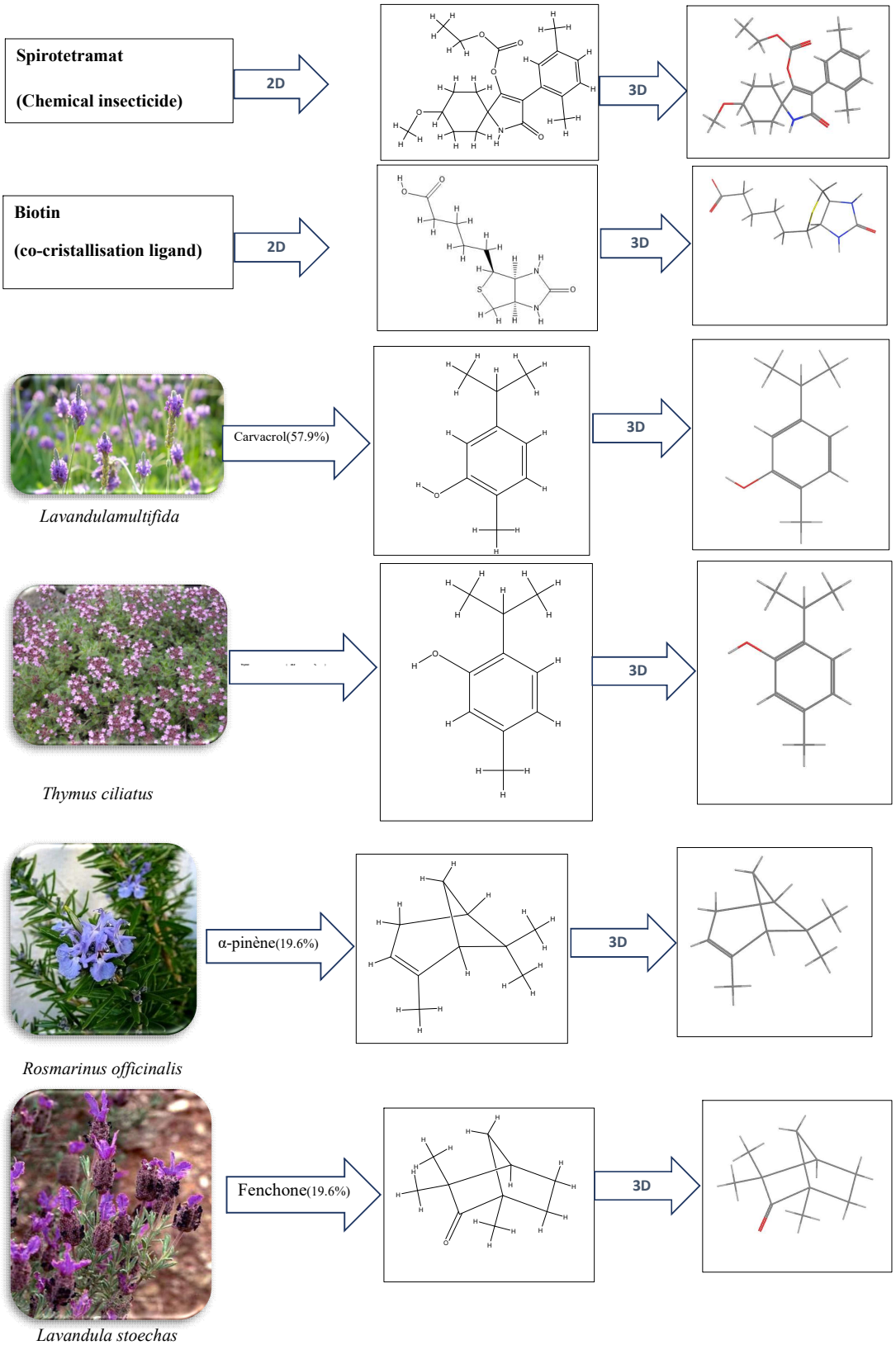


Fig. 1. 2D and 3D representations of the all the ligands used in the experiment. The ligand structures were taken from PubChem server (www.pubchem.ncbi.nlm.nih.gov)

kcal mol, followed by Biotine the reference ligand with a score of -4.6061 kcal mol, the values of the other scores (-4.2349 Kcal mol) of Carvacrol (-4.0341) for Fenchone, (-4.0278 kcal mol) of Thymol, and (-3.2004) for α-pinène. All the values score complexes; found that complex formed by 1BDO-Spirotetramat has the lowest value energy and giving the best docking score compared to Biotine co-crystallized inhibitor, on the other hand, Carvacrol has one hydrogen interaction with OG1-THR94 compared to 1BDO-Spirotetramat complex which has none hydrogen interaction, and it gives almost the same values of the score (-4.2349 Kcal/mol and -4.9816 Kcal/mol respectively) therefore can consider that the two complexes 1BDO- Carvacrol and 1BDO-Spirotetramat are stables with higher binding affinity. On basis of these docking results can classify Carvacrol as the good natural inhibitor of the enzyme 1BDO, compared to a chemical pesticide "Spirotetramat", and to all ligands studied. Molecular dynamics simulation: The Molecular Dynamics Simulation results are showed in the Figure 9.

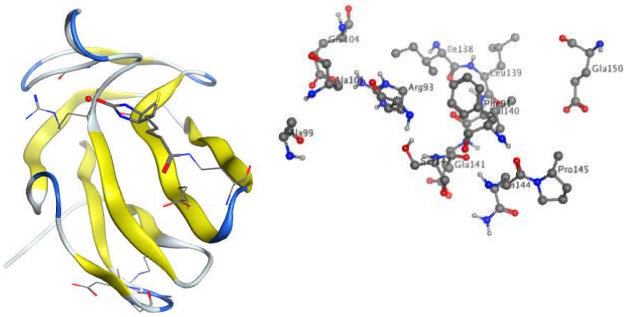


Fig. 2. 1BDO enzyme 3D structure

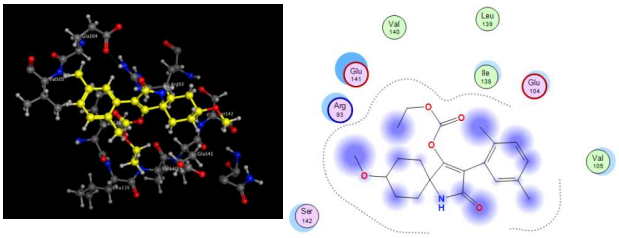


Fig. 3. 1BDO-Spirotetramat complex

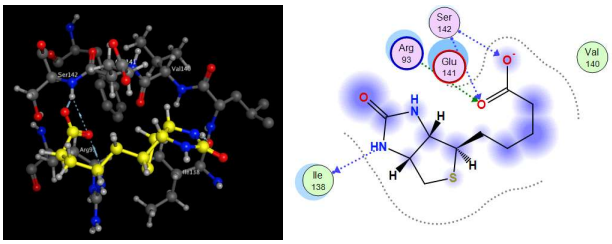


Fig. 4.1BDO-Biotine complex

The normal mode analysis (NMA) of 1BDO- Carvacrol complex is illustrated in Figure 9. A. The deformability graph of the complex indicates the peak, which correspond to the regions in the protein with deformability (Fig. 9B.) The B-factor graph of the complex gives easy visualization and understanding of the comparison between the NMA and the PDB field of the complex (Fig. 9C, D). The docked complex

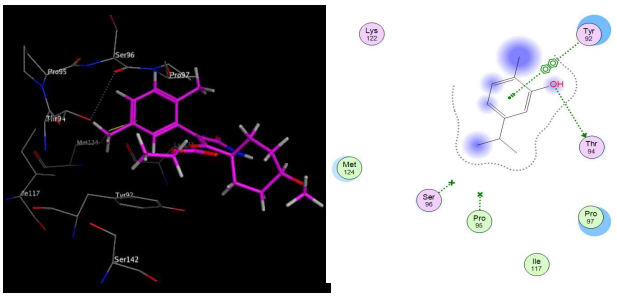


Fig. 5.1BDO-Carvacrol complex

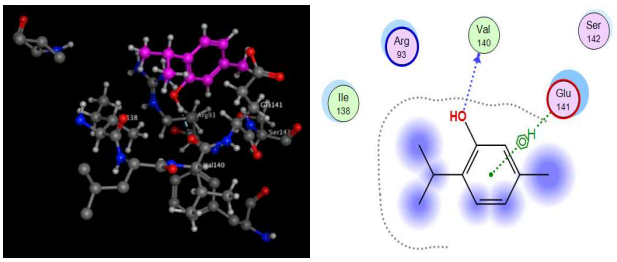


Fig. 6.1BDO-Thymol complex

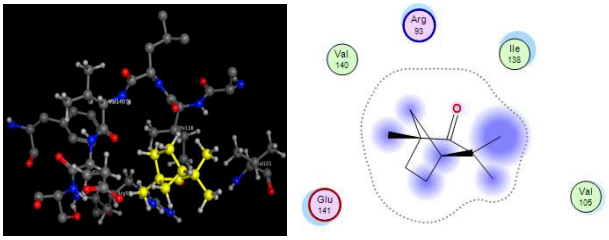


Fig. 7.1BDO- Fenchone complex

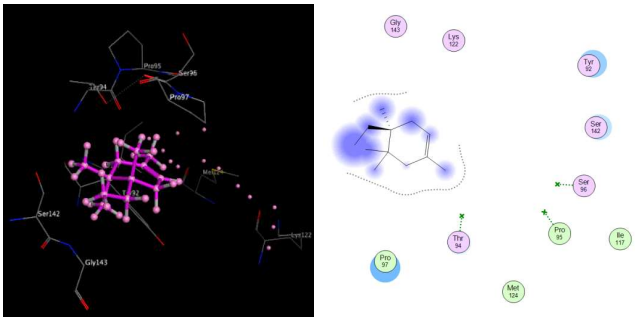


Fig. 8.1BDO- α-pinène complex

generated eigenvalue of 7.385787e-04 (Fig. 9D). The variance graph indicates the individual variance by red colored bars and cumulative variance by green colored bars (Fig. 9E). Figure 9F illustrates the co-variance map of the complexes where the correlated motion between a pair of residues is indicated by red color, uncorrelated motion is indicated by white color and anti-correlated motion is indicated by blue color. The elastic map of the complex shows the connection between the atoms and darker gray regions indicate stiffer regions (Fig. 9G). From the molecular dynamics study of 1BDO- Carvacrol docked complex, it is clear that the complex had a very good amount of deformability (Fig.9B) as well as it had high eigenvalue of 7.385787e-04. Due to this, the deformability would be quite difficult for the complex. However, the variance map showed high degree of cumulative variances than individual variances. The co-variance and elastic network map also produced satisfactory results (Fig. 9F and G).

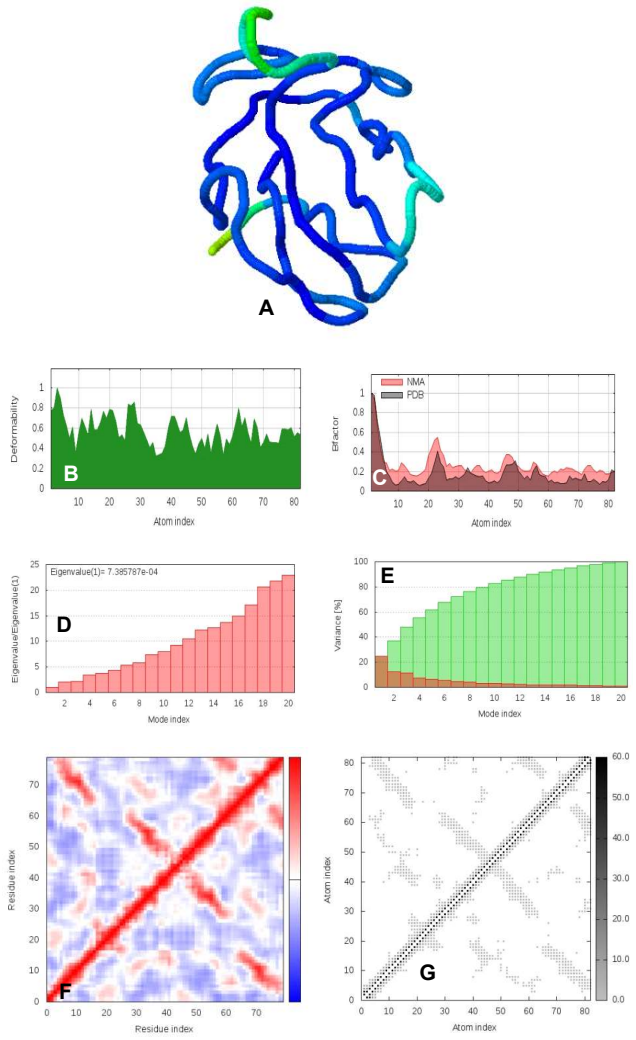


Fig. 9. Results of molecular dynamics simulation of 1BDO-Carvacrol Receptor. (A) NMA mobility, (B) deformability, (C) B-factor, (D) eigenvalues, (E) variance (red color indicates individual variances and green color indicates cumulative variances), (F) co-variance map (correlated (red), uncorrelated (white) or anti-correlated (blue) motions) and (G) elastic network (darker gray regions indicate more stiffer regions) of the complex

CONCLUSION

The aim of our study is to investigate the potent of natural's compounds extracted from lamiaceae family plants as inhibitors for Acetyl CoA Carboxylase target, the enzyme responsible for the synthesis of fatty acids in *Tylenchulus semipenetrans*, its alteration disrupts the synthesis of the surface layer. These compounds are tested *in silico* study for the inhibition to this enzyme. Molecular docking used to study interaction between new compounds “carvacrol” and 1BDO with score energy investigation and Molecular dynamics simulation have been performed to verify *in silico* the properties of this best ligand. The top ligand Carvacrol, which is the major component (57.9%), in *Lavandula multifida* has high binding affinity (score) and one almost stable interaction with 1BDO target. From this *in silico* study that *L. multifida* essential oils components can blocks the receptor of Acetyl CoA Carboxylase and could present a power as a bio-nematicide compared to spirotetramat, a chemical pesticide used against the citrus nematode *T. semipenetrans.*

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Micro-environmental Changes Under Poplar Canopy and Effect on Yield of Inter-cultivated Crops

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Abstract: Tree pruning, an important tending operation in agroforestry, facilitates to minimize the above ground competition. Though tree growth was not much affected by the pruning and topping treatments, but crop yield was significantly influenced by the treatments and so was the meteorological parameters. Cultivation of coriander under different pruning treatments had significant effect on its growth. Maximum plant height, primary branches, secondary branches and yield were observed in 75% pruning with topping. On the other hand, highest umbel and umbellate were found in 75% pruning without topping. Similarly effect on growth of bottle gourd under different pruning treatments was observed. Vine length, fruit weight and fruits per vine were best observed in 50% pruning with topping, but yield was maximum recorded in 75% pruning with topping. These differences were due to the variation in meteorological parameters due to imposition of different treatments.

Keywords: Poplar, Pruning, Topping, Meteorological parameters, Coriander, Bottle guard, Productivity

Indian agriculture is facing numerous challenges and constraints due to rising population pressure, increasing food feed and timber needs, degradation of natural resources, climate change, etc. (Dhyani et al 2013). Necessity of the day seems to be modification of existing farming systems by developing suitable agroforestry models (Dhillon et al 2012). Selection of suitable tree and crop species helps to enhance soil fertility, encourage land sustainability, improve yield and resource use efficiency (Chauhan and Ritu 2005). Intercropping with high density short rotation tree species is the viable alternative to meet growing food and industrial raw material demand through sustainable utilization of natural resources (Sarvade et al 2014). There is growing awareness among farming communities to integrate fast growing multipurpose trees in agroforestry systems to acquire early and good economic returns. *Populus deltoides* is one such tree, which avoid land degradation and obtain biological production on sustainable basis (Chauhan and Mangat 2006, Pandey 2007).

Populus deltoides based agroforestry system is one of the viable alternative land use system to diversify the rice-wheat rotation, avert further degradation and obtain biological production on sustainable basis in the irrigated agro-ecosystem. Replacing the wheat and paddy crop rotation, Poplar (*Populus deltoides*), because of its fast growth, straight growing stem, short rotation, good quality wood production and profitability, has been planted at large scale in north-western states of India-Haryana, Punjab, Uttrakhand and Uttar Pradesh (Chauhan and Mangat 2006). This species has been grown by farmers as boundary or block plantation, which expands the physio-chemical properties of soil through addition of organic matter in the soil and provides alternate sources of income and employment to the rural poor. Intercropping does not have preference only for good income from agriculture crops but it is also rather beneficial to the poplar crop itself. Intercropping is advocated as it offers agricultural returns on the one hand and alongside results in increased growth rate of poplar due to regular irrigation and other intermediately operations of agricultural crops (Chauhan et al 2015).

Generally, trees with the age advancement have a tendency to keep the growth and yield of associated crops in check due to canopy spread and the effect on the important meteorological variables. The complementary effect among these factors is the key for success of an agroforestry system. The modifications in micro-environment due to growing of trees, directly or indirectly affect numerous vital physiological processes of the crop plants raised under tree canopy. This effect is credited to both above and below ground competition (Geiger et al 1994). Shading by poplar canopies decrease crop growth roughly in direct proportion to the reduction in absorbed radiations (Fischer 1985). The tree shade lessens the wind velocity as well as soil temperature and results in reduced evapo-transpiration in the shaded crop (Dhillon et al 2007, 2010, Basavaraju and Rao 2000). To regulate the shade in agroforestry system at optimum level,

trees are normally pruned during the cropping period to avert the competition for light. Pruning is a silvicultural practice comprising the careful removal of parts of a plant, such as buds, branches, or roots. Pruning branches in agroforestry involve giving shape to trees and canopy keep growth under control, make better or maintaining health, improve light availability to inter-cultivated crop, and regulate favourable meteorological parameters for crop growth and yield.

Pruning is essential to make better stem form, superior quality timber and to put maximum wood in the main stem. The main objective of pruning is to produce maximum clear timber free from knots. Excessive pruning, not only reduces height and diameter growth, but also stimulates the continued resprouting of epicormic shoots, which may deteriorate the quality of timber wood. The poplar tree canopy moderates the microclimate and influences the physiological processes of understorey crops. With the increase in tree canopy spread with advancement in age, the photosynthetic active radiations (PAR) and temperatures drop-off, while humidity under the canopy rises up as compared to open conditions. PAR influences the tree-crop growth and yield (Baig and Gill 2005). To minimize resource competition and improve physiological processes of crops, such as turmeric, colocasia, zinger, etc., canopy management ensures better yield under poplar-based agri-silvicultural system.

The poplar generally shows terminal dominance and topping of leading shoots expectedly may support diameter growth but it may also lead to excessive branching. Therefore, canopy management is necessary to meet the light requirement of inter-cultivated crops, geometry of planting is one aspect to optimize the limiting resources but canopy management is another strategy to meet light requirement of the crop. It is critical to examine the effect of pruning regime on the growth of poplar stem and its influence on micro-climatic changes reflecting on the ultimate inter-cultivated crops.

MATERIAL AND METHODS

The present investigation was carried out at the University Seed Farm, Ladhowal, PAU, Ludhiana. The site is located at an altitude of 731 ft above mean sea level and lies at 30° 58" latitude and 75° 45" longitude, which represents the central agro-climatic zone of the Punjab. Experimental site is only 1.5 km away from Sutlej River bed. In general, the climate is sub-tropical with a long duration dry spell from October to mid-June and wet season from end of the June to mid-September. May and June are the hottest months with intensive evapo-transpiration losses, whereas, December and January are the coldest months. The area receives an average rainfall of 732 mm per annum and 75 per cent of total amount of rainfall is expected during July to September with an average of 37 rainy days. It is characterized by hot and dry early summers, which are followed by a hot and humid monsoon period and cold winters. Mean minimum and maximum temperatures exhibit significant fluctuations during summer and winter months. Topography of the study area is plain with characterized inceptisol soils (USDA classification). The soils are deep, well drained, sandy loam in texture with low humus content and soil pH value of 8.0. Crops are irrigated through shallow tube well. Study was conducted in four year old poplar trees of PL5 clone (G48) maintained at a spacing of 6m x 3m with two inter-cultivated crops i.e., Bottle guard var. – Punjab Komal during kharif season and Corriander var. – Punjab sugand during rabi season. Poplar trees were pruned and topped to facilitate insolation for inter-cultivated crop and redistribute photosynthates in favour of diameter instead of tree height and spreading canopy. Trees were pruned with intensity of 50% of the stem; 75% of the stem and lateral pruning (1.5m on both sides) and topped at 2m from top (cut the terminal shoot) and without topping as control (Table 1).

Twelve randomly selected trees from each replication were measured with the help of a Tangent height gauge and caliper for height in meters and diameter in cm, respectively. Canopy spread was measured along two perpendicular directions and standing biomass was calculated by using the regression equations developed by Sharma et al (2007). Meteorological parameters like light intensity, air temperature and humidity were measured at 2.30PM at fortnightly interval. Economically and biologically important crop parameters were measured at the time of harvesting. The data generated were statistical analysed by using OPSTAT software developed by the Department of Mathematics and Statistics, CCS HAU, Hisar in Completely Randomized Design with three replications.

RESULTS AND DISCUSSION

Tree parameters: Tree growth is an irreversible increase in size and shape of the tree and is influenced by the genetic composition of the tree species as well as the environmental factors viz. relative humidity, temperature, light intensity, PAR, management, soil properties, etc. The data for the height of the poplar trees were recorded at the start and at the end of the experiment, which revealed no significant differences for different treatments on tree height and clear bole length. However, significant differences in diameter were noticed among different treatments. The highest DBH growth was recorded in 50% pruned trees with topping (40.98 cm at the start of experiment and 44.77cm after one year).

The site seems quite favourable for poplar growth, DHB recorded was much higher than recorded by Chauhan et al (2012). Mishra et al (2006) also observed 3.92 to 41 per cent rise in DBH when poplar was intercropped with soybean. Verma et al (2013) reported that poplar had better performance of all growth factors (DBH, height and crown spread) of varied poplar clones underneath agroforestry plantation than in sole plantation.

The canopy spread, which regulates the different meteorological parameters like PAR, humidity, temperature, etc. for under-storey crops varied significantly and values ranged from 16.29 m^2 in lateral pruning with topping to 26.17 m^2 in 50% pruned trees with topping at the start of the experiment (among pruning treatments but significant less than unpruned treatments) and 18.90 m^2 in lateral pruning without topping to in 50% pruning with topping during 2016 (27.05 m^2). The response was obvious as the branches were lateral pruned in some treatments. The maximum canopy spread was observed with topping treatments, because topping resist the terminal growth of the trees and also sprouting of new buds initiate from the cut shoots, thus forcing the growth of lateral branches. Prevasto and Sekawin (1979) observed good reaction of cultural and agronomical practices like fertilization, irrigation, weeding, etc. applied to the inter-cultivated agricultural crop on poplar trees. The influence of microclimate modifications by trees in terms of reduced evapotranspiration rates and lower soil temperature also help in enhancing faunal diversity like earthworms, which may also boost tree growth (Price and Gordon 1999).

Rabi crop yield-Coriander: The crop growth parameter performance improved with 75% pruning coupled with topping at variable times of recording. Minimum values were recorded with 50% pruning without topping (Table 2). Wadud et al (2002) studied that, reduction in in photosynthetically active radiation influence all morphological and yield parameters of crop negatively. Plant height, number of leaves per plant, fresh yield, stem girth, leaf size, and dry yield reduced significantly with falling in light levels but the trend of response of various morphological parameters to different light levels were distinct. On the other hand, Belsky (1994) reported that improved microclimate, greater soil biotic activity and nitrogen mineralization, improved infiltration rate, etc. are crucial in increasing growth than light only. Sharma and Chauhan (2003) also recorded lower plant

Table 1. Different observation of poplar tree growth for one year

Treatment	Height (m)	Bole height (m)	DBH (cm)	Crown spread (m^2)
No pruning with topping	1.13	0.44	3.94	11.05
No pruning without topping	1.20	0.46	3.94	10.21
50% pruning with topping	0.91	0.38	4.03	0.88
50% pruning without topping	0.77	0.36	3.32	0.87
75% pruning with topping	1.17	0.51	3.79	1.01
75% pruning without topping	0.73	0.54	3.64	0.86
Lateral pruning with topping	1.70	0.44	3.86	2.82
Lateral pruning without topping	0.30	0.38	4.00	4.56
LSD (p=<0.05)	NS	NS	0.37	0.91

Table 2. Performances of coriander crop under different treatments

Treatment	Height after 50 days	Height after 80 days	Height after 110 days	Primary branches $plant^{-1}$	Secondary branches $plant^{-1}$	Umbel $plant^{-1}$	Umbellate	Test weight	Seed yield (q ha^{-1})
50% pruning with topping-	11.20	22.30	63.96	5.94	16.59	33.16	6.47	7.46	5.42
50% pruning without topping	9.23	21.20	58.30	5.52	15.36	28.74	5.82	7.39	4.98
75% pruning with topping	11.40	25.76	67.06	6.36	18.64	34.31	7.27	7.05	5.61
75% pruning without topping	10.13	25.13	64.66	5.98	17.53	33.15	6.70	7.24	5.23
Lateral pruning with topping	11.03	25.20	65.33	6.11	17.57	34.70	7.00	7.27	5.36
Lateral pruning without topping	9.56	22.76	59.36	5.76	15.81	30.18	6.20	7.13	5.02
Open	13.10	31.26	91.70	7.44	21.50	40.62	7.63	9.09	7.77
LSD (*P*=<0.05)	0.67	1.26	4.18	0.76	2.42	3.56	NS	0.33	0.66

height in inter-cultivated soybean crop.

The measurement of seed yield of crop was recorded after harvesting by randomly selecting plot size of 2x2 m in different treatments. The recorded parameters for yield were significant (Table 2). The seed yield was recorded highest (5.61 q ha^{-1}) under 75% pruned trees with topping, it was statistically at par with other yield values of different treatments, and lowest (4.98 q ha^{-1}) under 50% pruned trees without topping. There was maximum reduction of 35% in seed yield than open condition.

It was found that the crop productivity reduced significantly when intercropped with poplar tree than the yield acquired from open control fields. Chauhan et al (2010, 2011) also observed decline in crop productivity underneath poplar understorey than crop grown under control condition. Mishra et al (2004) reported that root biomass, shoot biomass, and nodules were more in pure soybean grown plot (control) than under tree canopy. Grain yield was the maximum in pure crop (14.5 q ha^{-1}) and reduced from 2.06 to 33.1% beneath different poplar clones. Light is a vital factor affecting crop photosynthesis, development, growth and productivity. Shade restricts the biological productivity in plant, although the extent of the restriction shows discrepancies with shade tolerance of the species. The reduction in yield per plot was generally due to the shadowing effect caused by trees. Usually, when soil nutrients, water and temperature are not restraining, crop growth and yields is dependent on the solar radiation, intercepted during growing season (Bellow and Nair 2003). Simpson (1999) also pointed out for the competition of light and not water was major factor, which destructively affected soybean and corn crop productivity and suggested tree pruning to reduce shading. Bhat (2015) recorded reduction of 45-50 per cent in capsicum but 70-74% in tomato, however reduction was almost negligible in winter crop. Chauhan et al (2013) also reported reduction in moong crop with increase in canopy cover.

Bottle gourd: The growth parameters recorded significant differences under different canopy management treatments. The marketable fruit weight was recorded, which is an appropriate stage for fruit harvesting. The recorded parameter had been significantly influenced by different treatments. The highest fruit weight of 473.95 gm was recorded in 50% pruning with topping treatment, it was also statistically at par with other values. Lowest fruit weight of 396.18 gm was recorded in 50% pruning without topping (Table 3). The total yield of fruits was recorded from first harvesting of fruit to final harvesting. It had significant effect due to different imposed tree treatments of pruning and topping. The highest fruit weight were recorded 269.41 q ha^{-1} in 75% pruning with topping treatment, which was statistically at par with the value of 259.41 at 75% pruning without topping. Lowest yield of 227.37 q ha^{-1} was recorded with 50% pruning without topping (47% reduction than control). Bhat (2015) also recorded 45 -50 per cent reduction in capsicum. The rate of decrease is directly related with canopy structure, which depends upon the intensity of pruning (Chauhan et al 2010) and also regulates the microclimate underneath the tree canopy (Chauhan et al 2013). Bijalwan (2012) also recorded lower biological yield of agricultural crop under agri-horticulture system in comparison to agricultural crop raised in open.

Meteorological Parameters

Temperature: Maximum and minimum temperatures were recorded at fortnight intervals. The parameters were recorded twice a day, first at 7.00 AM for minimum temperature and another one for maximum temperature at 02:30 PM. The highest maximum and minimum temperature throughout entire interval period of coriander and bottle gourd crop were founded in open condition, but within canopy treatments, it was recorded in different treatments throughout the year.

Relative humidity: RH (%) recorded at fortnight interval 02:30 PM with the uses of hygrometer had significant level of interactions among the different treatments. The lowest

Table 3. Performances of bottle gourd crop under different treatments

Treatment	Vine length (m)	Branches $vine^{-1}$	Days after first flowering	Fruits $vine^{-1}$	Fruit weight (gm)	Days after first fruit harvest	Marketable yield (q ha^{-1})
50% pruning with topping	4.71	5.64	46.71	4.05	473.95	69.58	236.83
50% pruning without topping	4.18	5.13	48.03	3.75	396.18	71.43	227.37
75% pruning with topping	4.67	6.13	44.85	4.32	457.18	69.23	269.41
75% pruning without topping	4.41	5.66	46.16	3.86	407.97	73.63	259.71
Lateral pruning with topping	4.40	5.88	48.05	3.92	431.97	69.87	235.96
Lateral pruning without topping	4.45	4.92	45.79	3.84	416.30	72.57	230.26
Open	5.22	6.85	39.92	5.56	611.67	61.51	432.75
LSD (*P*=<0.05)	0.58	NS	NS	0.99	77.65	NS	17.52

relative humidity was recorded in open treatment at fortnight interval and the highest relative humidity was recorded in different treatments at fortnight interval. However, no specific pattern was evident in values among different canopy treatments.

Light intensity: Light intensity was significantly effected due to different canopy management treatments. It was recorded highest in open condition, however within treatments no specific pattern was observed and highest values were recorded in different treatments and lowest among different treatments. Light intensify is governed by the canopy structure, which becomes a limiting factor for the inter-cultivated crops. Chauhan et al (2013) reported that it is essential to promote light conditions under canopy through managing geometry of plantations, exerting judicious pruning treatments, identification of suitable crops and their specific varieties to maximizing crop yield.

Leaf area index: The leaf area index (LAI) is a dimensionless quantity that characterizes plant canopies. Nature of a poplar tree is deciduous, it sheds it's leaves during winter to survive physiologically from harsh cold condition and new leaves emergence takes place just before beginning of summer season. Thus, highest leaf area index recorded in summer season was much higher than recorded during winter season. The parameter was recorded with the help of plant canopy analyser. The recorded parameter had non-significant interaction effect among different treatments for poplar trees on coriander crop except one day of fortnight interval, on that day (10 February 2016) highest LAI has recorded (1.28) in no pruning without topping and lowest (0.95) in lateral pruning with topping. All recorded values of poplar trees LAI during bottle gourd crop also had non-significant interaction effect among different treatments.

CONCLUSION

Coriander and bottle guard crop under poplar trees with 75% pruning and coupled with topping recorded best results for crop productivity among other different pruning treatments. Meteorological parameters were also modified under different tree pruning treatments, best results were obtained with light canopy (75% pruning). The relationship of canopy spread with diameter increment was though positive but very weak to exert significant influence on diameter.

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Invasive Alien Species Yellow Crazy Ant- Hemipterans Mutualism and Assessment of Unicoloniality

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Abstract: The present study dealt with the report of the mutualistic relationship between the yellow crazy ants *Anoplolepis gracilipes* and three groups of the order Hemiptera: plant hopper *Leptocentrus taurus* Fabricius, 1775 of the family Membracidae, scale insects *Lecanium* sp. of the family Coccoidea, and mealybugs *Phenacoccus* sp. of the family Pseudococcidae. These hemipteran bugs are providing honeydew as a source of carbohydrate to the yellow crazy ant, which is essential for the growth and development of the ant population. In return, the crazy ants are protecting these insects from predators like ant-mimicking spiders *Myrmarachne* sp. and garden lizards *Calotes versicolor* (Daudin, 1802). This mutualistic ecological interaction may be one of the causes of the success of invasiveness of the yellow crazy in Ganjam, Odisha. In this invaded area unicoloniality of the ant nets have been noticed, which is adding to the adaptive advantage of this invasive species.

Keywords: Ecological interaction, Polydomy, Polygynous, Supercolony

The proliferation of invasive species and their impact on the native ecology have been of great concern for the sustainability of the ecosystem (Bishal et al 2019, Linders et al 2019). Invasive species are moving from one geographical region to another by commercial or general transportation and are now able to cross the geographical borders across the globe (Ascensão and Capinha 2017). One such invasive species is the yellow crazy ants, which is listed as one of the world's 100 worst invasive alien species by the International Union for Conservation of Nature (IUCN). Its invasiveness and negative impact have been well documented from many parts of the globe including India (Sinu et al 2017, Seth et al 2019). Recently, the invasiveness of this yellow crazy ant has been noticed in the 32-37 hectare area of the coastal district of Ganjam, Odisha (19°17' 49.50'' N, 84°52' 58'' E) and its negative impact on the other ants and small crawling invertebrates species have been documented (Seth et al 2019). The route of their migration, how many super colonies they have established, the nature of these colonies, their biology, and the exact reasons for the success of their invasiveness in the said area have to be carried out, in order to develop control strategies to stop their invasiveness further. One reason for the adaptive advantage of the yellow crazy ant is the reproductive and 'trophic egg chefs' potential of the 'physogastric' workers (Lee et al 2017). These invasive ants can adapt to a nonnative environment as they are very opportunistic in terms of their food preference and requirement (Pontieri et al 2014). In this identified invaded area, the number of several plant-feeding hemipterans is also high. So this correlation, push us to dig further to know about the kind of interaction the yellow crazy ant and hemipterans are sharing. Unicoloniality is usually associated with the extreme form of polydomy and polygynous. In uniclonial ants: workers ants don't show any aggression, there is free movement of individuals from one nest to another, and individuals present at a distant part of the nest are tolerable to each other. Further, the energy which may be lost in territorial fighting is being utilized for the common good. These polydomy and polygynuos traits enable the ant population to expand indefinitely and can grow over a large geographical range forming supercolonies (Debout et al 2007, Helantera et al 2009, Moffet 2012). Therefore, the work also focused on the worker's aggressive behavior in order to assess the unicoloniality as well.

MATERIAL AND METHODS

In the invasive area, field studies were carried out at the rate of 7 days per month in pre and post-monsoon during 2018-19. During monsoon, it was very difficult to employ the field studies as ants were hiding under the leaf litter during rain. The foraging behavior of crazy ants was observed three times per day: one hour during the morning, one hour during noon, and one hour during the afternoon. The ant trails were followed till the canopy of the trees and small plants. The behavior for food uptake and interaction with other animals were observed using a magnifying glass. Overall

methodologies for the mentioned observation were as per Steiner et al (2004). Hemipeterans insects were identified up to the species level in the case of plant hopper, and up to genus level in the case of scale insects and mealybugs using the features as described by Ananthasubramanian (1996) and Varshney et al (2015). For the assessment of the number of supercolonies and their unicoloniality, sampling of ants was carried out from six different sites/nests (A-F), which are approximately 100 meters distant from each other and there were no distinct boundaries in between the sites (Figure 1). The ants from each site/nest were collected by an aspirator and individuals of different nests were kept in separate plastic containers. The containers were provided with nesting materials like layers of soil and strips of cut papers and to maintain humidity, water was sprayed regularly. Everyday ants were fed with sugar syrup as food. Each container was marked by its GPS coordinates from where the individual ants were collected. A clear plastic container of size 15 cm length X 15cm width X 13cm height was used to study the worker aggression between different colonies. Underneath the plastic container, white paper was kept for better visibility. Ants from the separate nest were taken in 5:2 ratios and were introduced in a matrix pattern, where ants from each nest could interact with every nest. Each interaction was observed for 15 minutes. The study area and the sites are presented in figure 1. Positive (+) and negative (-) symbols are used for tolerance and intolerance of the worker ants behavior respectively. The overall methodologies for the worker aggression behavior were as per Lim et al (2003).

RESULTS AND DISCUSSION

The yellow crazy ants usually surround in a cluster around plant hopper (both nymphs and adults) of the species *L. taurus* Fabricius, 1775 belonging to the family Membracidae. The plant hoppers did not show any escape response to the yellow crazy ants and attach firmly to the tree bark. The ants which are predators of a variety of insects were not harming the plant hoppers. The crazy ants did not milk the plant hoppers but used to wait until the drop of honeydew oozes out and then quickly gulped it. This honeydew is very important for crazy ants, as it is used as a source of energy for larval growth and providing fuel for the worker foraging activities. It was observed that the ants carrying the plant hoppers from one to another location of the tree (Fig. 2C) and also rendered protection to the plant hopper from the other predators like ant-mimicking spiders *Myrmarachne* sp. and garden lizards *C. versicolor.* In this study area, scale insects and mealybugs were also found in large numbers along with yellow crazy ants. The scale insects *Lecanium* sp. of the family Coccoidea, and mealybugs *Phenacoccus* sp. of the family Pseudococcidae secrete a sugary substance to form the protective shield. The yellow crazy ants licked that shield to obtain carbohydrates and protect the ants from predators as it rendered to the plant hopper. This relationship shared between yellow crazy ants and plant hopper, scale insects, and mealybugs respectively clearly indicate mutualistic behavior (Fig. 2).

The workers collected from six different sites/nets were tolerable to each other and not showing any aggressive

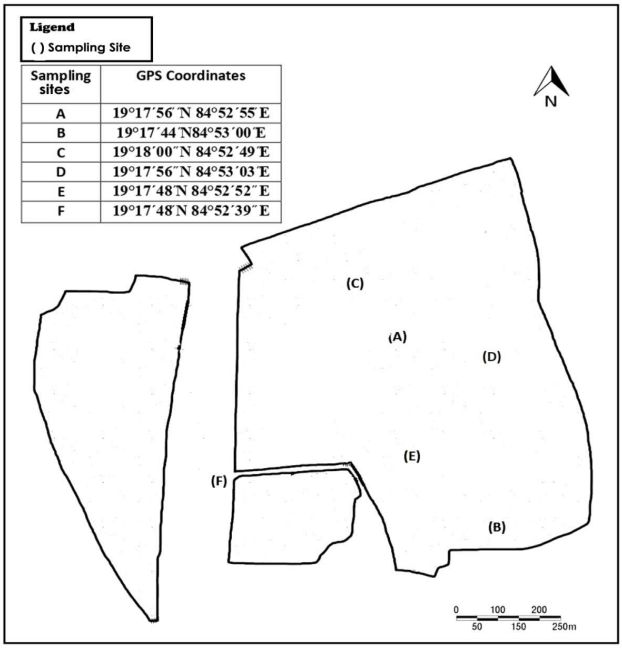


Fig. 1. Study area

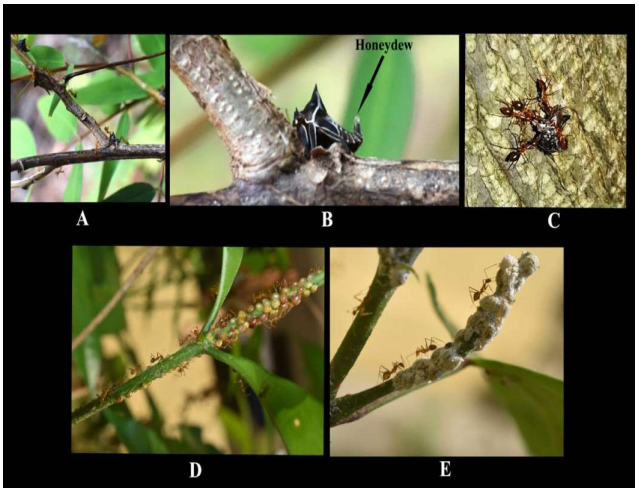


Fig. 2. Mutualism between yellow crazy ant and hemipterans **A**: with Plant hopper *Leptocentrus taurus*, **B**: *Leptocentrus taurus* releasing honeydew, **C**: Yellow crazy ants carrying *Leptocentrus taurus* from one place to other, **D**: *Lecanium* sp., **E**: *Phenacoccus sp*

Table 1. Worker's aggressive behaviour between the ants sampled from different sites (A-F) in the study area

Sampling sites	A	B	C	D	E	F
A		+	+	+	+	+
B	+		+	+	+	+
C	+	+		+	+	+
D	+	+	+		+	+
E	+	+	+	+		+
F	+	+	+	+	+	

behavior even towards the workers, which were separated by quite far from each other (Table 1). This non-aggressive behavior of the workers clearly shows that the ants in this invaded area are forming a single supercolony and the colony is unicolonial.

CONCLUSIONS

The yellow crazy ant shared a mutualistic relationship with the hemipterans insects viz., plant hopper, scale insects and mealybugs in the invaded area. Worker aggression behavior studies show that in the invaded area there is a single supercolony and it is unicolonial. The mutualistic behavior of the yellow crazy ant with hemipterans is one of the causes of the success of invasiveness of this ant in the study area. This mutualistic relationship is providing benefit to both the participants; however, it may have a negative impact on native ecology in the future. Due to the increase in the number of ants, plants are getting protected from other herbivores insects, but the increase in the number of hemipterans may have a negative impact on the plant's growth, development, and overall yield as well. The unicolonility trait of the ant colonies helping the ant to expand its territory, which intern will have a drastic negative impact on the mentioned area and its surrounding ecology in the long run, if not controlled.

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Quantitative Assessment of Anthophilous Insects Associated with Medicinally Important Weed Plants of Genus *Cirsium*

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Abstract: The act of pollination is the most significant plant phenomenon that allows for sexual reproduction. Medicinal plants are particularly useful and insects play a large part in the pollination process. It is therefore essential to analyse insect pollinators associated with medicinally important plants. The species of genus *Cirsium* is a weed plant with some very important medicinal properties. This study aimed to document updated information about the quantitative bio-spectrum of insect pollinators associated with the three species of genus *Cirsium* (C. *arvense*, *C. verutum* and *C. vulgare*). These plants were visited by 41 species of insects belonging to four orders i.e. Lepidoptera, Hymenoptera, Diptera and Coleoptera. In terms of total number of species, *Apis cerana* showed maximum abundance, whereas *Eurema brigitta rubella* showed minimum abundance. The diversity of insect visitors was higher in the morning session as compared to afternoon session.

Keywords**:** *Cirsium*, Insects, Plants, Pollinator, Species

Vegetation is the most valuable gift given to us by nature and meets all kinds of basic human requirements in the form of fruit, fodder, wood, medicine, timber, resins, oil etc. (Gaur 1999). Flowering plants depend on pollen vectors that include, wind, insects, and birds to transport their pollen (Mandela et al 2018). Plant- insect pollinator network are largely mutualistic networks, providing benefits for both plants and insects (Waser and Ollerton 2006). The flowering plants are mainly pollinated by insects, which belongs to Order Hymenoptera, Lepidoptera, Diptera, Coleoptera and Thysanoptera (Wilson 1999). Insect pollinators diversity and pollination ecology of various medicinally important plants has been discussed ambiguously across the different parts of the globe (Wadhwa and Sihag 2012, Duara and Kalita 2013, Rollin et al 2016, Kapkoti et al 2016, Jugran et al 2019). The genus *Cirsium* (thistle), which belongs to the family Asteraceae, is widely distributed worldwide. Around 200 species of *Cirsium* are distributed in Europe, Asia, North Africa, and North and Central America (Mabberley 2008). The purpose of selection of genus *Cirsium* for this analysis is to attract a variety of orders of generalist insect pollinators and flower-feeding insects due to their flower heads (Proctor et al 1996, Thesis et al 2007). *Cirsium* species are sometimes viewed in agriculture as invasive weeds to which immense means of control are deployed. On the other hand, some countries, such as Turkey, regard some *Cirsium* species as edible plants (Khramova et al 2007, Vizgirdas and Rey-Vizgirdas 2009). Not every weed is unwanted, dangerous plant. Some weeds have economic values such as medicinal products, nutrition, industry and forages. Therefore, the elimination of weeds from crop fields due to their role in nutrient cycling is not always helpful. A broad variety of literature emphasizes nutrition between plants and weeds. A variety of literature on the medical use of weeds is available (Cunningham 2001, Dhanam and Elayraj 2014). Flavonoids, phenolic acids, lignans, sesquiterpenoids, triterpenoids, sterols, alkaloids, acetylenes, polyacetylenes, hydrocarbons and a few other natural products are included in the *Cirsium* species (Jordon-Thaden and Louda 2003). The principal secondary metabolites of *Cirsium* species are flavonoids and their glycosides. (He et al 2014). Compounds isolated from *Cirsium* species and extracts have a broad variety of biological functions, including antimicrobial, antioxidant, antidiabetic, anti-inflammatory, vasorelaxant, astringent, hepatoprotective and anticancer activities (Demirtas et al 2016).

Different species of Genus *Cirsium* plants harbour immense medicinal values. In comparison, *Cirsium vulgare* (Savi) Ten. is used against inflammation, urinary and digestion problem (Ahmed 2016). Similarly, *C. arvense* (L.) Scop. is used as remedy for toothache, diuretic, astringent, antiphlogistic and hepatic (Coffey 1993) while, *Cirsium verutum* (D. Don) Sprengel roots are used in cuts and its roots are also mixed with the paste of raw root of *Cirsium falconeri* Hook. f. and *Onopordum acanthium* L. to treat

arthritis (Bisht et al 2006 , Chakraborty et al 2017). Therefore, it is an important plant for medicinal purpose and for the conservation of pollinator insects also. The plant population play vital role in biodiversity conservation. Habitat destruction, exotic species invasions, deforestation, over-harvesting, land use changes leads 1-10 per cent per decade of massive loss of biodiversity including pollinators (Bjerknes 2007, Aguilar et al 2008). The reduction in the diversity of wild bees has been closely associated with the drop-in wildflowers (Biesmeijer et al 2006, Bretagnolle and Gaba 2015). In order to provide medical knowledge of weeds, conventional knowledge, practices and identification of medically significant weeds should be studied and their full use should be made, which complements the weed control system in cropland (Dani and Tiwari 2018).

MATERIAL AND METHODS

Study area: The ranges of the three *Cirsium* species do not overlap and the species were analysed on the basis of their abundance in selected study sites within a botanical garden and two protected forests. *C. arvense* was studied at Himalayan Botanical Garden located 5 km away from Nainital (29°23'N Latitude and 79°26'E Longitude). The site has a mixed community of native and exotic invasive plants in mixed dense oak (*Quercus leucotriphora*) and Himalayan cypress (*Cupressus torulosa*) forest. *C. verutum* was studied at Naina Devi Himalayan Bird Conservation Reserve located in Nainital (29°24'N Latitude and 79°28'E Longitude). The site has a mixed community of native and exotic invasive plants in dense oak forest (*Quercus leucotriphora* and *Quercus floribunda*). *C. vulgare* at the Binsar Wildlife Sanctuary located in Almora (29°44'N Latitude and 79°49'E Longitude) was exmined. The field site is a shady understory within a mixed loblolly pine and oak forest, which is burned regularly by the management of the research preserve.

Description of selected plant species of genus *Cirsium*: The plant species of genus *Cirsium* (*C. vulgare, C. arvense and C. verutum*) are perennial herbs. Inflorescence originates from the axillary clusters (Table 1). *C. vulgare* is commonly known as Bull thistle. This herb is native to Europe, Western Asia and Northern Africa (Forcella and Randall 1994). *C. arvense* is commonly known as Canada thistle. This herb is native to Europe, Asia, and North Africa (Moore 1975). *C. verutum* (D. Don) Sprengel is commonly known 'Biskandara' or 'Kandaru' in Uttarakhand or thistle. It is distributed throughout subtropical, temperate, subalpine and middle Himalaya region of India. Some species are also distributed in Afghanistan, Bhutan, Myanmar and Nepal Himalaya (Suyal et al 2010, Sharma et al 2013).

Population density: Data was collected during flowering months of selected species of genus *Cirsium*, from twenty randomly selected plants of same species spacing at approx. 20 m distance from each other in patches. Only few were placed in isolation in selected study sites. The total selected plants i.e. twenty plants of each species were visited in an hour at an interval of five min. for each plant, once in a week on sunny days due to high activity of insect pollinators. The individuals of insect's visual counts were made for two minutes in each selected plant and were repeated during each sampling hour of the day.

Survey and identification of insect pollinators: Observation of insect pollinators (direct sighting) were carried out in selected species of *Cirsium* from the study sites, between 7:00 hours to 17:00 hours during the blooming months, when the *Cirsium* plants were in full bloom. Sampling of insect pollinators was observed by scan sampling method (Ratti and Garton 1996). The collected samples of insect pollinators were then confirmed by the literature available (indirect sighting). The identification of sampled insects was done with the help of literature and

Table 1. General characteristic features of selected species of genus *Cirsium*

General characteristic	*Cirsium vulgare*	*Cirsium arvense*	*Cirsium verutum*
English name	Bull thistle	Canada thistle	Thistle
Distribution (in study area)	2300-2400 m	1900-2000m	2100-2200 m
Plant height	Up to 210 cm	Up to 250 cm	Up to 200 cm
Leaves length	7-31 cm	6-20 cm	10-25 cm
Leaves shape	Lanceolate	Oblong-lanceolate	ovate-lanceolate
Flower type	Hermaphrodite	Hermaphrodite	Hermaphrodite
Flower colour	Purple	Pink	Pink
Flowering position	Axillary	Axillary	Axillary
Flowering month	June- September	July-September	April-June

different insect guides available in the Department of Zoology, D.S.B. Campus, Kumaun University, Nainital. The insect specimens which could not get identified in the laboratory were identified by scientists in Entomological Section, Forest Research Institute, Dehradun and Northern Regional Station, Zoological Survey of India, Dehradun, India.

Statistical analysis: Measures of different diversity indices *viz.* Shannon-Weiner index, Margalef index and Evenness were calculated by using the program PAST version 3.04 (Hammer et al 2014). The data are presented as an annotated list which is divided into three parts: (1) Species composition of anthophilous insects, (2) Flower-Insect interaction during blooming months of selected plant species of genus *Cirsium* and (3) Diversity and density of anthophilous insects across the plant species.

RESULTS and DISCUSSION

Species composition of anthophilous insects: Insect visitation studies showed that genus *Cirsium* flowers were visited by 41 species including 1184 number of individuals belonging to 4 orders and 12 families of class Insecta. Of these, 27 species belonged to Lepidoptera, 10 species belong to Hymenoptera, Diptera constituted 3 species and Coleoptera included only one species. It has been observed that Lepidoptera was represented by 5 families *viz,* Nymphalidae, Pieridae, Lycaenidae, Hesperiidae and Papilionoidae. Of the Hymenoptera, Apidae was the most dominant family followed by Sphecidae, Vespidae, Halictidae and Megachilidae which constituted only one species. Diptera represented only one family i.e. Syphridae that included three species *Eristalis tenax*, *E. cerealis* and *E. taeniops*. In addition, a single species of *Coccinella septempunctata* belonging to Order Coleoptera was represented by one family i.e. Coccinellidae (Tables 2, 3). Out of 41 species of insects, 37 species (Order: Lepidoptera and Hymenoptera) act as pollinators which depended on nectar resource. Whereas, 4 species act as flower visitors, which belonged to Order Diptera and Coleoptera, respectively (Table 2). The different species of insects associated with the three species of genus *Cirsium* (*C. arvense, C. vulgare* and *C. verutum*) reported from study area during the study period (Fig. 1).

Among the three selected species of genus *Cirsium, C. vulgare* accounts a maximum number of insect pollinators with 37 species followed by *C. verutum* with 35 species and *C. arvense* with 32 Species. 30 species of insects were found to be present on all three species of *Cirsium.* Six species of insects were found specifically visiting the flowers of *C. vulgare*. Similarly, two species of insect pollinators were specific to *C. verutum*. *C. verutum* shared two species of insect pollinator species of *C. arvense* and one species with *C. vulgare* (Fig. 2).

Relative abundance of anthophilous insects: Species composition, foraging activity, density and relative abundance of insect pollinators associated with three species of Genus *Cirsium* are shown in Table 2**.** The relative abundance of *Apis cerana* was calculated as maximum i.e. 7.43 followed by *Eristalis tenax*, *E. cerealis*, *Delias belladonna* (whereas, *Eurema brigitta rubella* showed minimum relative abundance i.e. 0.51 followed by *Pontia daplidice* (0.59)*, Catopsilla pomona* (0.68). In the present study most of the pollinator insects were active during 7:00-12:00 hr i.e. morning session, whereas were less active during afternoon session i.e. 13:00-17:00 hr (Table 4).

Flower-Insect interaction during blooming months: The maximum number of individuals of Order Lepidoptera was calculated in the month of April on *C. verutum* followed in June on *C. vulgare* and September on *C. arvense*. In case of Order Hymenoptera and Order Diptera, the maximum number of individuals was calculated in the month of April on *C. verutum* followed in September on *C. vulgare* and *C. arvense,* respectively. From Order Coleoptera, the maximum number of individuals was calculated in the month of June on *C. verutum* followed in July on *C. vulgare* and *C. arvense,* respectively (Fig. 3).

Insect diversity of anthophilous insects: The calculated Shannon diversity index (H') value was higher for *C. vulgare* (3.339), followed by *C. verutum* (3.339) and *C. arvense* (3.332). Similarly, *C. vulgare* showed maximum species richness i.e. 5.962 followed by *C. verutum* (5.663) and *C. arvense* (5.097). *C. arvense* showed maximum evenness i.e. 0.9033 followed by *C. vulgare* (0.8571) and *C. verutum* (0.8363) showed minimum evenness (Table 5).

Density of Anthophilous Insects Across the Plant Species

Cirsium verutum: *Apis cerana* showed maximum density i.e. calculated as 2.58 m^{-2} min^{-1} followed by *Eristalis cerealis* (2.17 m^{-2} min^{-1}), *E. tenax* (2.08 m^{-2} min^{-1}), *Coccinella septempunctata* (1.83 m^{-2} min^{-1}) and *Apis laboriosa* (1.58 m^{-2} min^{-1}). Whereas, the minimum density was recorded in case of *Megachile* sp. (0.17 m^{-2} min^{-1}) followed by *Vanessa indica, Beleois aurota, Sarangesa purendra, Byasa latreillei, Graphium sarpedon, Ceratina* sp. (0.33 m^{-2} min^{-1} each respectively), *Halictus* sp. and *Vanessa cardui* (0.42 m^{-2} min^{-1} each respectively).

Cirsium vulgare: *Apis cerana* showed maximum density i.e. calculated as 2.06 m^{-2} min^{-1} followed by *Eristalis tenax*, *E.*

Table 2. Species composition, foraging activity and relative abundance of insect pollinators of genus *Cirsium*

Order /Family	Species	Foraging activity	Density (m^{-2} min^{-1})			Relative abundance
			Cirsium vulgare	*Cirsium arvense*	*Cirsium vertutm*	
Lepidoptera						
Nyphalidae	*Aglais caschmirensis* (Kollar)	P/N	0.81	0.92	0.83	2.87
	Argynnis hyperbius Linnaeus	P/N	0.38	0.67	0.58	1.77
	Callerebia annada (Moore)	P/N	0.63	0.83	0.83	2.53
	Danaus chrysippus Linnaeus	P/N	0.38	0.58	0.83	1.94
	Junonia iphita Cramer	P/N	0.44	0.58	0.42	1.60
	Lasiommata schakra (Kollar)	P/N	0.50	0.50	0.33	1.52
	Neptis hylas Linnaeus	P/N	0.56	0.50	0.58	1.86
	Vanessa cardui Linnaeus	P/N	0.44	1.00	1.17	2.79
	Vanessa indica Herbst	P/N	0.56	0.75	1.08	2.62
Pieridae	*Aporia agathon* Gray	P/N	0.00	0.00	1.42	1.44
	Belenois aurota Fabricius	P/N	0.38	0.00	0.33	0.84
	Catopsilla pomona pomana Fabricius	P/N	0.50	0.00	0.00	0.68
	Colias fieldii Menetries	P/N	0.50	1.33	0.67	1.35
	Delias belladonna Fabricius	P/N	0.00	0.00	1.67	1.69
	Eurema brigitta rubella Wallace	P/N	0.38	0.00	0.00	0.51
	Eurema hecabe hecabe Linnaeus	P/N	0.63	0.00	0.00	0.84
	Gonepteryx rhamni nepalensis Doubleday	P/N	0.44	0.92	0.58	2.11
	Pieris brassicae Linnaeus	P/N	0.56	0.00	0.00	0.76
	P. canidia Linnaeus	P/N	0.50	1.33	0.92	2.96
	Pontia daplidice Linnaeus	P/N	0.44	0.00	0.00	0.59
Lycaenidae	*Celastrina argiolus* Linnaeus	P/N	0.31	0.92	1.08	2.45
	Heliophorus sena Kollar	P/N	0.94	1.58	1.08	3.97
	Lycaena pavana Westwood	P/N	0.50	0.75	0.58	2.03
Hesperiidae	*Polytremis eltola* Hewitson	P/N	0.00	0.83	0.83	1.69
	Sarangesa purendra Moore	P/N	0.38	1.08	0.33	1.94
Papilionoidae	*Byasa latreillei* Donovan	P/N	0.44	0.42	0.33	1.35
	Graphium Sarpedon Linnaeus	P/N	0.00	1.25	0.33	1.60
Hymenoptera						
Apidae	*Apis cerana* Fabricius	P	2.06	2.00	2.58	7.43
	Apis mellifera Linnaeus	P	1.38	1.33	1.17	4.39
	A. laboriosa Smith	P	1.00	0.83	1.58	3.80
	Bombus haemorrhoidalis Smith	P	1.44	1.25	1.33	4.56
	Ceratina sp.	P	0.63	0.50	0.33	1.69
	Xylocopa sp.	P	0.88	1.42	0.67	3.29
Sphecidae	*Ammophila punctate* Smith	P	0.56	0.00	0.00	0.76
Vespidae	*Vespa sp.*	P	0.69	0.58	1.17	2.70
Halictidae	*Halictus sp.*	P	0.38	0.33	0.42	1.27
Megachilidae	*Megachile sp.*	P	0.50	0.33	0.17	1.18
Diptera						
Syphridae	*Eristalis cerealis* Fabricius	FV	1.56	1.67	2.08	6.00
	Eristalis tenax (Linnaeus)	FV	1.81	1.83	2.17	6.42
	Eristalinus taeniops (Wiedemann)	FV	0.44	1.17	1.42	3.21
Coleoptera						
Coccinellidae	*Coccinella septempunctata* Linnaeus	FV	1.31	1.33	1.83	4.98

FV= Flower visitor; P/N= Pollen/Nectar

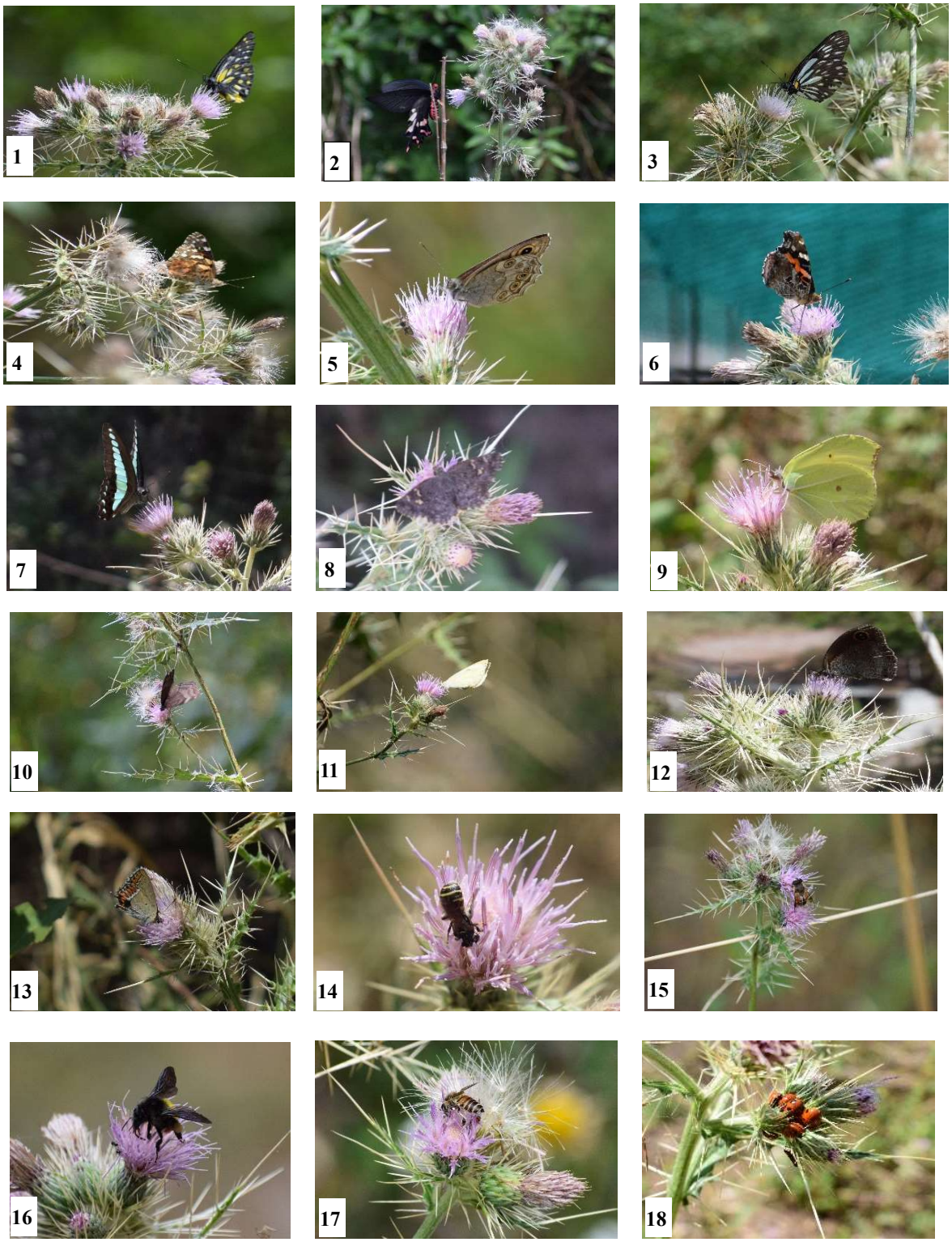


Fig. 1. The different species of insects associated with the three species of genus *Cirsium* (1- *Delias belladonna*, 2- *Byasa latreillei*, 3- *Aporia agathon*, 4- *Vanessa cardui*, 5- *Lasiommata schakra*, 6- *Vanessa indica*, 7-*Graphium sarpedon*, 8- *Sarangesa purendra*, 9- *Gonepteryx rhamni nepalensis*, 10- *Junonia iphita*, 11- *Pieris canidia*, 12- *Callerebia annada*, 13- *Heliophorus sena*, 14- *Ceratina sp.*, 15- *Eristalis tenax*, 16- *Bombus haemorrhoidalis*, 17- *Apis cerana*, 18- *Coccinella septempunctata*)

cerealis and *Bombus haemorrhoidalis*. The minimum density was in *Ceratina* sp. i.e. 0.31 m^{-2} min^{-1} followed by *Halictus* sp., *Beleois aurota, Sarangesa purendra, Eurema brigitta, Danaus chrysippus* and *Argynnis hyperbius*.

Cirsium arvense: *Apis cerana* showed maximum density i.e. calculated as 2.00 m^{-2} min^{-1} followed by *Eristalis tenax*, *E. cerealis*, *Heliophorus sena* and *Xylocopa* sp. The minimum density was recorded in *Megachile* sp. and *Halictus* sp., which constituted 0.33 m^{-2} min^{-1} each, respectively followed by *Byasa latreillei*, *Lasiommata schakra, Neptis hylas* and *Ceratina* sp.

The species of genus *Cirsium* spread across the globe, have flowers with a rich supply of nectar for pollinators. 41 species of pollinating insects were reported from three species of genus *Cirsium* (*C. vulgare, C. arvense and C.*

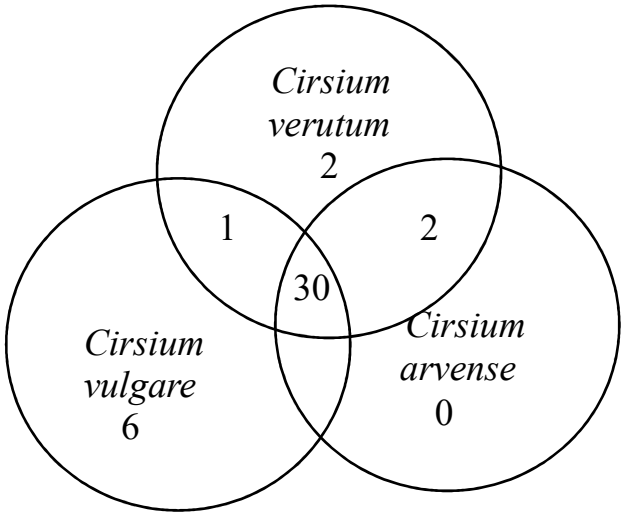


Fig. 2. Insect foraging network between selected species of genus *Cirsium*

Table 3. Percentage composition of number of species and number of individuals of *Cirsium verutum* in the study area

Order	*Cirsium* sp.	
	Number of species (%)	Number of individuals (%)
Lepidoptera	27 (65.85)	572 (48.31)
Hymenoptera	10 (24.39)	368 (31.08)
Diptera	3 (7.31)	185 (15.62)
Coleoptera	1 (2.43)	59 (4.98)
Total	41	1184

Table 5. Various diversity indices of foraging insects across the different plant species of *Cirsium* during study period

Index	*Cirsium vulgare*	*Cirsium arvense*	*Cirsium verutum*	Total
Shannon_H	3.457	3.332	3.377	3.517
Evenness_e^H/S	0.857	0.903	0.836	0.821
Margalef	5.962	5.097	5.663	5.652

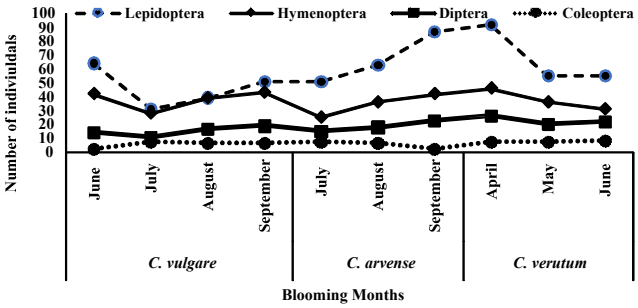


Fig. 3. Number of individuals of different orders during blooming period of *Cirsium* sp

Table 4. Total species of Anthophilous insects recorded in time blocks during flowering season in study area

Time block (h)		Lepidoptera	Hymenoptera	Diptera	Coleoptera
Morning session	7:00-8:00	12	6	1	0
	8:00-9:00	16	7	1	1
	9:00-10:00	19	4	1	1
	10:00-11:00	22	3	2	1
	11:00-12:00	21	4	2	1
Afternoon session	12:00-13:00	19	3	1	1
	13:00-14:00	16	2	1	1
	14:00-15:00	16	0	1	0
	15:00-16:00	11	0	0	0
	16:00-17:00	0	0	0	1

verutum) during the present study and showed a maximum number of individuals in the month of April, with probably many other plants blooming simultaneously on study sites, such as *Berberis asiatica, Valerina jatamansi, Pyrus pashia* and *Pyracantha crenulata. Cirsium* species share visits of several insect pollinators with other plant species blooming at the same time. The species of genus *Cirsium* (*C. vulgare, C. arvense and C. verutum*) were attracted by various insect orders in the present study area named as Lepidoptera, Hymenoptera, Diptera and Coleoptera. These species were mainly pollinated by butterflies and bees. Kapkoti et al (2016) also studied the pollinators of *Cirsium verutum* in the agricultural landscape of Nana Kosi-watershed, Uttarakhand, West Himalaya and reported 33 insect species including Lepidoptera as the most dominant order comprising 46% species followed by Hymenoptera , Diptera , and Coleoptera, Similarly, various workers reported insect pollinators of different species of *Cirsium*, Rollin et al (2016) observed order Diptera and short-tongued bees (e.g., Andrenidae, Colletidae, and Halictidae) were depending on *Cirsium arvense* for pollen and nectar reward.In the present study most of the pollinator insects were active during 7:00-12:00 i.e. morning session whereas, less active during afternoon session i.e. 13:00-17:00. In comparisons, Shakeel et al (2015) reported similar results and observed more pollinators foraging in the morning (10:00 am -12:00 pm) than afternoon (2:00-4:00 pm). Duara and Kalita (2013) also reported that the diversity of insect visitors was higher in the morning (8.00-12.00hr) as compared to afternoon (12.00-15.00hr).

The study was done in the protected areas and the species of *Cirsium* were visited by 41 insect species which shows it is good source of pollen and nectar for them. Kaur et al (2010) mentioned that *Cirsium verutum* was found to be degraded anthropogenically from 60% of canopy cover in Govind Wildlife Sanctuary and National Park, Uttarkashi. The risk of decline is greatest when pollinator mutualistic interaction is specialized (Rollin et al 2016). This is an important weed for medicinal purpose and also important source of foraging for anthophilous insects. Therefore, the present study recommends operative inclusion of this species in pollination management plans for sustainability of Himalayan ecosystems and its flora and fauna.

CONCLUSION

Genus *Cirsium* is medicinally essential with huge number of ethno-botanical use and affects the diversity of insect pollinators. The current analysis was supported by rich diversity of insects on *Cirsium*, which provide them nectar. Following study provides the anthophilous insects of three species of genus *Cirsium* named *C. vulgare, C. arvense* and *C. verutum* from the protected forest and botanical garden. Thus, it can be concluded that the following plants being weed does not do much harm to agricultural production, which attracts a number of pollinators that help to pollinate the nearby crops. It is therefore suggested that its conservation should be necessary.

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Current Perspective on Optimising Economics of Beekeeping in Punjab

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Abstract: The present study represents the effort aiming at optimizing the economics of beekeeping for honey, pollen and colony production based on quantitative data. Survey data from beekeepers scattered across 14 districts revealed that the influence of specific management practices and other confounding factors over productivity and income indicators. Specifically, study highlight the importance of floral availability, beekeeping experience, migration, number of colonies, educational status, requeening, on the productivity of *Apis mellifera* Linneaus colonies and also revealed the significant destructive impact of pesticides on honey production. In overall pool data, age distribution, educational status, family members, migration status, colonies damage due to various, factors, an abundance of flora, honey production, source of beekeeping information, diversification in beekeeping etc. are described to evaluate the present scenario of Punjab beekeeping. The average honey production per colony of *Apis mellifera* ranged between 15.67 and 33.12. The average family size of beekeepers within districts was ranging from 3.67 to 7.38 and the minimum family size was in district Firozpur. Majority of beekeepers families have the micro type with average family members 4.40. Large portion of beekeepers has used group migration and a small portion adopted single migration. Colony damage by pesticide and mite was the top most common problems for beekeepers, 79.17 per cent beekeepers were affected by this problem. The per cent fell to less than 20 kg honey production per hive was 41.67 and 20 to 40 kg was 57.29.

Keywords: Beekeeping, Economics, Honey, Floral diversity, *Apis mellifera*

Beekeeping should be considered a prime tool for sustainable development and can help low-income people to earn additional income from the sale of various bee products, thereby reducing the need to exploit other natural resources and creating incentives to protect habitat as food sources and nesting sites for the bees. The beekeeping contributes to the provision of pollination services, assures crop yields and helps to maintain natural plant biodiversity (Giannini et al 2014). Approximately 90 per cent of all horticultural crops especially hybrids, 80 per cent of flowering plants and three-quarter of staple crop plants that feed humankind in India depend upon bee pollinators to attain the production potential. Furthermore, a significant additional area of about 0.49 million ha has been brought under cultivation of horticultural crops through a centrally sponsored scheme (Ombir 2010). Moreover, around 50 million ha in India under bee dependent crops such as vegetables, fruits, flower, pulses, oilseeds, and legumes for cross-pollination and need at least 150 million colonies (Panigrahi 2010). Production of different bee products (pollen) from bee colonies, diversify the source of income of beekeepers and it mitigates the fluctuating effect of honey price in the international market (Hoover and Ovinge 2018). There is a great need to train Indian beekeepers for extracting these bee products and even government of India also emphasized that beekeeping cannot be restricted to honey and wax only because products like pollen, royal, jelly, propolis and bee venom can greatly help to Indian farmer to increase their income (PIB 2019). Punjab has witnessed exemplary fast-paced growth of beekeeping as an agro-based subsidiary occupation and also as the most important element of diversification in agriculture (Makkar et al 2015). Punjab leads India in honey production and produces around more than 39 per cent of the country's apiary honey production (Srivastva 2019). According to Agricultural & processed food products export development authority that during the year of 2018-19, the country has exported 61,333.88 MT of natural honey to the world for the worth of 105.48 USD millions (APEDA 2019). The survey plays a significant role to evaluate the present scenario of beekeeping in Punjab because it is the leading state of Indian natural honey production, and also help to boost of Punjab and Indian beekeeping.

MATERIAL AND METHODS

In this study, the direct contact method (Zee et al 2013) was used to collect the data from participant beekeepers. The survey asked qualitative questions about the present scenario of beekeeping such as age, education, family size,

experience in beekeeping, dependence on beekeeping, colonies number, migration (either single or group migration), an abundance of flora (it was measured through number of major crops visited by the beekeepers in one year), producing queens for sale (traditional or advance method), requeening in one year, colony damage (due to pesticides, disease, mite, wax moth, wasp), source of beekeeping information, species of bee used (*A. mellifera*, *Apis cerana*), honey and other bee products, etc. In this study, stratified random sampling was used for the survey of beekeepers. Total of 200 beekeepers from the fourteen districts was interviewed to record data. Beekeepers, whose answer were not valid or feasible according to survey due to lack of information were filtered out or removed from the collected data. For the statistical analysis, two softwares were used (PAST 4.01 Oslo Software and WASP 0.1, ICAR). For regression analysis, various models were created in which one variable in response (depended) and other were in predictor (independent) mode (Table 1a), critical differences and correlation were calculated in variables within different districts (Table 1).

RESULTS AND DISCUSSION

Stratified beekeepers data from different districts of Punjab: In the stratified data (Table 1) district Bathinda dominated in honey production, family members of beekeepers in Bathinda districts was also observed maximum and they are able to spend more time on migration or long route migration, may be due to this reason honey production was maximum. In honey production Bathinda was statistically at par with districts Barnala, Fatehgarh Sahib, Faridkot, Gurdaspur, Hoshiarpur, Rupnagar, Amritsar and Sangrur. The average honey production per colony of *Apis mellifera* ranged between 15.67 and 33.12. Low honey production was in district Firozpur, Moga and Mansa. Flora abundance within the district significantly varied from each other, highest diversity was reported in Fatehgarh Sahib followed by Hoshiarpur, Bathinda; and minimum in Firozpur, Mansa and Ludhiana. The floral plant bloom in different seasons of the year, assures a supply of food for honey bees. This contributes to an increased frequency of honey harvesting (Reda et al 2018).These studies showed a direct relation of floral availability with honey production and supported the variation of honey production in districts may be due to the abundance of flora. Honey production within districts depends on floral availability (p=0.001), resulting in increased colony honey production. Colonies migration and floral abundance were associated with each other (p=0.021).

Family size of beekeepers within districts was significant and maximum family size was observed in Bathinda and Sangrur, followed by Fatehgarh Sahib and Faridkot. The average family size of beekeepers within districts was ranging from 3.67 to 7.38 and the minimum family size was in district Firozpur. Family size of beekeepers positively impacted by the income generated from the sale of colonies and bee queens. There was significant variation in the sale of colonies and queen production for sale within stratified district data. Chanthayod (2017) indicated that the size of family, education level and years of beekeeping experience affected the income generation from honey. Households with bigger family sizes had higher production of honey. According to study, if a villager increased his experience of beekeeping by one year, acquired a higher educational level and involved more family members, the possibilities of making 1.35 times more profit than the baseline income.

However, within districts colony damage due to diseases, mite, wasp and wax moth were significantly varied from each other. There was a significant negative correlation between damage caused due to wax moth and requeening (p=0.015) of bee colonies within one year. Wax moth and wasp attack (p=0.0007) in bee colonies were positively associated with each other. Lowest damage due to diseases and wax moth was found in Barnala and Faridkot, respectively. Damage due to ectoparasitic mites was also significant within the district, maximum damage was in Gurdaspur, Firozpur, Ludhiana and Faridkot and the minimum in Sangrur district. Amiri et al (2017) observed, the negative impacts of pests and pathogens on queen health. Healthy and young queen produce a solid brood pattern, facilitating care of brood that can prevent disease, and a greater proportion of this bee brood will develop into healthy worker bees to replenish dying worker bees (Simeunovic et al 2014). These queenbee colonies can store more pollen and honey throughout the year than colonies headed by low-quality queens. Other parameters such as age of beekeepers, education, registered beekeepers, number of colonies, migration, screening of best queens, requeening, colony damage due to pesticides and pollen production were non-significant within districts.

Present scenario of beekeeping: The distribution of beekeepers on behalf of age showed that most of the respondents were belongs to mature adult followed by late adult, early adult and old age (Table 2). The mean age of early adulthood, mature adulthood, late adulthood and old stage was 31.24, 43.27, 54.93 and 85 years, respectively. Most of the participants have matric or less than matric in educational status followed by secondary education, diploma or graduate beekeepers. Postgraduate beekeepers were least. Majority of beekeepers families have the micro type with average family members 4.40. Most of the respondent adopted the

beekeeping profession as other source of income and least used as a hobby. Approximate one third percentage portion of beekeepers was completely depended on the beekeeping for their livelihood. More percentage of beekeepers was observed with more than 100 colonies, 40.63 per cent with 20 to 100 colonies and minimum were with less than 20 bee colonies.

Large portion of beekeepers has used group migration and a small portion adopted single migration. The abundance of flora was maximum under range 4 to 7 and least under

Table 1. Stratified beekeepers sample data from different districts of Punjab

District	Variable1 Honey Production per colony (Kg)	Variable2 Age of Beekeepers (Years)	Variable3 Education (Study years)	Variable 4 Registered beekeepers percentage	Variable5 Family Members	Variable 6 Experience in beekeeping (years)	Variable 7 Number of colonies	Variable 8 Migration	Variable 9 Income percentage from the sale of colonies and queens production
Hoshiarpur	26.50	48.88	12.25	25.00	4.62	19.13	266.25	100.0	12.5
Moga	16.13	43.88	10.13	50.00	7.00	16.50	165.63	050.0	50.0
Bathinda	33.12	48.38	11.13	12.50	7.38	17.13	484.75	75.00	62.5
Barnala	30.00	44.25	11.13	25.00	5.50	16.29	318.75	87.50	00.0
Mansa	16.63	43.75	11.00	00.00	5.00	15.38	109.25	62.50	12.5
Sangrur	23.25	42.88	13.00	25.00	7.38	15.50	503.50	62.50	12.5
Amritsar	24.63	39.38	12.38	50.00	5.25	16.00	160.00	62.50	12.5
Gurdaspur	26.71	47.13	12.71	20.00	4.71	19.75	076.88	62.50	00.0
Rupnagar	26.25	41.83	13.83	75.00	4.50	16.88	158.75	100.0	25.0
Firozpur	15.67	50.33	10.67	33.33	3.67	13.67	083.33	00.00	00.0
Ludhiana	17.83	40.83	11.00	16.67	5.67	15.33	081.67	50.00	40.0
Fatehgarh Sahib	27.50	43.75	11.75	25.00	6.75	16.75	200.00	100.0	25.0
Faridkot	27.40	49.17	12.17	00.00	4.67	17.50	175.00	80.00	00.0
Patiala	19.80	42.60	10.80	20.00	5.80	15.40	133.00	80.00	40 .0
C.D (0.05)	13.39	N.S.	N.S.	N.S.	2.14	N.S.	N.S.	N.S.	46.93
District	Variable 10 Availability of flora per year	Variable 11 Screening of best queens	Variable 12 Requeening (after one or within one year)	Variable 13 Colony damage due to pesticide	Variable4 Colony damage due to disease	Variable 15 Colony damage due to mite	Variable 16 Colony damage due to wax moth	Variable 17 Colony damage due to wasp	Variable 18 Pollen production
Hoshiarpur	6.38	12.50	37.5	75.0	75.0	100.0	50.0	62.5	00.0
Moga	4.50	25.00	75.0	100.0	50.0	75.0	25.0	00.0	00.0
Bathinda	6.12	12.50	62.5	62.5	12.5	87.5	37.5	00.0	00.0
Barnala	5.25	00.00	50.0	50.0	00.0	62.5	37.5	12.5	00.0
Mansa	3.38	00.00	25.0	100	50.0	87.5	50.0	00.0	00.0
Sangrur	4.43	00.00	62.5	87.5	12.5	37.5	12.5	00.0	25.0
Amritsar	5.50	00.00	87.5	62.5	50.0	75.0	25.0	25.0	12.5
Gurdaspur	4.86	00.00	50.0	75.0	75.0	100	87.5	87.5	00.0
Rupnagar	4.25	00.00	87.5	75.0	87.5	50.0	12.5	00.0	25.0
Firozpur	3.67	00.00	33.3	100	33.3	100	33.3	00.0	00.0
Ludhiana	3.17	16.67	33.3	100	50.0	100	50.0	50.0	16.7
Fatehgarh Sahib	6.50	50.00	75.0	100	50.0	100	25.0	00.0	00.0
Faridkot	5.20	00.00	80.0	100	20.0	100	00.0	00.0	00.0
Patiala	4.40	00.00	60.0	60.0	60.0	80.0	20.0	00.0	20.0
C.D (0.05)	1.93	N.S.	N.S	N.S.	57.30	47.01	56.45	35.99	N.S.
Variable A & Variable B			1&10	17&16					
Significance Correlation Student t (0.05)			0.79	0.56					

more than 7 crops diversity. Colony damage by pesticide and mite was the top most common problems for beekeepers, 79.17 per cent beekeepers were affected by this problem. After that, diseases, wax moth and wasp caused severe damage to the bee colonies. Majority of beekeepers had fallen under the slab of 10 to 20 years experience and least fell under more than 20 years experience. Income generated from the sale of colonies or queen was only 20.83 per cent. Only 6.25 per cent best queens were screened by the beekeepers and most of the beekeepers used the traditional method (division method) to produce new queens. Majority percentage of honey production per hive was placed in the slabs of less than 20 kg or 20 to 40 kg. The per cent fell to less than 20 kg was 41.67 and 20 to 40 kg was 57.29.

Various studies reported different types of constraints of Indian or Punjab beekeeping. According to Kumar and Singh (2002) and Singh (2000) that 60 to 75 per cent beekeepers have highlighted the problem of low price for bee products and honey marketing. The beekeeping restricted to honey production only, other bee products such as pollen, royal jelly, propolis and bee venom can greatly help to Punjab and Indian farmer to increase their income. Production of different bee products (pollen) from bee colonies, diversify the source of income of beekeepers and mitigates the fluctuating effect of honey price in the international market can boost the apiculture as subsidiary source of income (Hoover and Ovinge 2018).

Small beekeepers and large beekeepers: The responding beekeepers divided into two categories, small beekeepers have 80 or less bee colonies and large beekeepers have more than 80 colonies. The average annual honey production per colony of large beekeepers was significantly more than the small beekeepers. The percentage migratory respondent large beekeepers (94.64%) were significantly higher than small beekeepers. The flora abundance significant varied between small and large beekeepers. Lower flower availability was explored by the small beekeepers (3.9) than large beekeepers (5.72). The large beekeepers (69.91%) were more active in requeening after one year and significantly varied from small beekeepers (45.83%). Contrary, small beekeepers (92.68%) operated a traditional method of queen production and significantly varied from large beekeepers (62.50%). The percentage of registered beekeepers in large beekeepers (36.90%) was comparatively more than small beekeepers (12.5%). Oberrreiter (2020) observed that low colony losses were associated with indicators for advanced beekeeping: keeping a large number of colonies or migratory beekeeping. The large beekeepers are more aware of the advance techniques of beekeeping and commercially used these practices. The migration of honey bee colonies is generally practised with commercial beekeepers (Bansal et al 2013). The beekeepers in Pakistan are maintaining a fairly large number of bee colonies and are capable of producing pollen,

Table 1a. Regression estimates of the stratified data, standard errors (SE), Regression coefficient, t-values and p-values for all best models. Estimates are provided for each level of the categorical predictors

Response	Predictors	Regression Coefficient	Standard Error	T	p	R^2
Honey production	Floral Abundance	3.6834	0.82359	4.4724	0.000762*	0.62503
Honey production	Number of colonies	0.018974	0.008678	2.1863	0.049332*	0.28486
Number of family members	Percentage income generation from sale of colonies and queens	0.03755	0.012509	3.0018	0.01103*	0.42886
Colony damage due to wax moth	Colony damage due to wasp	0.59849	0.13294	4.5019	0.000724*	0.6281
Migration	Floral availability	15.189	5.7361	2.6479	0.021262*	0.3688
Honey production	Migrate	0.042458	0.038159	1.1127	0.29469	0.39224
	Availability of flora	3.4769	0.99533	3.4932	0.006796*	0.62503
	Screening of best queens	-0.1186	0.057141	-2.0756	0.067747	0.002113
	Requeening after one year	0.012924	0.042179	0.30642	0.76626	0.16291
Honey production	Family	-1.4155	1.0427	-1.3575	0.20768	0.014494
	Number of colonies	0.022471	0.008854	2.538	0.031813*	0.28486
	Engaged with Industry	1.1143	0.72037	1.5468	0.15631	0.35651
	Migration	0.055696	0.044172	1.2609	0.23905	0.39224

*=(Significance at $p < 0.05$)

Table 2. Overall pool data and present scenario of beekeepers in Punjab

Age of Beekeepers	Adolescence (12-20)	Early Adulthood (Ages 20-35)	Mature Adulthood (Ages 35-50)	Late Adulthood (Age50-80)	More than 80
Percentage	0	21.88	45.86	31.29	0.97
Mean ± S.D.	0	31.24±2.79	43.27±3.83	54.93±6.89	85.00±00
Education	Less than matric	Secondary	Diploma and Graduate	Post Graduate	
Percentage	35. 42	33.33	22.92	8.33	
Mean ± S.D.	9.06±2.30	11.83±0.38	14.06±1.03	17.33±0.71	
Family Size	Micro family (5 and less than 5)		Macro family (more than 5)		
Percentage	59.375		40.625		
Mean ± S.D.	4.40±0.73		7.33±1.79		
Profession	Hobby	Other source of income	Completely depended		
Percentage	10.41667	54.16667	35.41667		
Number of colonies	Less than 20	20-100	More than 100		
Percentage	16.66667	40.625	41.66667		
Mean ± S.D.	12.38±5.69	72.23±23.93	450.38±419.25		
Migration	Migrate colonies	Single Migrate type	Group Migrate		
Percentage	70.83333	26.47059	73.52941		
Flora availability/ year	0_3	3_7	more than 7		
Percentage	17.02	76.60	6.38		
Mean ± S.D.	2.56±0.63	5.01±1.05	9.00±1.10		
Colony damage	pesticide	Disease	Mite	wax moth	wasp
Percentage	79.16667	44.79167	79.16667	34.375	18.75
Engaged in this industry		Less than 10 years	More than 10 and less than 20 years		More than 20 years
Percentage		33.33333	47.91667		18.75
Mean ± S.D.		7.17±2.18	14.69±3.40		24.88±3.48
Percentage of income generated		Pollination	Queen and packagecolonies		
Percentage		Nil	20.83333		
Screening of best queens		Best Queen screened	Best Queen not screened		
Percentage		6.25			
Scientific method for producing queen		Traditional	Grafting		
Percentage		82.29167	17.70833		
Honey production per hive		Less than 20 kg	20_40kg		More than 40 kg
Percentage		41.66667	57.29167		1.041667
Mean ± S.D.		13.55±6.23	31.07±5.44		42±00
Sources of Beekeeping Information	From other beekeepers	Newspaper, radio and television	Internet	Beekeeping Associations	PAU, Ludhiana
Percentage	73.95833	9.375	23.95833	54.16667	95.83333
Requeening Percentage			58.33333		
Registered beekeepers percentage			25		

*= Mean±S.D

Table 3. Comparison between small and large beekeepers of Punjab

Parameters	Small beekeepers, Less than 80 colonies*(56.84 %)	Large beekeepers, More than 80 colonies*(43.16 %)	CD (p=0.05)
Honey production per colony	16.54	18.20±7.34	3.16
Migrate	50.00	94.64±23.12	15.68
Floral availability per year	3.9	5.72±1.70	0.63
Requeening after one year or within one year	45.83	69.91±46.35	21.25
The traditional method of queen produce	92.68	62.5±44.23	16.73
Income generation from queen and packages	8.89	29.63±46.09	17.84
Registered percentage	12.50	36.90±48.83	17.73

*=Mean±S.D

royal jelly and bee wax. The honey production and value addition of bee by-products would supplement the beekeeper's income (Ashfaq 2006). The net return of beekeepers was higher with the increase in the number of colonies (Kumar 2012, Verma et al 2018).

CONCLUSION

This study showed that higher the value of floral abundance resulting in increased honey productivity of *A. mellifera*. Family size of beekeepers was directly correlated with the income generation with the sale of colonies and bee queens. There was a significant negative correlation between damage caused due to wax moth and requeening of bee colonies within one year. Both damages due to wax moth and wasp were positively correlated with each other. In overall pool data of Punjab, distribution of beekeepers on behalf of age showed that most of the respondents were belongs to mature adult. Most of the participants had matric or less than matric in educational status. Majority of beekeepers family were the micro type. Most of respondent adopted beekeeping as other source of income and least used as a hobby. Participants who migrated to their colonies had considerable more in percentage. Colony damage by pesticide and mite was the top most common problems for beekeepers.

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Numerical Response of Predator *Chrysoperla mutata* MacLachlan to Varying Densities of *Lipaphis erysimi* (Kalt.)

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Abstract: The numerical response of *Chrysoperla mutata* Maclachlan instar larvae to a different density of mustard aphid *Lipaphis erysimi* (Kalt.) were observed under laboratory conditions. Early hatched larvae were exposed to a varied constant number of the prey (2, 4, 8 and 12 per day). The numbers of the prey consumption were recorded after 24h until complete larval development and the emergence of adults. There was significant increase in the survival rate, fecundity and longevity of predator's adult with the increase in the prey, *L erysimi* density. Prey consumption was highest for the third instar larvae and considered as the most effective stage of *C. mutata* predation. The reproductive numerical responses of the predator were synchronized to prey density. It was possible to complete the larval development of the predator despite the limited prey, which had a negative impact on increasing the average number of days needed to complete the development.

Keywords: Numerical responses, *Chrysoperla mutata*, Survival rate, Oviposition, Fecundity

The mustard aphid *Lipaphis erysimi* (Kalt) considered as the most destructive pest among several insects infesting many important crops of Brassica family. It may cause yield losses ranging from 35.4 to 96 percentages in suitable conditions and can reduce the oil content to 5-6 percentage (Sahoo 2012). Insecticides and the plant resistance play important role in the control of *L. eryisimi*. Several species of natural enemies including predators and parasitoids attacked *L. erysimi.* The knowledge of the predator aggregation response to prey density and oviposition is particularly important to understand the relationships and interactions in field crops between the predator and the prey. The effectiveness of the natural enemies can be determined by the numerical response of the predator to different density of the prey. The predator can respond to the minimum number of prey densities without being vulnerable to competition or predation from that uses similar resources. Increasing in the prey density leads to increase in the number of consumed prey because of the interference of stimulation factor (Omkar and Kumar 2013). The dynamics of predator-prey leads to change the predator density due to the increase in prey numbers, which is known as the numerical response of the predator. The predators in nature respond functionally and numerically towards the changing in the population of the prey, and these responses considered as the key factor to estimate the predator efficiency. Aggregation of predators may result in the increase of predators due to increase the survival rate and reproduction of the predator and consequently increase the attack rates of the predator. *Chrysoperla mutata* are among the most common natural enemies of pest insects found worldwide in almost all the agriculture ecosystems. Several previous studies have focused on the response of predatory insects in agricultural systems. Hamad and Al-Rawy (2008) observed the effect of various densities of Dubas bug, *Ommatissus lybicus* deBergevin on the *C. mutata.* Abdulhay and Al-Rawy (2012) observed the impact of *C. carnae* feeding on cabbage aphid, *Brivecoryne brassicae*. The present study aimed to investigate the reproductive responses of *C. mutata*, in terms of preovipositon period, oviposition and fecundity to different densities of *L. erysimi* under laboratory conditions.

MATERIAL AND METHODS

Rearing the *L. erysimi* (Kalt.) (Homoptera: Aphididae): The adults of mustard aphid were collected from infected leaves of cauliflower, *Brassica oleracea* (L.) from a field in Al-Jadiriya, Baghdad. To obtain insect of the fourth nymphal instars; the *L. erysimi* adult were kept in Petri dishes (9 cm diameter) containing cauliflower leaves and covered with muslin. After 24 hour the young first instars nymphs were moved to another Petri dishes with the same incubation condition (27± 2°C and 70 ± 5% relative humidity) and monitored for moulting to the next nymph instars. Continuous monitored until reaching the fourth instars which were used in the experiments (Abdulhay 2015).

Rearing the predators, *C. mutata* McLachlan (Neuroptera: Chrysopidae): The adults were collected in March 2019, maintained in plastic cylindrical cup supplied

with water and an artificial nutrient solution consisting of honey yeast diet in 1:1 mass ratio (Montoya-Alvarez et al 2010). The larvae were kept individually to avoid cannibalism and reared with eggs and larvae of the Mediterranean flour moth, *Ephestia kuehniella* (Hamad and Al-Rawy 2008).

Effect of prey density on the predator numerical response: The newly hatched larvae of *C. mutata* less than 24 hours old were isolated, placed individually in test tubes (8.5 x 2 cm) and supplied daily with different constant numbers of *L. erysimi* fourth nymphs instar (2, 4, 8 and 12) with pieces of cauliflower leaves for aphid nutrition. The number of consumed nymphs and larval survival rate were recorded daily until larval development were completed and adults emergence. The study carried out with 20 larvae for each feeding pattern (Abdulhay and Al-Rawy 2012). The adults of the predator (male and female) pairs were placed in glass containers (24 x 9 cm). The sexes were distinguished depending on the shape and size of the female's abdomen .The containers were covered with muslin fixed with rubber bands, supplied with yeast solution and water (1:1) daily. The preoviposition period, the number of eggs per female and longevity in the adult female was recorded (16 lights: 8 darks)).

RESULTS AND DISCUSSION

There was significant increase in the consumption of *L. erysimi* by the different predator instar larvae with the increase in the prey density. The highest prey consumption was in the third instar larvae of *C.mutata* was 20.20, 28.01, 36.40 and 40.20 for the densities of 2, 4, 8, and 12, respectively (Table 1). Prey consumption by the three larval instars of *C. mutata* increased curvilinearly with increasing the density of the prey. The last instar larvae was the most effective stage of *C. mutata* predation, and this may be due to their extra requirement of nutrients which is needed for their subsequent non-feeding pupal. But if the prey densities were high, the search time for the predator will be short. The present results are based on laboratory condition, but in nature the consumption of the prey depends on the densities of both the prey and predator and complexity of habitat to estimate the efficiency of *C. mutata* as a biocontrol agent and to understand the predator behavior and the interactions. Abdulhay and Al-Rawy (2012) indicated that the larvae of the predator, *C. carnae* had a distinct ability to survive in conditions of inadequate feeding. Increasing the number of prey consumption in the larval stage had a positive impact on the survival rate of larval instars, accelerated development and longevity of adults as well as increasing oviposition period, fecundity and decreasing both of preoviposition and postoviposition periods. The preoviposition period s decreased significantly with the increasing number of nymphs per day. The average period was 14.61, 9.437, 4.0 and 3.0day for the prey densities 2, 4, 8, and 12, respectively.

Table 2. The effect of different numbers of *Lipaphis erysimi* nymphs supplied daily on preoviposition, oviposition period and fecundity of the predator *C. mutata*

No. nymphs/day	Preoviposition Period (days) (Mean ± SD)	Fecundity / female	Longevity (day) (Mean ±SD)
2	14.61±3.03 c	84± 9.81 d	26± 4.67 c
4	9.43± 1.67 bc	175± 11.92 c	35± 3.89 bc
8	4.0±1.98 ab	295± 18.65 b	60± 5.90 ab
12	3.0± 0.54 a	468± 30.67 a	78± 8.3 a

Table 1. Effect of *Lipaphis erysimi* density supplied daily on the larval development and survival rate *Chrysoperla mutata*

Predators' larvae	No. nymphs /day	No. consume nymphs (Mean±SD)	No. days/instar (Mean ±SD)	Survival rate (%)
First instar	2	7.0 ± 1.52	6 ± 0.80	97
	4	10.2 ± 1.84	5.6 ± 0.65	97
	8	15.32 ± 2.40	4.5 ± 0.72	99
	12	20.57 ± 3.87	3 ± 0.50	100
Second instar	2	11.53 ± 2.19	7 ± 1.13	96
	4	15.66± 3.51	6.5± 2.40	96
	8	23.71± 2.94	5± 0.47	98
	12	34.04± 3.03	4.5± 0.43	100
Third instar	2	20.20± 1.25	12± 1.09	80
	4	28.01± 1.63	10± 1.28	90
	8	36.40± 3.38	7± 1.50	95
	12	40.20 ± 4.40	5± 0.71	98

The predator's longevity was directly affecting by increasing the numbers of the prey and the larval developmental period was longer than the predators larvae reared on more prey numbers.

C. mutate female laid maximum of the eggs (468.00) at the prey density of 12, followed by 8 (295), 4 (175) and 2 (84.3). The number of eggs laid was positively increased with prey, *L. erysimi* density. The reproductive response of *C. mutata* exposing to various densities of nymphs *Ommatissus lybicus* was highly correlated with the amount of consumed prey (Hamad and Al-Rawy2008). The low reproductive rate or predator fecundity may be correlated to low food requirements. The results revealed that when the prey densities increase, the consumption of the prey and oviposition are increase too and the efficiency of exploitation the prey. Evans (2000) mentioned that increasing in the quantity of food supports the development of large numbers of ovarioles. Agarwala and Bardhanroy (1999) observed the reproductive numerical response of two species of coccinellids to aphid as the prey in a bean field and indicated that the increasing in *A. craccivora* population had two effects on the predator oviposition. First increasing the number of eggs per cluster and the second was stimulating the production of egg mainly in the species *C. transversalis.* The numerical responses were synchronous with the density of aphid and suggested that oviposition in ladybirds was a function of prey abundance. Canard and Volkovich (2002) mentioned that the preoviposition period for *Chrysoperla* reached 5-13 days, which is necessary for the gonads to mature, depending on the type and amount of food in the larval stage.

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Population Dynamics of *Catopsilia pyranthe* in Butterfly Garden

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Abstract: The *Catopsilia pyranthe* butterfly population was investigated in the butterfly garden. The oviposition rate was highest in September 2017 and reproduction becomes lower in following months. Adult *C. pyranthe* population was highly controlled by the predator *Solenopsis* sp. (red imported fire ant) even there was high egg and larval prevalence. Hence, *C. pyranthe* from egg to pupal stage needs protection with suitable enclosures, if not, their numbers dwindle.

Keywords: *Catopsilia pyranthe, Cassia siamea,* Butterfly garden, *Solenopsis* sp.

Anthropogenic disturbances lead to rapid destruction of the environment by unplanned developmental activities (Czech et al 2000). There is scope to restore ecological balance by using *ex-situ* conservation of both plant and animal species. Despite biodiversity crisis butterflies can have a secure future. Butterflies apart from the aesthetic value, have ecological significance as well (Kocher and Williams 2000, Pocewicz et al 2009). Butterfly gardens help to increase the population of butterflies and could sustain even in urban areas. Butterfly gardens can be set up in any location by introducing butterfly host plants and by recreating suitable habitats. Gardens with nectar sources and larval host plants have been proposed to prevent the decline in butterfly abundance caused by habitat loss (Anu et al 2009, Shanthi et al 2009, Tiple and Khurad 2009). There is a growing need to restore the lost habitats to conserve biodiversity in available open space of the urban area. Larger gardens are likely to contain higher diversity and abundance compared to smaller gardens (Koh et al 2004). From a conservation perspective, the need to quantify the conservation value of butterfly gardens. It is necessary to gather information on the impact of habitat creation through such gardens and their effectiveness in increasing the population. The present study aimed to study the predatory influence on the population dynamics of *Catopsilia pyranthe* butterfly on *Cassia siamea* host plants in the butterfly garden.

MATERIAL AND METHODS

The sprawling campus of 16 ha of The American College has large number of trees. In the butterfly garden five *Cassia siamea* plants were maintained as they are the appropriate host plant of the butterfly *Catopsilia pyranthe*, belonging to the family Pieridae. The plants were about 5 feet in height and they were checked for the presence of egg, larva and pupa of *C. pyranthe* once in 3 days. All life stages of *C. pyranthe* were examined to determine whether gardens with larval host plants contribute to the prevalence, abundance and persistence. The population dynamics of *C. pyranthe* on *C. siamea* host plant were observed in the butterfly garden of The American College, Madurai, Tamil Nadu, India from September 2017 to March 2018. The foliage of host plant was visually inspected for life stage. The egg survival was determined by the fate of eggs marked in each plant. To prevent the influence of natural enemies the egg masses were covered with fine mesh bags. The number of eggs and larvae prevalence were recorded. The relationship of the abundance of immature stages of *C. pyranthe* with their natural enemies was evaluated.

RESULTS AND DISCUSSION

The butterfly garden with *C. siamea* plants was able to attract *C. pyranthe* butterflies. The adult butterflies laid eggs in the host plant *C. siamea.* The eggs were laid on the tender leaves of *C. siamea* both on the upper and lower surface of the young leaves. The eggs were laid on the leaves singly. Leaves of young plants contain more of digestible nitrogen and less of indigestible fibre. The oviposition rate was the highest (833 eggs) in September 2017 (Table 1). The percentage of *C. pyranthe* larva was highest in February 2018 followed by January 2018 and December 2017.

Hence, the numbers of adult are highest in September, 2017 and later the numbers of eggs dwindled. September was found to be the favourable season for the prevalence of higher incidence of eggs. The butterfly garden was suitable site for the butterfly *C. pyranthe*. Even though there was an increase in the number of eggs, the survival rate of larva, pupa and adult was decreased. Adult percentage was highest in September 2017. The eggs were laid mostly in single on the young and tender leaves of *C. siamea* both on the upper and lower surface of the young leaves and similar egg laying habit was found in previous studies (Atluri et al 2012). The eggs were consumed by predators. The most common predator was the ant, *Solenopsis* sp. (red imported fire ant) was more numbers, and these predators consume the eggs, larva, and pupa. Larvae were also consumed by spiders and predatory bugs in the natural environment (James and Nunnallee 2011). Correlation showed that the number of predators appeared where the prevalence highest egg numbers ($r^2 = 0.74$) and represents that number of larvae were highly reduced ($r^2 = -007$) where predator number increased (Table 2). Therefore predator influence highly affects the population dynamics of *C. pyranthe* (Table 3). Earlier studies showed that mortality rate occurred in that population where natural enemies were found to be the most important factor regulating the population of *Papilio polytes*. Among all life stages, the eggs suffered the most attack especially by the predators and parasitiods. Spiders, such as *Oxyopes spp.* were the most important predators. Others include red ant (*Solenopsis* sp.) and *Ooencyrtus papilionis* (Suwarno 2009, Fleming et al 2005).

The population of butterflies decreased due to predators. *C. pyranthe* is prevalent throughout all the seven months of study period but only the prevalence of their eggs varied. The adult population ranged from 5 to 30 numbers. The predator numbers varied from 10 to 50. Even though the reproductive success was highest in September, the survival rate was only 3 per cent. The ants were able to gain entry into the mesh by cutting open through the sharp mandible and consume the larva. *C. pyranthe* can be propagated in the butterfly garden with suitable host plant like *C. siamea* and however, survival of the younger stages of the butterfly should be protected by suitable enclosures. Maximum number of species and individuals of butterflies were recorded in during the summer season, followed by rainy and

Table 1. Variation in number of eggs, larva and adult of *Catopsilia pyranthe* and its predator number in different months

Months	No. of eggs	No. of larva	No. of adult	No. of predators
September-2017	833	6	30	50
October-2017	371	4	0	30
November-2017	144	6	5	15
December-2017	286	28	8	20
January-2018	368	32	17	20
February-2018	144	38	15	40
March-2018	100	18	6	10

Table 2. Correlation matrix for predator influence on *C. pyranthe* life cycle

Population parameters	No. of eggs	Larva (%)	Adult (%)	No of predators
No. of eggs	1			
Per cent of larva	-038	1		
Per cent of adult	-041	067	1	
No. of predators	071	-007	013	1

Table 3. Predatory influence on *C. pyranthe* life cycle

Population parameters	No. of eggs	Larva (%)	Adult (%)	No. of predators
Mean	321	19	4	26
Minimum	100	4	0	10
Maximum	833	38	10	50

winter seasons (Arya et al 2020). Environment controls reproductive success, but survival and propagation depend on parasites and predators. Prevalence of predator is inevitable and it relies upon climatic changes for their abundance which had a significant positive correlation with temperature (Amin et al 2018, Amin et al 2019).

CONCLUSION

The butterfly garden helps in the propagation of butterflies. Though there is a high oviposition rate in September, there is the declination of adult population due to predator entry. *C. pyranthe* from eggs to pupal stage needs protection with suitable enclosures, if not, their numbers dwindle. The predator population has to be taken into account for the improvement of butterfly survival rate. Moreover, habitat creation is needed to improve the survival and propagation of butterflies.

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Symbiosis and Crisis: Study on Elephant-Fisher folks Ecology in Deepor Beel Ramsar Site, Assam

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Abstract: The present study was carried out in the eco-sensitive zone of Deepor Beel wildlife reserve, the only Ramsar site of Assam, where Asian elephants and fisher folks have co-existed for centuries. The elephants have established a symbiotic relationship with the fisher folks by providing a series of ecological services that help in the wetland resource management of the beel. Therefore the present study deals with the role and significance of elephants on the livelihood system of the fisher folks. The study resulted in identifying two crucial means of ecological services that elephants provide through their wide ranging feeding ecology and diet composition, first as a means to control the invasive aquatic species and second as a means to enhance the productivity of the benthos fish species. The study also focuses on the change in their symbiotic relationship that has taken the form of livelihood crisis for the fisher folks due to the adverse impact of deforestation and urbanization within the beel ecosystem.

***Keywords*:** Asian elephant, Aquaculture management, Urbanization, Environmental degradation, Livelihood crisis, Wildlife protection

Taxonomically, Asian elephants (*Elephas maximus* L.) are one of the living species of the order Proboscideans under the class Mammalian whose physiological adaptations like the large prehensile trunk, dentition and digestive system as well as the behavioural adaptations help them to efficiently exploit the diverse ecological settings especially under the highly changing heterogeneous tropical environments (Baskaran et al 2010). These mega-herbivores have the ability to feed on both browse (trees, shrubs, herbs and bamboo) and grass species ranging from grassland, tropical evergreen forest, semi-evergreen forest, moist deciduous forest, dry deciduous forests, and dry thorn forest to scrublands and cultivated lands (Borah and Deka 2008, Baskaran et al 2010). Hence, they are considered as the keystone species whose wide-ranging feeding ecology and diet composition make them interact highly with its habitat, thus influencing the direction of development of its biotic environment including human civilization and cultures (Sukumar 2003). In terms of the wild elephant population, Assam, one of the North-Eastern states of India, ranks second among all the states in India according to the Synchronized Elephant Population Estimation, MoEFCC, India (2017). Like other parts of the Indian subcontinent, Assam features a long term relationship between the people and the elephants as Assam's lush tropical forest areas with large water bodies make the region a suitable abode for the elephants, thus creating an environment of coexistence between the two species. Very least is known about their present-day relationship with the local indigenous communities who are found to reside within the elephant inhabited regions. Therefore the present study makes an attempt to do so by exploring the relationship found between the elephants and the fisher folks of Deepor Beel Ramsar site in Assam. At present, understanding such relationship between the wildlife species and humans is an urgent requirement to deal with various issues related to human-wildlife conflict, livelihood security and environmental protection. The study mainly aims at throwing light on the very nature of symbiotic role of wildlife species on the human population who are otherwise misconceived as vulnerable to human survival and hence they do not get due priority and are looked down upon.

MATERIAL AND METHODS

Study area: Located about 10 km south-west of Guwahati city between 91°35' - 91°43' E longitude and 26°05' - 26°11' N latitude and 55m above the mean sea level, Deepor Beel wetland is considered as one of the largest and prominent flood-plain lakes in the Brahmaputra valley of Assam. It serves as the natural fishery ground, supporting total 61 fish species, 5 of which are listed as exotic while 54 are listed as indigenous species of Assam and the fish yield rate accounts for 245 kg ha^{-1}, comparatively higher than the national level (Saikia 2005). The beel is reported to spread over an area of 40.14 km^2 during the monsoon season when the water level raises to its maximum (including encroached/reclaimed/

developed area) and the depth is estimated to range from 1.5 m during the dry season to 6 m during the monsoon season. Average annual rainfall in the area is about 1660 mm, most of which occurs by the south-west monsoon between April and September. The average temperature ranges between 10.C during dry winter and 30.C during wet summer. From the environmental point of view, the site is important as it serves to be the only major storm water storage basin for Guwahati, the largest city of Assam (Planning Commission, Government of India 2008). The 40.14 km² area has been designated as "Wetland of International Importance" under the Ramsar Convention on Wetlands, 1971 and was declared as Ramsar site in 2002 because of the presence of rich aquatic, avian and mammalian fauna, some of which are listed as endangered and endemic species while its core zone of 4.14 km² area was proposed as a wildlife sanctuary under the Wildlife Protection Act of India, 1972 (Basistha 2016). Falling under the Burma monsoon forest bio-geographic region, Deepor beel wetland features tropical moist and mixed deciduous forest covers on the adjoining steep Rani and Garbhanga hills on the south and south-east forming backdrop with the presence of a large lake. This, in turn, makes the area ideal habitat for the endangered Asian elephants as they can fulfill their nutritional requirements from the forest sources on the one hand and from the water body on the other hand. The elephants are found to range from about 50 m to 1400 m elevation, regularly moving across the interstate boundary between Assam and Meghalaya and their total habitat stands for about 6850 km² with 750 km² in Assam and 6100 km² in Meghalaya (Choudhury 1999).

Data collection: The present study is mainly of qualitative research and the data were generated from both primary and secondary sources. Primary sources included data collected through field observations, semi-structured interviews and resource mapping of the site. The secondary sources included data collected through a review of available literatures. Narratives derived from the fisher folks of Deepor Beel Paachpara Samabai Samiti (a fishing co-operative society formed by the fisher folks for control of access to the Deepor beel resources) were widely used for data analysis in order to deal with the human-elephant relationship in the region over time and space. These key informants were mostly the aged fishermen (above the age of 40) who were known to be adept in the fishing skills and resource management of the lake. A field visit was carried out in between June 2018 and July 2019 where presence of footprints and feeding signs were recorded along the rail-road tracks in the site. Three frequently used elephant corridors in between the forest and beel area were identified in the site which were being fragmented by the rail-road tracks (Fig. 1).

RESULTS AND DISCUSSION

Elephant-fisher folk ecology: Elephants are found to play a significant role for the livelihood management of the Deepor beel fisher folks. Their feeding pattern and dietary composition influence the growth and decline of fish and other aquatic species on which these fishermen depend on for their aquaculture. The elephants have a great potential to increase the size of the fish population as they physically make breeding ground for the fish species within the beel. Elephants often come down the surrounding Rani-Garbhanga reserve forests to utilize the beel for drinking water in order to consume a large quantity of food on the one hand and for cooling their huge body during the period of high ambient temperature on the other hand. In such a situation, impressions of their footprints are formed in the marshy baseline of the water body as a result of their playful movements on the water. These impressions gradually take the form of depressions on regular visits which serve as the breeding as well as resting ground for benthos (bottom dwelling) fish species (Table 1). These depressions then become the ideal safe zone for fish breeding as compared to open space breeding that may otherwise attracts threats to the fish population from other aquatic predators. With the retreating monsoon period, when the water level recedes to its minimum, such depressions can be easily identified and made used for fish catches (Fig. 2).

The elephants are also found to influence the health of the fish species by removing the polluted *Eichhornia crassipes* from the water surface. *Eichhornia crassipes* is a fast growing floating invasive aquatic plant species which retards the growth of many aquatic species by adversely affecting the steady flow of water and blocking the sun rays from entering into the base. As a consequence, the flow of dissolved oxygen is affected for which decline in the fish population becomes a common problem. When elephants hunt for their aquatic food such as *Eichhornia crassipes* and *Euryale ferox* in the beel, they often uproot and remove many unwanted portions of their eatables from the shores, thus making the water surface clean. This helps in unblocking the sunrays which allow the smooth flow of dissolved oxygen into the base: an essential requirement for continuation and growth of many aquatic species including fish (Fig. 2).

Such feeding ecology of elephants, thus influence the aquatic ecosystem of the beel and this in turn helps the fisher folks in maintaining their livelihood system. It saves their time and labour required for fishing operation as they can easily identify the whereabouts of the fish population by tracing the

location where the depressions are formed. In addition to it, removal of water hyacinth from the surface promotes the smooth navigation of the fishing boats which is a matter of safety for the fisher folks. Fishing trips in the clean surfaces also promote for safe collection of *Euryale ferox* which is a local delicacy as well as a source of secondary income for the fisher folks. *Euryale ferox* is a perennial aquatic plant which produces edible starchy white seeds inside the sharp thorny nuts that grow beneath its large and round floating leaves.

Symbiosis to crisis: The very regenerative role played by the elephants within the Deepor beel ecosystem has now turned into a form of conflict and has created a series of livelihood risks for the fisher folks. This has happened due to the entry of the alien factors in the form of urbanization and deforestation process that pose a threat to elephant habitats. According to the Elephant Task Force report, Assam had witnessed the highest number of elephant mortality cases (39.34%) due to train hits among all the states in India between 1987 and 2007 (Rangarajan et al 2010). Such unnatural death has been very critical in the Kamrup East division (under which the Rani-Deepor beel site falls) and recorded highest frequency of elephant mortality due to train hits among all the 8 forest divisions in the state between 1990 and 2006, where 6 deaths out of total 7 were taken place during the monsoon months of May-June while the rest 1 death during the paddy ripening month of November (Sarma et al 2006). Hence, it becomes one of the critical eco-sensitive zones for elephant habitat. Elephants often visit the beel in search of food and water supply and while crossing the railway stretches lying in between the beel and the Rani reserve forest, they are often being knocked down to death by the moving trains. The frequency of their visits to the beel increases with increase in the ambient temperature and growth of grass species like *Imperata cylindrical*, *Leersia hexandra* and aquatic plants like *Euryale Ferox* and *Eichhornia crassipes* during hot monsoon season which force these mega-herbivores to graze and bath in the beel and hence death incidence rate is high during the monsoonal season. Even the cases of injured elephants were being reported from the site, accounting a total of 9 injury cases, out

Table 1. Fish species found in the marshy depressions of the Deepor *Beel*

Scientific names	English name	Order	Family	IUCN red listed species	Key Features of Habitat Type (Pethiyagoda 1991, Talwar and Jhingran 1991)
Botia dario	Bengal loach	Cypriniformes	Botiidae	Least Concern (LC)	This species can adapt to low oxygen levels in marshy substrate by being able to gulp up atmospheric oxygen
Macrognathus aral	One-Stripe spiny eel	Synbranchiformes	Mastacembelidae	(LC)	They inhabit in silt or muddy substrate and are nocturnal feeder on insects and worms.
Monopterus Cuchia	Swamp-eels	Synbranchiformes	Synbranchidae	LC	Fused gill membranes and presence of vestigial dorsal and anal fins with a slit or pore gill opening underneath the throat have helped them to adapt for burrowing into soft mud or marshes during periods of drought and hence often found in the muddy substrate underneath a dried up water body.
Mastacembelus armatus	Zig-Zag eel	Synbranchiformes	Mastacembelidae	LC	They can survive in partly buried condition under fine substrate and are mostly attached to the benthic zone for food (almost same habitat like that of swamp eels)
Mystus tengara	Tengara catfish	Siluriformes	Bagridae	LC	They can survive under standing water with macrophytes and muddy bottoms
Heteropneustes fossilis	Stinging catfish	Siluriformes	Heteropneustedae	LC	They can survive in muddy swamps, ditches and marshes and spawning usually takes places in muddy shallow depressions.
Channa gachua	Dwarf snakehead	Perciformes	Channidae	LC	Supplementary breathing apparatus in the form of paired supra-branchial chambers located behind and above gills allows these species to survive in an inhospitable condition across land by being able to gulp up atmospheric air and hence they survive without water for a considerable period of time.
Channa punctata	Spotted snakehead	Perciformes	Channidae	LC	

Source: Self investigation from field

of which 8 cases were due to vehicle hits and the remaining 1 case due to human-elephant conflict during 2018-2019 (Kalita and Das 2020). The study reported that 8 cases were recorded during the cold winter season between November and March. The possible causes for such incidence might be due to high speed of vehicles in the elephant corridors or due to foggy roads during cold winter that might cause blur situation for the drivers to trace the elephant movement on the roads. The mega-herbivores under such distress might have a greater tendency to change their behavioural state, making them aggressive towards the humans and this leads to the rise of human-elephant conflict. On the contrary, there is a less possibility of forming depressions under the impact of elephant foot impressions if the elephants face foot injury, which is a matter of concern for the fisher folks.

Deforestation is another crucial factor that has been a threat to habitat loss for the mega-herbivores within the beel ecosystem. Urbanization of the Guwahati city and increased population pressure on its neighbouring area have adversely affected the biodiversity and forest cover. Das and Bhagabati (2017) showed that during the period between 1977 and 2010, in the Rani-Garbhanga forest reserves, there has been a sharp decline in the land covers like dense forest, followed by wastelands, agricultural lands and water cover, amounting to -5456.5 ha, -4162.68 ha, -2942.96 ha and -664.04 ha, respectively on one hand while remarkable increase in the settlement and open forest land covers is evident, amounting to 8292.3 ha and 4754.1 ha, respectively. In addition to these land uses, city's garbage dumping ground lying to the eastern side of the beel is abutting its margin with a great possibility of the solid and liquid wastes, leaching into it during the rainy season, further deteriorating the water quality. Such anthropogenic activities adversely affect the aquatic life species including fish and block the elephant passage to the beel. Large scale establishments in the form of brick kilns, stone mining and industrial construction in the beel periphery along the forested foothills have adversely affected the natural routes of elephant movement to the beel and as a result, it has a negative impact on the aquaculture management among the fisher folks. Prior to these establishments, elephants were able to utilize the entire beel for its diet fulfilment and under their wide-foraging habits formation of depressions was widely concentrated over a larger area. This, in turn, had encouraged the growth of fish population in such impacted areas, providing them a wider safe and secure resting and breeding ground. At present, such symbiotic environment has been deteriorated with such establishments that have obstructed the mega-herbivores to forage over a larger area, rather they are now more inclined to utilize only the southern peripheral boundary of the beel,

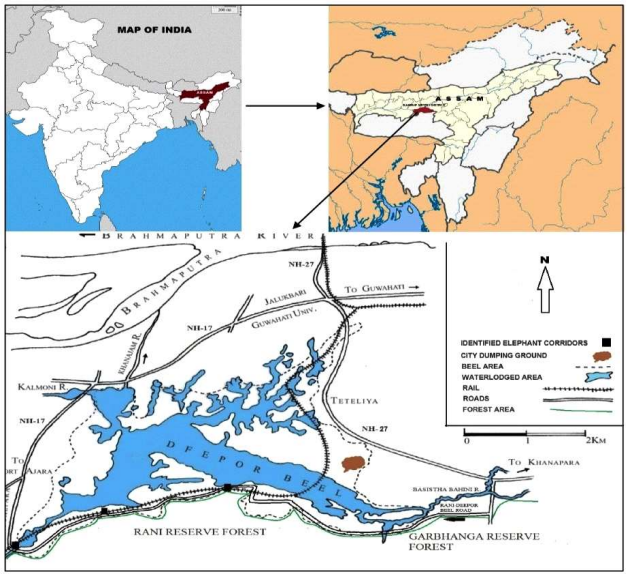


Fig. 1. Map of the study area, Deepor Beel Ramsar site

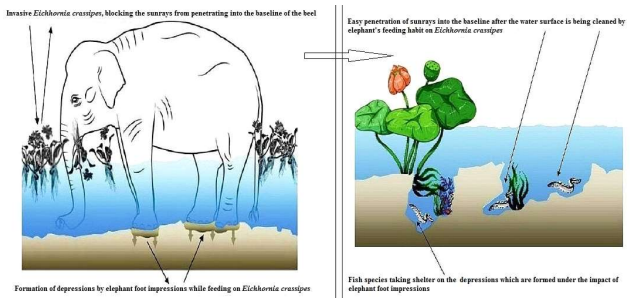


Fig. 2. Diagrammatic representation showing elephant's role on the Deepor Beel ecosystem



1. A sign board for protecting the elephant corridors. 2. Elephants taking bath during the dawn. 3. *Monopterus Cuchia* (left) and *Heteropneustes Fossilis* (right) as primary source of income. 4. *Euryale ferox* as secondary source of income (a common delicacy for both humans and elephants)

Fig. 3. Elephants and Deepor Beel resources

being the least polluted and affected area under urbanization. The elephant movements are quite frequent in this part and depressions under their impact are now more concentrated over this part as compared to earlier situation. Similarly, invasive growth of *Eichhornia crassipes* was once largely controlled by the mega-herbivores as they primarily feed on it and thus, reduce its invasion over the other aquatic species. Such ecological balance has been under threat since elephants are now unable to feed on wider areas of vegetated *Eichhornia crassipes* and this often leads to the over-growth of the species over entire beel, polluting the aquatic ecosystem. This ultimately creates livelihood risk among the Deepor Beel fisher folks.

CONCLUSION

The data suggested that elephants have a great potential in ensuring the livelihood security among the fisher folks and such symbiotic relationship is now under threat due to the loss of elephant habitats which is a matter of economic loss for the fisher folks. Economic sustainability of the fisher folks has been deeply rooted in the ecological sustainability of the elephants whose diet and foraging habits in the Deepor Beel ecosystem have favoured the growth and sustenance of aquatic species. The study tries to throw light on the importance of ecosystem ecology model in understanding the livelihood crisis among the indigenous human groups whose economy greatly depends on the smooth functioning of the natural resources.

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Comparison of Streams Delineated using Various SRTM, ASTER and Cartosat DEM

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Abstract: Results from the study on the comparison of the stream network delineated from Shuttle Radar Topography Mission (SRTM) DEM, Advanced Space borne Thermal Emission and Reflection Radiometer (ASTER) DEM and Cartosat DEM with the stream network extracted from Toposheets concluded that SRTM DEM of 30m resolution was correlated well with the stream network extracted from SOI toposheets compared to ASTER and Cartosat DEM. It is recommended to utilise SRTM open access DEM of 30m resolution from research work carried out over the study area.

Keywords: DEM, SRTM, ASTER, Cartosat, Toposheets

Management of watershed is a key factor that is required for the development of a particular region and research activities regarding the development of watershed is carried out by the study of streams flowing through the region (Suresh et al 2015). In earlier days, drainage for the particular region are digitized manually from SOI Toposheets. Extraction of stream network from Toposheets for a larger area requires huge effort and man work (Bose et al 2012). With the introduction of GIS tools, the extraction of streams network were digitalised but the same amount of man power is required with the knowledge to handle GIS data With the advancement in technology, remote Sensing satellites are widely used in various platforms for management and decision making (Verma et al 2017). DEM obtained from satellite are in grid format with each pixel holding elevation values in it, is widely used for the extraction of watershed, drainage or streams, topographic study, etc. Based on the size pixels in the DEM used, the accuracy of the result varies. Smaller the pixel size higher the accuracy and larger the pixel size lower the accuracy of the delineated streams from DEM. There are several studies, carried out on DEM comparison for various applications like landslides (Vaishnavi et al 2019), flood modelling (Suresh et al 2018), disaster management (Vaishnavi et al 2020), etc. With GIS Tools and DEM, the watershed can be delineated in ease and used for various analysis such as hydrogeological studies, Disaster Management, environmental studies, land use studies (Baral et al 2016).

MATERIAL AND METHODS

Study area: The study was carried for a coverage of 79° 15' E to 79° 30' E Longitude and 12° 45'N to 13°N Latitude focusing on a coverage of a SOI 1:50,000 scale Toposheet (D44T5). The study area covers a portion of Vellore and Tiruvannamalai Districts and has a varying topology with Palar River flowing through it (Fig. 1).

Method: Providing DEM as input, the streams are extracted in GRASS environment by using watershed command. The threshold for the minimum number of pixel in each watershed is provided as 100. DEM is evaluated based on the upslope value based on the D8 flow model based on which the flow direction is generated. Flow model helps to obtain the stream network downslope along the D8 flow direction pixels. Streams are said to move down the slope based on the D8 Flow model until other stream channel is being identified. The pattern continuous to identify the streams through until it creates the flow raster for the whole study area. The flow accumulated from each pixel based on the slope helps in the delineation of streams based on D8 concept (Fig. 2). The process is repeated with SRTM, ASTER and Cartosat DEM and the river network is extracted for the study area. DEM used in the present study are shown in Table 1.

The total number of stream network generated by using Cartosat, SRTM and ASTER DEMs are 8543, 8256 and 10599 respectively with the total length of 16,57,528.43 m, 17,47,783.6 m and 14,83,680.22 m. The average length of the stream network delineated from the open access Cartosat, SRTM and ASTER DEMs are found to be 194.02 m, 211.70 m

and 139.98 m respectively. Considering the total number of streams networks generated in comparison with the stream networks of Toposheet, Cartosat and ASTER streams are found to be less accurate compared to that of the streams delineated using SRTM DEM of 30m resolution. Analysis is performed by generating stream network at different threshold values whereas the results obtained for various DEMs are not

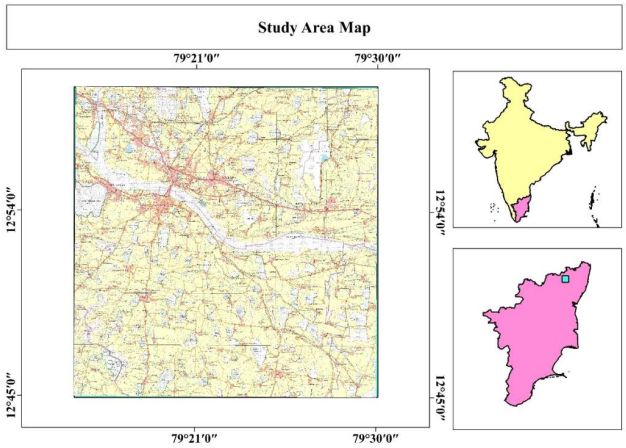


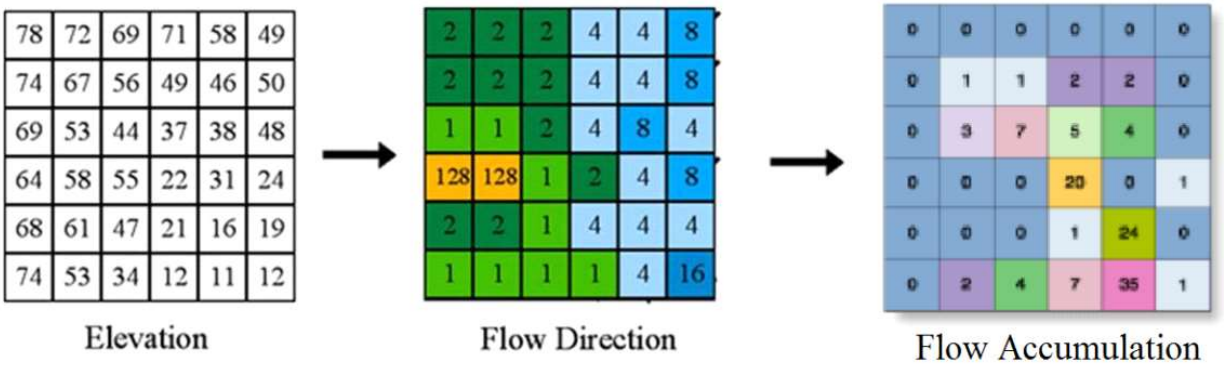
Fig. 1. Geographical location of the study area

Table 1. DEM used in the present study for delineation of stream network

DEM	Spatial resolution (m)	Source	Organisation
Cartosat	30	Bhuvan	ISRO
SRTM	30	USGS Earth Explorer	NGA and NASA
ASTER	30	USGS Earth Explorer	NASA and METI

Table 2. Comparison of the streams obtained from Cartosat, ASTER and SRTM DEM

DEM	Total no. of streams generated	Total length (m)	Mean length (m)
Cartosat	8543	16,57,528.43	194.02
SRTM	8256	17,47,783.6	211.70
ASTER	10599	14,83,680.22	139.98



Source: ArcGIS

Fig. 2. Process of obtaining streams from DEM

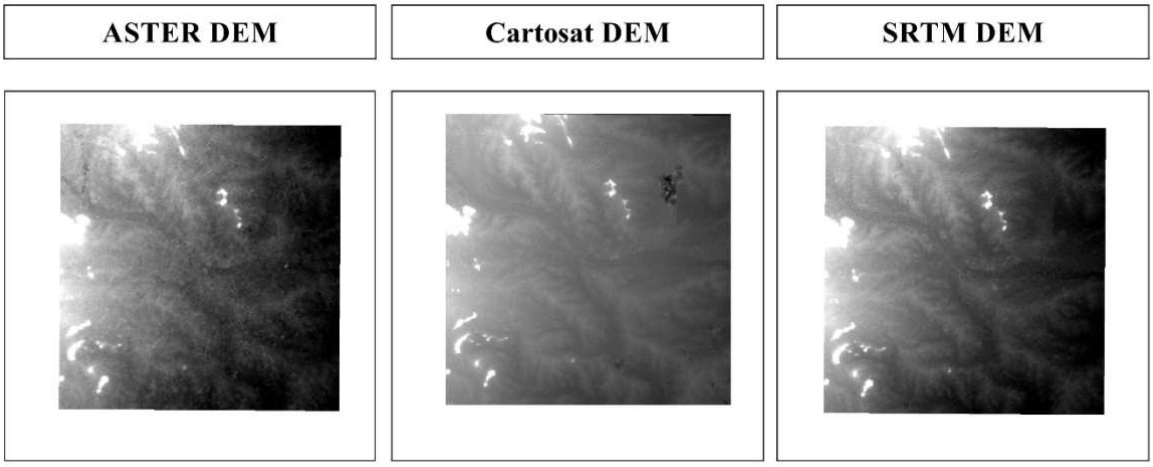


Fig. 3. Various DEM used for the study

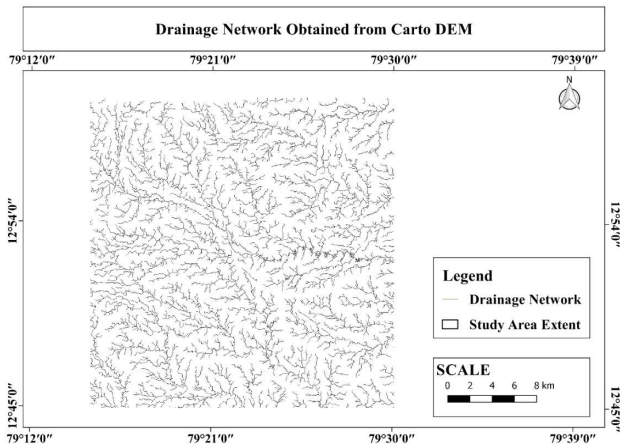


Fig. 4. Drainage network obtained from Cartosat DEM

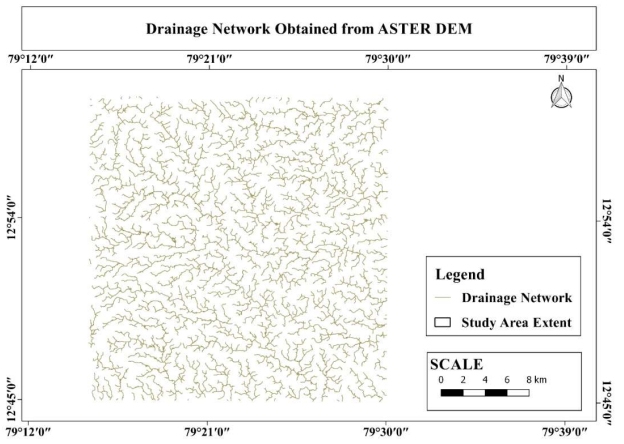


Fig. 5. Drainage network obtained from ASTER DEM

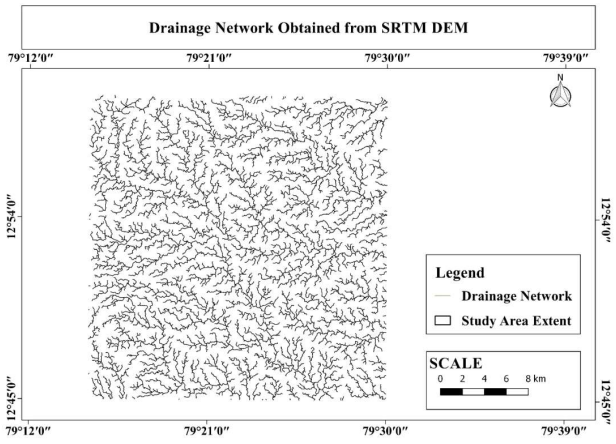


Fig. 6. Drainage network obtained from SRTM DEM

sufficient enough to compare the stream network within the considered study area. Stream network being considered as one of the major input for various analysis, the streams generated at a threshold unit of 100 using SRTM DEM is suggested over the study area compared to Cartosat and ASTER DEM.

CONCLUSION

Results from the study suggested to use SRTM DEM of 30m resolution for various hydrological analysis. The study has to be adopted prior to stream network delineation from DEMs in order to identify the DEM that provides stream network of higher accuracy. It is also recommended to use higher resolution commercial DEMs obtained from Worldview stereo pairs, Cartosat Stereo pairs, TanDEM, etc to obtain finer results.

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Geoinformation Methods for Development of Intensive Animal Husbandry in Catchment Basins of Small Rivers in the Belgorod Region

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Abstract: The article discusses the area of distribution of livestock complexes in Korochansky district of the Belgorod region, as well as in the catchment areas of the rivers (Koren, Korocha, Mokraya Ivitsa and Razumnaya) located on its territory. The quantitative characteristics of manure runoff from livestock complexes in the territory of the studied catchment basins, as well as the specific load of production waste on the catchment area caused by them, are discussed.. The areas of livestock breeding complexes in the basins of the rivers explored were mapped using the high-resolution remote sensing data. Geoprocessing tools helped to figure out the main parameters of the production sites of livestock breeding complexes. This made it possible to calculate the intensity of distributed area loads of livestock waste through the areas of typical production complexes. The obtained indicators served as the basis for modeling the degree of anthropogenic load on the studied catchments. The method of scoring the intensity of the impact of the livestock industry on the river basin structures of the Korochansky district was developed. Based on geoprocessing tools, the maps of anthropogenic load were created. They represent the determined zones of the most significant impact of the livestock industry on the territory of the Korochansky district as well as river catchment basins within this territory. The key assessment factor for territorial distribution of animal waste is to take into account the boundaries of the basin structures. This is due to the fact that livestock wastewater is distributed subject to the relief pattern, and the boundaries of the basins act as barriers to the spread of pollutants.

Keywords: Catchment basins, Small rivers, Intensive animal husbandry, High-resolution space imagery, Pig breeding complexes, Hydroecological situation

The Belgorod Region ranks the first in pig population in the Russian Federation (Expert and Analytical 2020), and the Korocha District is one of the pig breeding development leaders in the Belgorod Region. Having advantageous geographical position, favourable climatic conditions, significant production, economic and human potential as well as experience and traditions of livestock breeding, the Belgorod Region enjoys exceptional opportunities for intensive development of the latter. However, the development of cattle-breeding industry has a significant impact on the natural environment. This is particularly evident in terms of production waste disposal. The impact produced by any livestock-breeding complex on the environmental conditions can be determined by parameters of human-induced atmospheric effects, soil cover, surface and ground waters (Bezuglov 2013, Koronkevich et al 2017). Surface waters, including river waters, are the most accessible type of water resources for economic purposes, but they face the greatest threats in terms of quantitative and qualitative depletion (Gupta et al 2020, Lisetskii 2021). Water bodies are one of the main natural environment elements affected by pollution. Rivers and water runoff can act as sensitive and integral indicators of various natural and economic situations at catchments (Mukharamova et al 2020, Giri 2021, Zhang et al 2021). An integrated approach to the territorial arrangement of catchment areas and the protection of surface waters using geoinformational technologies and remote sensing has already been previously implemented for Belgorod oblast (Lisetskii et al 2014 a, b, Yermolaev et al 2015, Buryak et al 2019).To assess the degree of impact produced by a livestock-breeding complex on the ecological state of water bodies, should know where it located as well as its quantitative characteristics: animal inventory, waste released, waste disposal method, etc. Since such data is confidential, one of the most effective ways for its identification is to interpret high-resolution satellite images of the areas with production site clusters of livestock breeding complexes.

MATERIAL AND METHODS

Study site: In the central part of the Belgorod Region the pig-breeding complexes are predominantly located in the basins of the Koren', Korocha, Mokraya Ivitsa and Razumnaya rivers in the Korocha District. Most of the pig-breeding

complexes are located in the elevated upland areas. The distance between the complexes and the channels of the nearest rivers is within from 1500 to 7000 m. The satellite image of a typical existing pig-breeding complex located on the territory of the Korocha District of the Belgorod Region (the Koren' river basin, Fig. 1).

Using ArcGIS tools, measured the surface areas for the typical production sites of pig-breeding complexes on the high-resolution images (Table 1). Using the official statistical data, calculated the ratio between the area of the swine-production sites and the capacity of the pig-breeding complexes. As a result, with rare exceptions, there are 25 to 30 thousand pigs per 1 conventional typical site of pig-breeding complex in the Korocha District. Figures 2 and 3 show satellite images of cattle and poultry farming units located in the Korocha District of the Belgorod Region.

The lagoons used by cattle breeders for manure management are rectangular in shape, their area is 17,000 to 19,000 m^2 (Fig. 2). Although there are far less cattle breeders on the territory of the Belgorod Region than pig production ones, the related waste can also cause substantial environmental damage to the nearby river basins. Figure 3 shows a satellite image of the poultry farm of Agrofirma Rus JSC located in the settlement of Bekhteevka (the Korocha river basin), the Korocha District, the Belgorod Region. This is the only poultry farm on the territory of the Korocha District. The satellite image shows that the poultry farm is located at a distance of 1,700 meters from the Korocha river bed and has a sizeable poultry stock (772,400 birds). Using satellite images, identified the locations of the production sites of the livestock breeding complexes in the Korocha District of the Belgorod Region. Based on them constructed a map (Fig. 4) and the map showed the site locations of pig-breeding complexes, cattle and poultry farms in the catchment areas of the river basins within the Korocha District. The statistical data on the animal stock available on the territory of the Korocha District as well as in the Koren', Korocha, Mokraya Ivitsa and Razumnaya river basins located within its boundaries is given in Table 2.

The catchment areas are subject to heavy load due to the high concentration of livestock breeding complexes located at small distances from each other as well as because of a large number of livestock heads (especially that of pigs) on the territory of the Korocha District. The level of river basins pollution significantly increases due to the



Fig. 2. Scheme of an agricultural enterprise for breeding large horned cattle on the territory of the Korochansky district Belgorod region. 1 - Premises for the maintenance of cattle, 2-Utility rooms, 3-Lagoons for the liquid fraction of manure



Fig. 1. A typical scheme of a pig-breeding complex on the territory of the Korochansky district of the Belgorod region. 1-Lagoons for the liquid fraction of manure, 2-Valliers for walking animals, 3-Rooms for keeping pigs, 4-Utility rooms



Fig. 3. Scheme of a poultry farm on the territory of the Korochansky district of the Belgorod region. 1-Rooms for raising and keeping birds, 2-Utility rooms, 3-Lagoons for waste

release of a large amount of manure, which is further taken to agricultural fields (Gostischev 2016).

RESULTS AND DISCUSSION

For a typical pig-breeding complex in the Belgorod Region, the manure output was 4.8 kg per day on average for one livestock unit (10 % of the mass), including 0.48 kg of solid waste products (1 % of the mass) and 0.34 kg of volatile waste products (less than 1 %). (Kiselyov Kornilov 2019). For a typical cow house located on the territory of the Belgorod Region, the manure output for one livestock unit is 16.8 kg per day, solid waste is 1.7 kg and volatile waste is 1.1 kg. A typical poultry farm located on the territory of the Belgorod Region produces daily 140 g of droppings, 14 g of solid waste and 9.8 g of volatile waste per livestock unit (Kurepina Kiselyov Kornilov 2019). The waste quantities calculated by us for the pig-breeding complexes located within the catchment basins of the Korocha District mentioned in Table 3.

As a basis for identifying the most polluted areas, the calculated volumes of livestock production waste for each production site within the studied river basins on the territory of the Korocha District were recorded. During the study, used a scoring method to assess the degree of impact made by livestock production on the basin structures of the Korocha District. The method is based on object density analysis performed with the use of ArcGIS tools – "Density of Kernels". The method essentially means that the tool conceptually selects a smooth curved surface for each point. The surface value is maximum at the point location, and reduces with increased distance from the point and reaches zero at a distance equal to the specified radius for search from the point. For each output, raster cell the density value is calculated by adding the values of all kernels at the points where they overlap the raster cell centre. The kernel function is based on the quartet kernel function. The number of point counts is subject to the value specified in the weight field, which have set as waste volume; this makes it possible both to show the load in terms of the number of sites and to take into account the related animal stock. This method distributes phenomena over the surface and identifies the scope of the studied phenomenon for each location and spatially related measurable values. The sites density of the livestock breeding complexes with due account for waste volume at

Table 1. Areas of pig production facilities

River basin	Total area of the site (ha)	Area of production premises (ha)	The area of the lagoon (ha)
Mokraya Ivitsa	6.7	2.9	3.8
Koren	7.0	4.0	3.0
Korocha	7.6	4.6	3.0
Razumnaya	7.4	4.0	3.4
Korochansky district	7.2	3.9	3.3

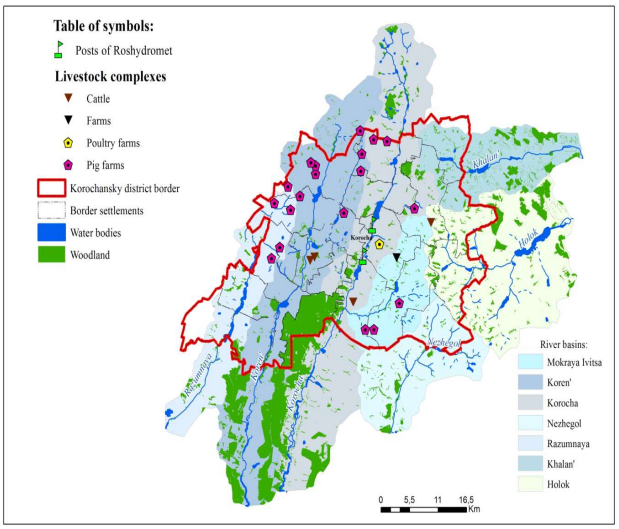


Fig. 4. Placement of livestock breeding grounds on the territory of the catchment basins of the Korochansky district rivers

Table 2. Presence of pigs, cattle and poultry in agricultural enterprises in the territory of the Korochansky district and in the catchment basins of rivers

Location of site	Pig farms, number of heads, units	Large horned cattle, number of heads, units	Poultry farms, number of heads, units
Korochansky district (1 417 km ^{2})	515237	9 171	772400
The site of the catchment area of the Koren river on the territory of the Korochansky district (410, 3 km^2)	168238	4635	–
Site of the catchment area of the Korocha river on the territory of the Korochansky district (325,3 km^2)	85840	1389	772400
Site of the catchment area of the Mokraya Ivitsa river on the territory of the Korochansky district (266 km^2)	153655	2045	–
Site of the catchment area of the Razumnaya river on the territory of the Korochansky district (173 km^2)	105026	–	–

Table 3. Waste output from pig-breeding complexes, cattle and poultry of the Korochansky district (per day, per year)

District, square	Waste	Per day	Per year
Pig-breeding complexes			
Korochansky district (1 417 km^2)	Daily manure waste	2 473 t (1.8 t km^{-2})	902 695 t (637 t km^{-2})
	Solid waste	247,3 t (0.18 t km^{-2})	90 264,5 t (63.7 t km^{-2})
	Volatile waste	175,2 t (0.12 t km^{-2})	63 948 t (45,1 t km^{-2})
Site of the catchment area of the Koren river on the territory of the Korochansky district (410, 3 km^2)	Daily manure waste	808 t day^{-1} (2 t km^{-2})	294 920 t year^{-1} (718,8 t km^{-2})
	Solid waste	80,8 t (0.2 t km^{-2})	29 492 t (71,9 t km^{-2})
	Volatile waste	57.2 t (0.14 t km^{-2})	20 878 t (50.9 t km^{-2})
Site of the catchment area of the Korocha river on the territory of the Korochansky district (325,3 km^2)	Daily manure waste	412 t (1,3 t km^{-2})	150 380 t (462.3 t km^{-2})
	Solid waste	41,2 t (0.13 t km^{-2})	15 038 t (46.2 t km^{-2})
	Volatile waste	29,2 t (0.09 t km^{-2})	10 652 t (32.7 t km^{-2})
Site of the catchment area of the Mokraya Ivitsa river on the territory of the Korochansky district (266 km^2)	Daily manure waste	738 t (2.8 t km^{-2})	269 204 t (1 012 t km^{-2})
	Solid waste	73,8 t (0.28 t km^{-2})	26 920 t (101 t km^{-2})
	Volatile waste	52 t (0.19 t km^{-2})	18 980 t (69.4 t km^{-2})
Site of the catchment area of the Razumnaya river on the territory of the Korochansky district (173 km^2)	Daily manure waste	504 t (2.9 t km^{-2})	183 960 t (1 058.5 t km^{-2})
	Solid waste	50,4 t (0.29 t km^{-2})	18 396 t (105.9 t km^{-2})
	Volatile waste	35,7 t (0.21 t km^{-2})	13 031 t (75.3 t km^{-2})
Cattle			
Korochansky district (1 417 km^2)	Daily manure waste	154,1 t (0,1 t km^{-2})	56 237 t (40 t km^{-2})
	Solid waste	15,6 t (0,01 t km^{-2})	5691 t (4 t km^{-2})
	Volatile waste	10,1 t (0.007 t km^{-2})	3 682 t (2,6 t km^{-2})
Site of the catchment area of the Koren river on the territory of the Korochansky district (410, 3 km^2)	Daily manure waste	78 t (0,2 t km^{-2})	28 422 t (69,3 t km^{-2})
	Solid waste	7,9 t (0.02 t km^{-2})	2 876 t (7 t km^{-2})
	Volatile waste	5.1 t (0.01 t km^{-2})	1 861 t (4,5 t km^{-2})
Site of the catchment area of the Korocha river on the territory of the Korochansky district (325,3 km^2)	Daily manure waste	23,3 t (0,07 t km^{-2})	8 517,3 t (26,2 t km^{-2})
	Solid waste	2,4 t (0,007 t km^{-2})	862 t (2,7 t km^{-2})
	Volatile waste	1,5 t (0.005 t km^{-2})	547,5 t (1,7 t km^{-2})
The site of the catchment area of the Mokraya Ivitsa river on the territory of the Korochansky district (266 km^2)	Daily manure waste	34,4 t (0.13 t km^{-2})	12 556 t (47,2 t km^{-2})
	Solid waste	3,5 t (0,013 t km^{-2})	1 277 t (4,8 t km^{-2})
	Volatile waste	2,3 t (0,008 t km^{-2})	840 t (5,2 t km^{-2})
Poultry			
Korochansky district (1 417 km^2)	Daily manure waste	108,1 t (0,08 t km^{-2})	39 457 t (27,8 t km^{-2})
	Solid waste	10,8 t (0,008 t km^{-2})	3 945 t (2,8 t km^{-2})
	Volatile waste	7,6 t (0.005 t km^{-2})	2 774 t (1,8 t km^{-2})
The site of the catchment area of the Korocha river on the territory of the Korochansky district (325,3 km^2)	Daily manure waste	108,1 t (0,33 t km^{-2})	39 457 t (121,3 t km^{-2})
	Solid waste	10,8 t (0,03 t km^{-2})	3 945 t (12,1 t km^{-2})
	Volatile waste	7,6 t (0.02 t km^{-2})	2 774 t (8,5 t km^{-2})

each site within the Korocha District. The results are presented in the form of a grid, which was classified into six types to identify load scores where 1 point corresponds to the load value of up to 1,000 kg km^{-2} of livestock wastewater (Fig. 5).

The distribution of waste water from the livestock breeding located within the basin structures with due account for the relief aspects on the territory of the Korocha District was obtained by integrating all density distribution grids for livestock farms per each individual basin, which made it possible to take into account the principle of mass transfer within the basin structures (Fig. 6).

The areas of the highest man-induced impact made by the livestock grounds through calculation of the density of the sites for livestock breeding complexes with due account for waste quantity factor was identified. The highest anthropogenic impact is produced on the catchment areas of the Koren', Korocha and Razumnaya rivers in the north-western part of the Korocha District because 12 pig production sites are accumulated there. The level of man-induced load from manure runoff was 6 tons km^{-2} there. The small area in the south of the Korocha District in the Mokraya Ivitsa river basin where there is also a high level of human-induced load made by manure runoff – 6 tons km^{-2}. However, this is due to a significant livestock population – 153,655 pig heads rather than because of the number of production sites

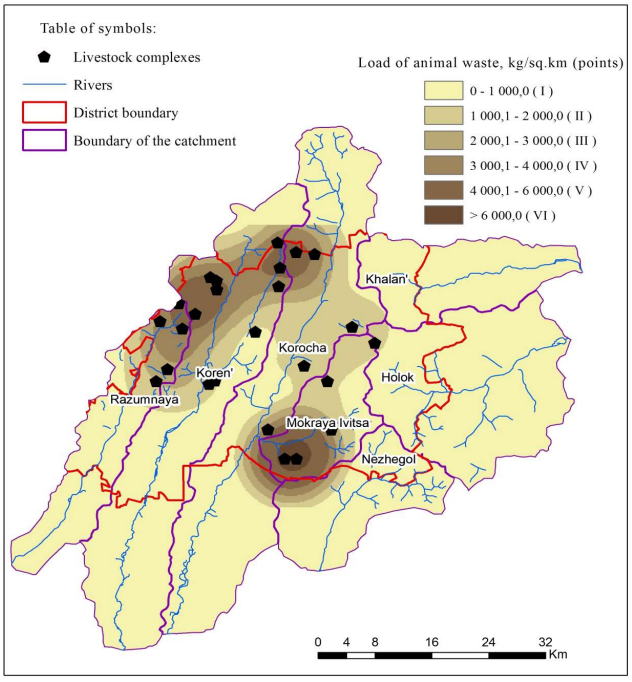


Fig. 5. Load of livestock waste on the territory Korochansky district of the Belgorod region

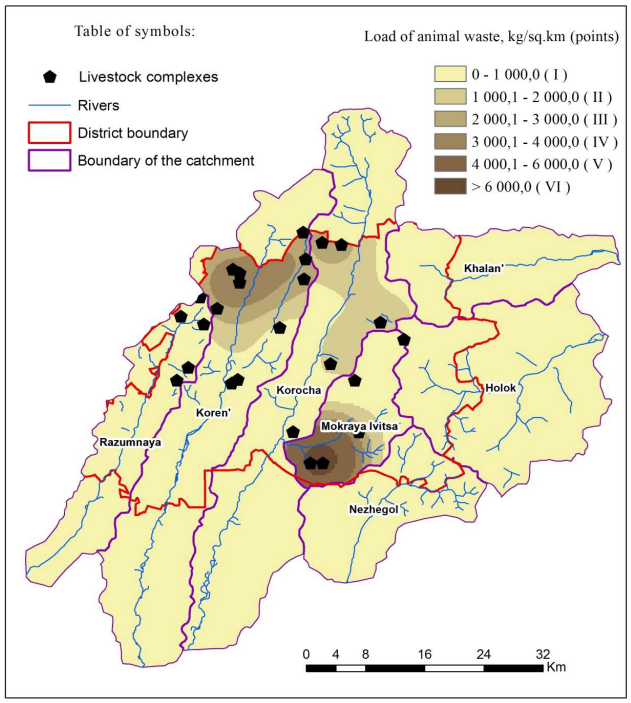


Fig. 6. Load of livestock waste on the basin structures of the Korochansky district of the Belgorod region

of pig-breeding complexes in this area (3 units). Although similar results obtained by comparing the two maps with slight deviations between the Korocha and Koren' river basins. This is due to significant number of production sites of pig-breeding complexes located in the watershed areas of these rivers. In the absence of mass runoff migration factor and taking into account the terrain relief the production sites can give fictitious picture because the Korocha and Koren' river basins are in close proximity and, as a result, the sites are located at a minimum distance from each other within the boundaries of their basins.

CONCLUSION

An intensive development of livestock industry is one of the main factors for worsened hydro-ecological situation in the basins of the Region's small rivers. The main volumes of information related to livestock production are confidential, which makes geo-information research methods to be the basic ones to study this problem. It is advisable to assess the human-induced load from livestock breeding complexes as point-type objects with the use of the density tools of geo-information systems, which take into, account not only their locations and quantity but also volumes of waste produced by each complex. During approbation of methods for assessing the man-made load from livestock breeding complexes it was found that the key assessment factor for territorial distribution

of animal waste is to take into account the boundaries of the basin structures.

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Karyotypic Analysis of Freshwater Crab, *Maydelliathelphusa masoniana* (Henderson, 1893) from Jammu Region of J&K

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Abstract: Present communication is the first report on the cytological and karyotypic analysis of an ecologically and economically important species of freshwater crab, *Maydelliathelphusa masoniana* (Decapoda: Brachyura) from India. Such aspects of freshwater crabs, in particular, have been least investigated probably because of the comparatively small size of their chromosomes which pose a significant problem in handling the material. Colchicine treatment of 48 hrs gave efficient results in respect of the degree of condensation of chromosomes. The cytogenetic study revealed the diploid number of 96 chromosomes and sex chromosomes were indistinguishable. The karyotype indicated the presence of 8 metacentric, 1 sub-metacentric, and 39 telocentric chromosome pairs. The haploid karyotypic formula for *Maydelliathelphusa masoniana* could be inferred as n = 8m+1sm+39t. The length of the chromosome varied from 0.35µm to 1.15µm. The present study will help in planning intra and interspecific hybridization/breeding programmes besides solving various taxonomic ambiguities.

Keywords: Cytogenetics, *Maydelliathelphusa masoniana*, Freshwater crab, Karyotype, Idiogram

Within Crustacea, the most species-rich order is Decapoda and despite being ecologically and economically important there is very limited knowledge regarding their karyology. This extremely multifarious group plays an important role in the aquatic trophic relationships and a variety of them are economically significant as they are used for human consumption, for the treatment of stomach and respiratory ailments in different countries around the world. In the freshwater ecosystem, they shred the leaf litter and dead remains of animals into small pieces, thus play a significant role in nutrient recycling. Despite the importance of this group, cytogenetic studies of crustaceans have less been investigated owing to the difficulty encountered while handling the decapod chromosomes as these are usually small-sized, numerous, and highly condensed (Gonzalez-Tizon et al 2013 and Phimphan et al 2018). Decapods have the highest number of chromosomes in the animal kingdom. Large differences in the number of chromosomes are found even among the related decapod species. Crabs are found both in the marine and freshwater ecosystems. At the global level, freshwater crabs make up 1564 species placed in six families.

Maydelliathelphusa masoniana (Fig. 1) is a freshwater crustacean along Ganga and Brahmaputra valleys ranging from Punjab to Nagaland (Brandis and Sharma 2005). From the Jammu district, this species has been reported from the Gho-Manhasan stream and the Chakrali stream (Bandral et al 2014). It belongs to the family Gecarcinucidae, infra-order Brachyura of the order Decapoda in the class of Malacostraca of the sub-phylum Crustacea. *Maydelliathelphusa masoniana* is a commonly occurring dark- chocolate brown colored, bearing heterochelous chelas in both sexes. Carapace width and chela length are bigger in males than females. During the daytime, they prefer to live in the burrows closer to the water level and at night they come out for feeding. Freshwater crabs are the efficacious bio-indicators of a multitude of environmental factors. They are good indicators of the pollution of water bodies, so knowledge about their distribution and ecology is paramount. Some important cytological investigations on crustaceans are those made by various workers (Ashraf et al 2010, Radwan et al 2014, Swagatika and Kumar 2014, Jara-Seguel et al 2020, Iannucci et al 2020 and Jasrotia and Langer 2021). Karyotyping and molecular markers are significant taxonomic tools for evaluating the diversity between the species, subspecies, and population (Kore et al 2016, Kumar et al 2017, Mir et al 2017 and Omar et al 2019). Karyotyping can be used to determine the fundamental information about the number, size, and morphology of chromosomes. The present finding is the first report on the various meiotic stages, karyotype, and standardized idiogram of *Maydelliathelphusa masoniana* from J&K UT.

MATERIAL AND METHODS

Specimens of *Maydelliathelphusa masoniana* used in this study were collected from the Gho-Manhasan stream

(30° 67' N latitude and 74° 79' E longitude), located at a distance of 12 km from the University of Jammu. This stream is being fed from the river Chenab. Crabs were collected by netting with the help of a local fisherman or by dipping the hand into the burrow gently. The samples were transported alive to the laboratory and were kept in an aerated aquarium. Identification of species was done following Kour et al (2019). Adult crabs were injected with 0.1% colchicine solution and were allowed to swim in the water. After 48 hrs of colchicine treatment, the testes were taken out and immersed in 0.8% KCl for 50 minutes at room temperature. The tissues were then fixed thrice in freshly prepared Carnoy's fixative (methanol: glacial acetic acid 3:1), each treatment lasting for 10 minutes. Fixed tissues were then centrifuged three times at 1000rpm for 5 minutes. After that supernatant was decanted and new Carnoy's fixative was added. Two to three drops of suspension of cells were put on a slide glass and inflamed immediately. After air-drying, the slides were stained using 10% Giemsa stain solution. The stained slides were rinsed using distilled water and allowed to air-dry. The slides were observed under Olympus camera-aided microscope with 1000x magnification. Well spread metaphase plates were selected for subsequent photomicrography. The metaphase chromosomes were classified based on chromosome arm ratio (Levan et al 1964). Measurement of chromosomes including the length of the long arm, length of the short arm, total length, and arm ratio were calculated using an occulometer and depicted in Table 3. Idiogram of the chromosome pairs was constructed to show the relative size of the chromosomes.

RESULTS AND DISCUSSION

Out of 63 spermatogonial metaphase plates observed (Table 1), 34 plates had 96 chromosomes, while 2 had 95, 5 had 94, 4 had 92, 2 had 90, 3 had 89, 4 had 88, 1 had 97, 5 had 98 and the rest 3 had 100 chromosomes. Therefore, the modal diploid chromosome number of this species was determined to be 2n=96 (Fig. 2a) and out of 63 cells, the modal diploid cells percentage was 53.97%. Most of the chromosomes were telocentric varying from rod to dot shape. Out of 55 meiotic spermatocytes metaphase plates observed (Table 2), 29 plates had 48 chromosomes, 2 had 47, 5 had 46, 1 had 44, 3 had 42, 7 had 50, 4 had 52, 2 had 53 and the rest 2 had 54 chromosomes. The modal haploid cells percentage was 52.73% so the modal haploid chromosome number of the species is n=48 (Fig. 2b). The chromosomes were round to dot-shaped.

Hence the chromosome number of this species is 2n=96 (Fig. 3a) with the karyotype (Fig. 3b) consisting of 8 metacentric, 1 sub-metacentric, and 39 telocentric



Fig. 1. *Maydelliathelphusa masoniana* **(**Adult male crab)

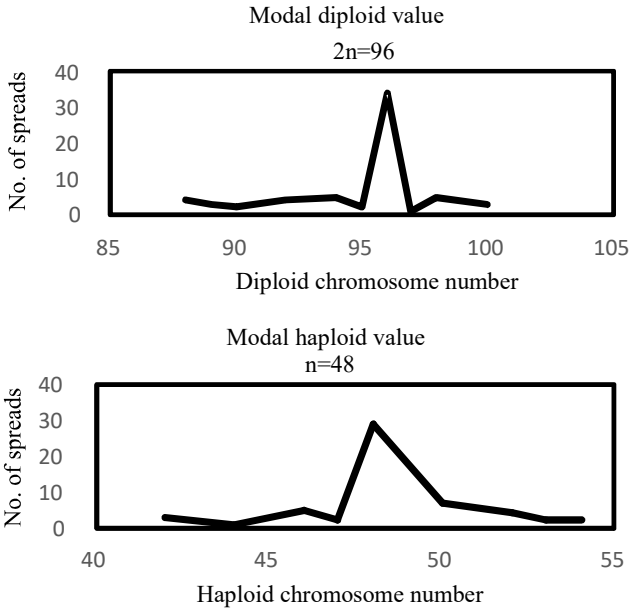


Fig. 2a. 2n values of 63 metaphase spreads representing modal diploid value, b n values of 55 metaphase spreads representing modal haploid value

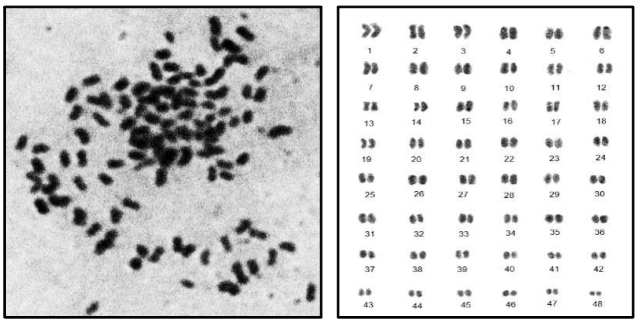


Fig. 3a. Spermatogonial metaphase complement from the testicular tissue, b. Karyotype (2n=96) of *Maydelliathelphusa masoniana*

chromosome pairs. The relative length percentage of the chromosomes of this species varied from 3.38 to 1.03 from the largest to the shortest chromosome pairs (Table 3). The absolute length of the longest and shortest chromosome was 1.15µm and 0.35 µm respectively. The ratio of the longest to the shortest chromosome was 3.28. The mean haploid length was found to be 33.93µm. Arm ratio of chromosomes ranged between 1 to ∞. Histogram was prepared based on decreasing order of their length by taking chromosome pair number on X-axis and relative percentage length on Y-axis (Fig. 4a). Construction of the idiogram of the chromosome pairs was done to represent the shape and size of the chromosomes (Fig. 4b). In the present study, neither of the chromosome so particular in shape and behavior during meiotic phases was found which could be considered as sex chromosomes, such an observation is in accordance with those reported for the other related species like *Scylla serrata, Portunus pelagicus, Barytelphusa cunicularis* in which sex chromosome is cytologically indistinguishable (Swagatika and Kumar 2014, Indhumathi et al 2018). Various meiotic stages (Fig. 5), leptotene (characterized by long and thin filament-like chromosomes), zygotene (chromosomes were thread-like), pachytene (chromosomes were thicker and shorter than in the zygotene), diplotene (chromosomes were held by chiasmata), and metaphase-II (with 48 chromosomes) were observed.

Table 1. Diploid chromosome number of *Maydelliathelphusa masoniana*

Metaphase spreads	Diploid number (2n)	Percentage
4	88	6.35
3	89	4.76
2	90	3.17
4	92	6.35
5	94	7.94
2	95	3.17
34	96	53.97
1	97	1.59
5	98	7.94
3	100	4.76
63		100

Table 2. Haploid chromosome number of *Maydelliathelphusa masoniana*

Metaphase spreads	Haploid number (n)	Percentage
3	42	5.45
1	44	1.81
5	46	9.09
2	47	3.64
29	48	52.73
7	50	12.73
4	52	7.27
2	53	3.64
2	54	3.64
55		100

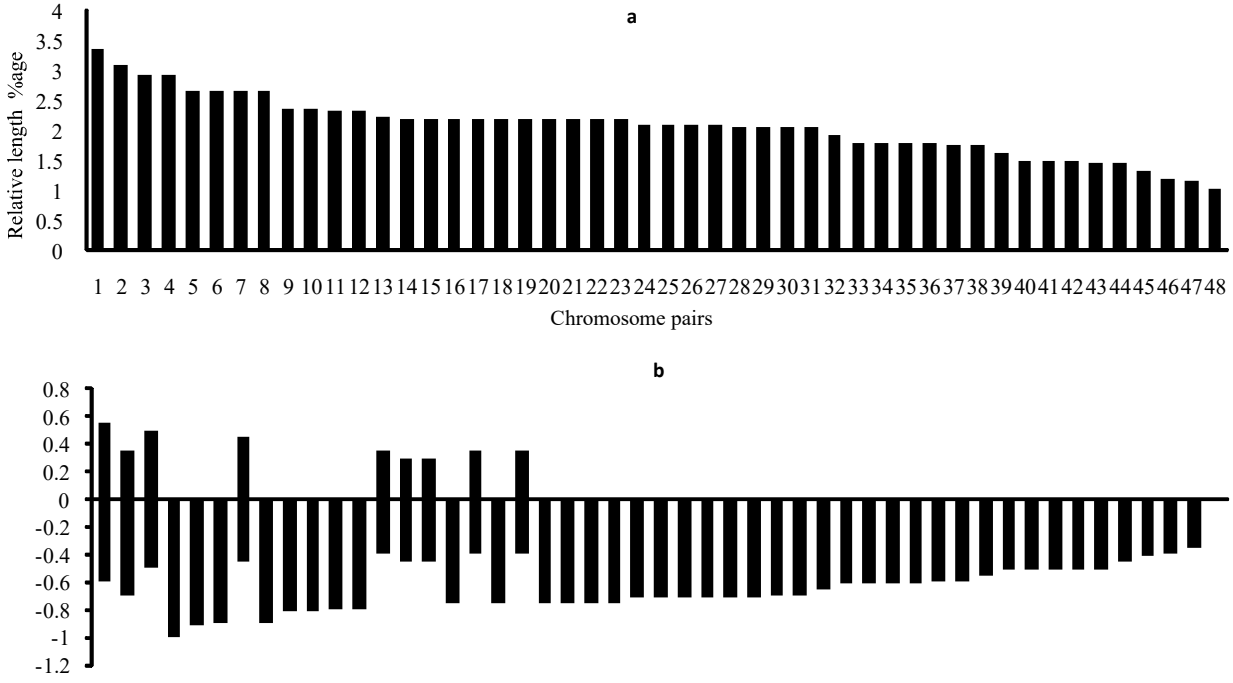


Fig. 4. *Maydelliathelphusa masoniana* a. Histogram b. Idiogram (Short arm (µm) above the axis and the long arm (µm) below the axis)

Table 3. Morphometric data of karyotype of *Maydelliathelphusa masoniana*

Chromosome pair number	Mean length of the short arm (p) in µm	Mean length of the long arm (q) in µm	Absolute length (p+q) of the chromosome in µm	Arm ratio (q/p)	Relative length percentage	Centromeric index	Nomenclature
1.	0.55	0.6	1.15	1.09	3.38	47.82	Metacentric
2.	0.35	0.7	1.05	2	3.09	33.33	Sub-metacentric
3.	0.5	0.5	1	1	2.94	50	Metacentric
4.	-	1	1	∞	2.94	0	Telocentric
5.	-	0.91	0.91	∞	2.68	0	Telocentric
6.	-	0.905	0.905	∞	2.66	0	Telocentric
7.	0.45	0.45	0.9	1	2.65	50	Metacentric
8.	-	0.9	0.9	∞	2.65	0	Telocentric
9.	-	0.81	0.81	∞	2.38	0	Telocentric
10.	-	0.805	0.805	∞	2.37	0	Telocentric
11.	-	0.8	0.8	∞	2.35	0	Telocentric
12.	-	0.8	0.8	∞	2.35	0	Telocentric
13.	0.355	0.4	0.755	1.13	2.22	47.02	Metacentric
14.	0.3	0.45	0.75	1.5	2.21	40	Metacentric
15.	0.3	0.45	0.75	1.5	2.21	40	Metacentric
16.	-	0.75	0.75	∞	2.21	0	Telocentric
17.	0.35	0.4	0.75	1.14	2.21	46.66	Metacentric
18.	-	0.75	0.75	∞	2.21	0	Telocentric
19.	0.35	0.40	0.75	1.14	2.21	46.66	Metacentric
20.	-	0.75	0.75	∞	2.21	0	Telocentric
21.	-	0.75	0.75	∞	2.21	0	Telocentric
22.	-	0.75	0.75	∞	2.21	0	Telocentric
23.	-	0.75	0.75	∞	2.21	0	Telocentric
24.	-	0.71	0.71	∞	2.09	0	Telocentric
25.	-	0.71	0.71	∞	2.09	0	Telocentric
26.	-	0.71	0.71	∞	2.09	0	Telocentric
27.	-	0.71	0.71	∞	2.09	0	Telocentric
28.	-	0.705	0.705	∞	2.07	0	Telocentric
29.	-	0.705	0.705	∞	2.07	0	Telocentric
30.	-	0.7	0.7	∞	2.06	0	Telocentric
31.	-	0.7	0.7	∞	2.06	0	Telocentric
32.	-	0.655	0.655	∞	1.93	0	Telocentric
33.	-	0.61	0.61	∞	1.79	0	Telocentric
34.	-	0.61	0.61	∞	1.79	0	Telocentric
35.	-	0.61	0.61	∞	1.79	0	Telocentric
36.	-	0.61	0.61	∞	1.79	0	Telocentric
37.	-	0.6	0.6	∞	1.76	0	Telocentric
38.	-	0.6	0.6	∞	1.76	0	Telocentric
39.	-	0.55	0.55	∞	1.62	0	Telocentric
40.	-	0.51	0.51	∞	1.50	0	Telocentric
41.	-	0.51	0.51	∞	1.50	0	Telocentric
42.	-	0.51	0.51	∞	1.50	0	Telocentric
43.	-	0.505	0.505	∞	1.48	0	Telocentric
44.	-	0.505	0.505	∞	1.48	0	Telocentric
45.	-	0.455	0.455	∞	1.34	0	Telocentric
46.	-	0.405	0.405	∞	1.19	0	Telocentric
47.	-	0.4	0.4	∞	1.17	0	Telocentric
48.	-	0.35	0.35	∞	1.03	0	Telocentric

Table 4. Cytogenetic studies of various crab species

Species	Diploid number	Karyotypic formula (n)	References
Sudanonautes aubryi	66	m+a	Awodiran et al (2016)
Acanthotelphusa martensi	88	-	Vishnoi (1972)
Portunus pelagicus	102	4m+24sm+23t	Ashraf et al (2010)
Scylla tranqubarica	102	-	Gopikrishna and Shekhar (2003)
Scylla serrata	106	-	Gopikrishna and Shekhar (2003)
Portunus trituberculatus	106	20m+3sm+30t	Zhu et al (2005)
Charybdis japonica	114	17m+7sm+1st+32t	Yan et al (2009)
Barytelphusa cunicularis	128	7m+1sm+56t	Indhumathi et al (2018)
Eriocheir japonica	146	-	Lee et al (2004)

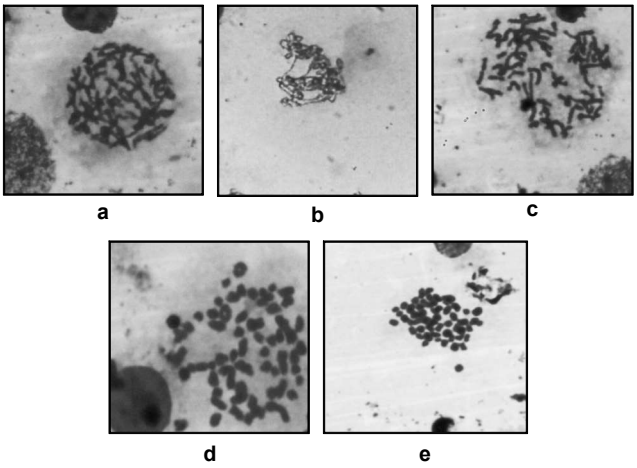


Fig. 5. Various meiotic stages observed in *Maydelliathelphusa masoniana*. a. leptotene, b. zygotene, c. pachytene, d. diplotene, e. metaphase II stage

Rapidly growing tissues are apt to acquire the well-spread metaphase plates for karyological analysis (Tan et al 2004 and Radwan et al 2014). The data obtained draws support from the earlier studies that revealed the provision of testis tissue to be used for chromosomal analysis as it is the source of both the meiotic and mitotic metaphases (Awodiran et al 2016 and Milnarec et al 2016). The preliminary work in this study was to determine the combination of colchicine level and the time required for acquiring good metaphase spreads. Different levels of colchicine 0.1%, 0.5%, and 0.01% were tried with varying treatment periods (12 hrs, 24hrs, and 48 hrs). A combination of 0.1% colchicine at the rate of 0.075ml for 80.725 grams of body weight for 48 hours gave satisfactory results. The study on the chromosomes of crustaceans has manifested expansive variations due to their large number and small size. The Brachyura display a broad span of chromosome number from 66 (Awodiran et al 2016) to 146 (Lee et al 2004). In previous studies, the number and appearance of chromosomes of various crab species were metacentric, submetacentric, and telocentric and most of these are telocentric (Table 4). Great disparities in the number of chromosomes even among the related species have been found. *Barytelphusa cunicularis,* a freshwater crab belonging to the same family as *Maydelliathelphusa masoniana i.e.,* Gecarcinucidae has 128 chromosomes, and are metacentric, submetacentric, and telocentric (Indhumathi et al 2018), thus depicting the variations in the chromosome number of crabs belonging even to the same family suggesting that within a family, genetically different species exist. The present study is the first attempt to document the karyotype and various meiotic stages of this freshwater crab species from the Jammu region and the diploid chromosome number was found to be 2n=96.

CONCLUSIONS

Testicular tissues administered with 0.1% colchicine for 48 hrs with 50 minutes of hypotonic treatment, and after that fixation and staining for 30 minutes are highly advocated for cytological analysis of *Maydelliathelphusa masoniana* and give the apt metaphase spreads for analyzing the karyology in the freshwater crab. 2n=96, with 8 metacentric, 1 sub-metacentric, and 39 telocentric chromosome pairs is the karyotype of the freshwater crab, *M. masoniana* as established and authenticated by the above said method.

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Diversity and Distribution of Trichoptera in Three Streams of Eastern Ghats, India

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Abstract: The present work was carried out from October 2017 - February 2018 to contemplate the diversity and distribution of caddis fly larvae in Manikyan kada, Ayyanar, and Siruaruvi streams of Eastern Ghats. Canonical correspondence analysis was used to find the relationship between ecological attributes and caddis fly larvae. A total of 749 individuals belonging to fourteen genera and eight families were collected during the study. Hydropsychidae was found to be the more dominant taxa in all three streams. The diversity indices values show that Siruaruvi falls was the most diverse among the three streams. Temperature, pH, rainfall, and DO become the most important element in governing the diversity and distribution of trichopterans in the three streams. CCA results reveal that taxa *Cheumatopsyche* sp becomes the most dominant taxa due to their high degree of survival to a wide range of water quality parameters.

Keywords**:** *Cheumatopsyche*, Hydropsychidae, Temperature, pH

Trichopterans are also known as caddis flies, larvae of caddis flies are aquatic and they mostly reside in the freshwater habitat. It serves as potential bio indicators of good water quality and they are sensitive to anthropogenic impacts (Chang et al 2014). Currently, there are about 16,000 species described which makes them as seventh abundant insect order in the world and the second most abundant aquatic insects. Other than bio monitoring activity, they do certain important roles in food webs of the freshwater ecosystem, climatic changes effects in the lotic environment and also helpful in forensic investigations by their scavenging activity and cases build by them. Trichopterans in conjunction with other aquatic insect orders like Ephemeroptera and Plecoptera serve as excellent bio indicators to assess aquatic biodiversity and stream health (Anbalagan and Dinakaran 2006).

Indian trichopterans comprise about 28 families, compare to North India, Southern parts of India were exposed less in the light of the taxonomy of trichopterans. The larval taxonomy is poorly studied in trichopterans due to a lack of knowledge and the difficulty in associating larvae with adults. Only a few works have been done in the taxonomy and ecology of Trichoptera in the Eastern and the Western Ghats of Southern India such as the spatiotemporal distribution of larvae in the Western Ghats of peninsular India (Dinakaran and Anbalagan 2010), description of new species of *Lepidostoma* from Alagar hills (Dinakaran et al 2013) and little reports from southern Eastern Ghats (Dinakaran and Anbalagan 2010, Srinivasan et al 2019). Canonical correspondence analysis (CCA) was used to find the relationship between environmental attributes and the trichopteran population (Dinakaran and Anbalagan 2010). So this investigation means to contemplate the diversity and distribution of caddis fly larvae and CCA was used to find the relationship between ecological attributes and caddis fly larvae.

MATERIAL AND METHODS

Study area: The selected areas of study were Karanthamalai manikyan kada waterfalls, Iyyanar falls, Siruaruvi on the Eastern Ghats of Tamil Nadu from October 2017 to February 2018. The latitude and longitude of the three streams were 10º32' N 78º23' E, 10º32' N, 78º19' E, and 10º10' N, 78º21' E, respectively.

Sampling: Physico-chemical parameters of stream water were analyzed following APHA (2005). In riffle samples, caddis flies larvae were collected utilizing180-µm-mesh kick-nets, 500-µm-mesh dip nets were utilized for pool inspecting, and handpicking was also made. All caddis fly larvae were distinguished to the least conceivable taxonomic level using available keys (Wiggins et al 1994, Dudgeon 1999). The collected larvae were preserved in 80 % alcohol.

Data analysis: The statistical analysis such as Shannon and Simpson indices and CCA were done with the help of PAST 4.02 software packages (Hammer et al 2001).

RESULTS AND DISCUSSION

Sampling trichopteran immature from October 2017 - February 2018 resulted in a total of 749 individuals belonging to fourteen genera and eight families from Manikyan kada, Ayyanar, and Siruaruvi streams (Table 1). In the three streams, Siruaruvi has more diverse taxa in all three months of sampling whereas Manikyan kada supports less diverse taxa in February 2018 consists of only eight genera. Among the eight families, Leptoceridae and Hydropsychidae were the most diverse families, which holds four and three genera respectively in Siruaruvi falls, whereas Hydropsychidae was the most diverse family in Manikyan kada and Ayyanar falls. Hydropsychidae was the more dominant taxa in all three streams consisting of 126 individuals in Siruaruvi falls, 99 individuals in Manikyan kada stream, and 73 individuals in Ayyanar falls. The same trend was observed by Henriques-Oliveira et al (2015), indicating, Hydropsychidae is the most dominant taxa.

Shannon and Simpson's indices indicate the total amount of diversity that exists in the ecosystem. Shannon index was highest in October 2017 of Siruaruvi falls indicating the presence of higher diversity of trichopterans in the ecosystem and lowest in February 2018 of Manikyan kada stream. The same trend was seen in Simpson's index also as the value tends to be highest in October 2017 of Siruaruvi falls and it is lowest in February 2018 of Manikyan kada stream (Table 2). On the whole, these diversity indices show that Siruaruvi falls were the most diverse among the three streams and it supports 13 genera of trichopterans in all three months, whereas the other two streams show little changes in diversity in various months. The reason for the loss of abundance of trichopterans in all the three streams in February is due to fact that it was a post-monsoon period that lacks rainfall and trichopterans show a high level of positivity towards low rainfall period compared to high rainfall and dry seasons (Kim et al 2018). The present study also substantiates with that, as the taxa tend to increase in the low rainfall month of December whereas low diversity was seen in the high rainfall (October) and dry period (February).

Water quality parameters form a most important element in controlling the population dynamics of all the aquatic insects and results also substantiate that as trichopterans show variation in diversity and distribution with water quality parameters (Table 3). The pH of running waters ranges from

Table 1. Number of trichoptera larvae collected from three streams of Eastern Ghats

Family	Genus and species	Manikyan kada			Ayyanar falls			Siruaruvi		
		October	December	February	October	December	February	October	December	February
Rhyacophilidae	*Rhyacophila* sp	10	12	4	12	11	11	13	17	11
Philopotamidae	*Wormaldia* sp	7	7	2	6	7	2	5	9	3
	Chimarra sp	4	9	0	1	3	0	4	3	1
Polycentropodidae	*Polycentropus* sp	8	12	3	12	16	6	9	14	5
Hydropsychidae	*Hydropsyche* sp	12	22	10	8	14	10	18	19	9
	Cheumatopsyche sp	14	25	12	13	15	7	19	29	17
	Macrostemum sp	0	4	0	0	5	1	5	8	2
Lepidostomatidae	*Lepidostoma* sp	7	7	3	5	9	2	6	9	6
Leptoceridae	*Adicella* sp	0	2	0	0	3	0	4	5	2
	Leptocerus sp	4	4	0	4	7	4	5	9	7
	Oecetis sp	0	0	0	0	0	0	1	3	1
	Setodes sp	0	0	0	0	0	0	2	5	1
Glossosomatidae	*Agapetus* sp	8	12	2	1	0	2	0	0	0
Stenopsychidae	*Stenopsyche kodaikanalensis*	5	8	1	0	0	0	8	13	5
	No of individuals	79	124	37	62	90	45	99	143	70
	No of taxa	10	12	8	9	10	9	13	13	13

Table 2. Diversity Indices of three streams of Eastern Ghats

Diversity indices	Manikyan kada			Ayyanar falls			Siruaruvi		
	October	December	February	October	December	February	October	December	February
Shannon Index (H)	2.22	2.28	1.78	1.96	2.16	1.95	2.32	2.37	2.23
Simpson Index (1-D)	0.88	0.88	0.79	0.84	0.87	0.83	0.88	0.89	0.86

6.5 to 7.5 and falls within the limit except in the February of Manikyan kada stream and Ayyanar falls. The reason for this is because of detergents and soap use by the tribal peoples to bath and washes the clothes. In the monsoon period, due to high water flow, this polluted water runs off easily and it does not affect that much and during the post-monsoon period, due to decreased rainfall the polluted water settled in the ecosystem due to less water flow, as a result of that every parameter of water quality affected and this, directly and indirectly, affects the diversity of trichopterans and other pollution sensitive taxa in the freshwater habitat. A similar trend was seen in the air and water temperature, as the temperature tends to increase in the February of all the three streams, and this high temperature subsequently affects dissolved oxygen levels, and this depletion in DO can cause major shifts in the population dynamics of trichopterans. Dissolved oxygen levels below 3 mg/l are stressful to most aquatic organisms. The present study results show that DO values were above the permissible value except in February in all three streams. The other water quality parameter falls within the permissible limit. The results show that temperature, pH, rainfall, and DO become the most important element in governing the diversity and distribution of trichopterans in the three streams.

CCA was performed to compare the Trichoptera community with each of the 11 environmental variables (Fig. 1). CCA ordination diagram, shows that axis 1 accounts for 63%, and axis 2 for 36%, and the results show that taxa

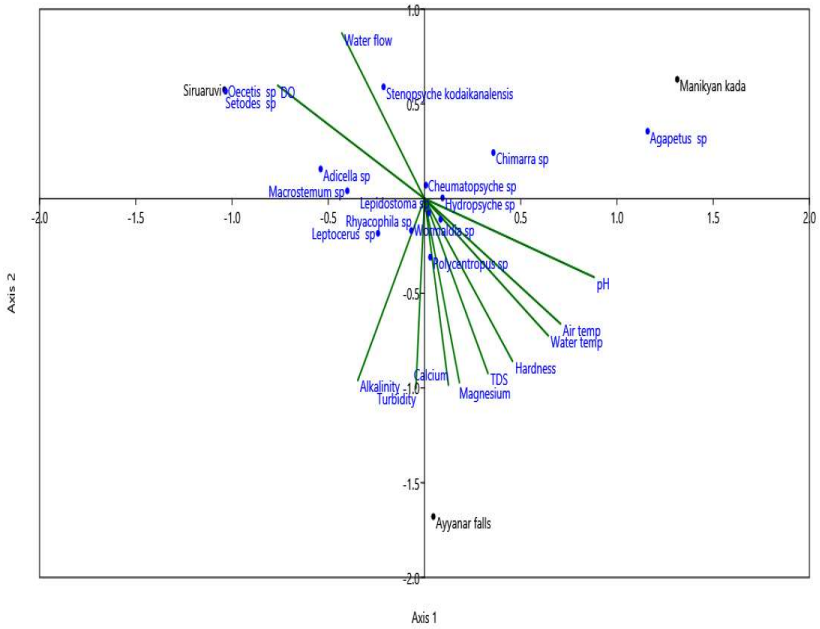


Fig. 1. CCA plot of trichoptera and ecological attributes in three streams of Eastern Ghats

Table 3. Physico-chemical parameters ofthree streams of Eastern Ghats

Physico-chemical parameters	Manikyan kada			Ayyanar falls			Siruaruvi		
	October	December	February	October	December	February	October	December	February
Water temperature (°C)	21.2	20.3	23.5	21.4	20.5	23.9	20.9	19.9	22.4
Air temperature (°C)	28	27.2	30.6	28	27.4	30.9	27.3	26.7	30.1
pH	7.3	7.5	7.8	7.4	7.3	7.8	7.2	7	7.2
DO (mg l^{-1})	3.33	5.13	2.6	3.53	5.02	2.2	4.53	5.43	2.9
Alkalinity (mg l^{-1})	15.42	14.95	14.23	16.12	15.16	15.73	15.12	14.85	15.38
Calcium (mg l^{-1})	5.16	4.8	5.23	5.38	4.92	5.53	5.03	4.79	5.23
Magnesium (mg l^{-1})	3.24	2.64	3.5	3.47	2.89	3.67	3.04	2.54	3.60
Water flow (m s^{-1})	0.38	0.67	0.23	0.29	0.53	0.20	0.43	0.72	0.36
TDS (ppt)	0.17	0.16	0.21	0.19	0.17	0.23	0.17	0.15	0.19
Turbidity (NTU)	0.04	0.03	0.04	0.05	0.03	0.06	0.04	0.03	0.04

Cheumatopsyche sp. has a positive correlation with high levels of almost all water parameters and this leads to the fact that it becomes the most dominant taxa due to their high degree of survival to a wide range of water quality parameters. The taxa such as *Hydropsyche* sp, *Lepidostoma* sp, *Wormaldia* sp, and *Polycentropus* sp shows positivity to temperature, pH, hardness, total dissolved solids, calcium, and magnesium and shows negativity towards high levels of dissolved oxygen and water flow and it reveals that they forms the most tolerant taxa next to *Cheumatopsyche* sp. Other taxa like *Macrostemum* sp, *Oecetis* sp, *Setodes* sp, *Adicella* sp, and *Stenopsyche kodaikanalensis* which show different community structure in contrast with *Hydropsyche* sp as these taxa prefer low levels of temperature, pH, hardness, total dissolved solids, calcium and magnesium and high levels of dissolved oxygen and water flow. *Leptocerus* sp and *Rhyacophila* sp prefer high levels of alkalinity and turbidity whereas *Chimarra* sp and *Agapetus* sp prefer low levels of alkalinity and turbidity. This result supports the findings of Bonada et al (2004) as Hydropsychidae were a very tolerant family which tolerates a wide range of water quality parameters.

CONCLUSIONS

The present study gives more knowledge in the diversity and distribution of trichopteran larvae. Ecological attributes like temperature, pH, DO and rainfall become the most important element in governing the diversity and survival of trichopterans in the three streams, and taxa tend to increase in the low rainfall in December whereas low diversity was seen in the high rainfall (October) and dry period (February). CCA results reveal that *Cheumatopsyche* sp becomes the most dominant taxa due to their high degree of survival to a wide range of water quality parameters. This study suggests more researches to be carried out to find the exact status of the ecology and community structure of trichopterans and their bio monitoring potential in the Western and the Eastern Ghats of India.

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Assessment of Impact of Sub-Lethal Dose of Mustard Oil Cake on Haematological Biomarkers in Indian Air-Breathing Fish, *Channa gachua* (Hamilton)

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Abstract: Impact of short-term exposure of mustard oil cake to certain haematological biomarkers in Indian air-breathing fish, *Channa gachua* was assessed. First of all, By the Probit analysis method, the LC50 dose of mustard oil cake was calculated 4965-5165 mg l^{-1},respectively with an average of 5065 mg l^{-1}. The range of LC50 dose indicates the slightly toxic or practically non-toxic nature of mustard oil cake. The fish were then exposed to 50.65 and 253.25 mg l^{-1}sub lethal dose of mustard oil cake for 24, 48 and 96 hours exposure and the alterations in activities of haematological biomarkers were determined. The TEC, Hb and PCV exhibited a significant decrease in treated fish while leucocytes and thrombocytes count got increased significantly ($p<0.05$) to 50.65 and 253.25 mg l^{-1}dose of mustard oil cake at all the treatments. The levels of MCV increased but MCHC lowered significantly ($p<0.05$) to above doses of mustard oil cake at all the treatments as compared with untreated fish. However, MCH decreased in 50.65 mg l^{-1} but increased in 253.25 mg $l^{-1}$of mustard oil cake. The percentage of eosinophils and neutrophils also declined while basophils, monocytes and lymphocytes elevated significantly ($p<0.5$) in treated fish. These findings may be used in the assessment of the potential risk of mustard oil cake on food chains and aquatic ecosystems.

***Keywords*:** Short-term toxicology, Blood parameters, Mustard oil cake, *Channa gachua*, Fish health.

The utilization of inorganic fertilizers is common practice to increase the growth and production of fish. But it has some adverse effects on the environment. The biological factor, probiotic bacteria, organic fertilizer, as well as biofertilizer, is another option to lessen the antagonistic consequences for the environment and induce growth of the major carps (Abbas et al 2001, Ojha et al 2019, Kumar et al 2019). Mustard oil cake is one of the randomly used biofertilizers for supplementary feeding in pisciculture in all Southeast Asian Countries including India (Rajendran and Devaraj 2004, Kumari and Pandit 2019). Considering other aspects, fishes are commonly utilized as bioindicators of aquatic pollution due to their sensitivity to the surrounding environment. Haematological biomarkers are generally applied as tools for determining the physiological changes, stress and wellbeing status of fish. Simultaneously, variation in haematological parameters is considered as a compensatory response to improve the oxygen-carrying capacity of a fish (Al-Rudainy et al 2015). *Channa gachua* (dwarf snake-headed murrel) is a hardy fish inhabiting paddy fields and ponds in India and the Shahabad region of Bihar. The IUCN status of this fish indicates that its number is diminishing (Chaudhary 2010). This work aim is to study the effect of acute sub-lethal doses of biofertilizer on haematological parameters in *Channa gachua*.

MATERIAL AND METHODS

The study was conducted during 2018 in the Department of Zoology, Veer Kunwar Singh University, Arrah (coordinates: 25°33′27″N 84°40′12″E /25.55750°N 84.67000°E), India. Healthy specimens of *Channa gachua* (Hamilton) (BW: 55-75g and TL: 13-16cm) were obtained from the local market of Arrah (Bhojpur) during 2018 and were acclimatized for a fortnight. A set of three specimens and three replicates were used. Powder of mustard (*Brassica napus*) oil cake was selected as a biofertilizer. The 96hr-LC50 dose of mustard oil cake for fish was 4965-5165 mg l^{-1} with an average of 5065 mg l^{-1} was determined by Probit method and fishes were exposed to 1 and 5 for 96hr-LC50 dose of mustard oil cake study haematological parameters (Finney 1971, Pandit and Kumari 2019). Based on the average 96hr-LC50 dose of a mustard oil cake in *Channa gachua*, mustard oil cake may be treated as slightly toxic (500-5000 mg l^{-1}) or practically non-toxic (5000-15000 mg l^{-1}) to *Channa gachua* as per guidelines of EPA (2015). The total erythrocyte count (TEC), hemoglobin (Hb) content, packed cell volume (PCV) and total leucocyte count (TLC) were determined by adopting standard methods (Hesser 1960, Wintrobe 1967).

RESULTS AND DISCUSSION

TEC, Hb, PCV, TLC and thrombocytes: Total erythrocyte

count (x10^6/mm^3) of 3.705 were in control *Channa gachua* and showed progressive and significant decrease to 2.762 and 2.025 in mustard oil cake added fed fish after 96hr. Haemoglobin (g/100ml) was 13.85 in controlled specimens also demonstrated progressive and significant abatement to 10.261and 8.495in mustard oil cake included fed of fish at the end of short term exposure. Similarly, packed cell volume (%) of 32.875 in controlled samples exhibited progressive and significant diminishing to 29.781 and 27.009 in mustard oil cake dealt with fish after 96 hr (Table 1). Conversely, total leucocyte count (x10^3/mm^3) of 18.52 and 21.24 was observed in *Channa gachua* intoxicated with mustard oil cake in comparison to its initial value of 15.64 after 96 hours exposure. Thrombocytes (x10^3/mm^3) were 8.26 and 9.02 in the fish inebriated to mustard oil cake in contrast with its underlying estimation of 15.64 following 96hours treatment (Table 1). The TEC, Hb content, PCV and thrombocytes of *Channa gachua* decreased but TLC increased at different exposure periods when compared to control. Adesina et al (2017) observed a decline in total erythrocyte count, haemoglobin content and packed cell volume of *Clarias gariepinus* with treated soybean meal when compared to controlled value. Similarly, Nath et al (2017) revealed that total erythrocyte count, haemoglobin content and packed cell volume of controlled *Channa punctatus* declined in mustard oil cake treated fish after 28 days. The mechanism of mustard oil cake is by destroying total erythrocyte count leading to blood haemolysis, reducing oxygen availability for the body and this is the reason for alteration in Hb concentrations. The mustard oil cake contains phytic acid (Swati and Das 2015) as one of the ingredients, which has a high ability to chelate iron. The chelation of iron results in its poor bio-availability by which Hb content was found to decrease due to deficiency of iron. The increase in TLC may be due to the protection of the fish against infections under innate immune response.

MCV, MCHC and MCH: Mean corpuscular volume (μm^3) of 88.73 in controlled specimen also demonstrated progressive and insignificant/significant increment to 107.82 and 133.38 in mustard oil cake included fed of fish. Similarly, Mean corpuscular haemoglobin (pg) of 37.38 in controlled fish exhibited progressive and insignificant/significant diminishing/ascending to 37.15 and 41.95 in mustard oil cake included dealt with fish after 96hr. Mean corpuscular haemoglobin concentration (%) of 42.13 in controlled *Channa gachua* showed progressive and significant decrease to 34.15 and 31.45 in mustard oil cake added fed fish after 96hours (Table 2). Kumar and Sharma (2015) reported that mean corpuscular volume and mean corpuscular haemoglobin of *Channa punctatus* significantly increased when exposed to 15 days for Atrazine toxicity. Nath et al (2017) also observed that thrombocytes of *Channa punctatus* lowered but mean corpuscular haemoglobin increased in 28 days of biofertilizer exposure.

Differential leucocyte count (%): Eosinophils of 11.54 in controlled specimen also demonstrated progressive/ retrogressive and insignificant abatement to 10.91 and 10.26

Table 1. Variation in hematological parameters in *Channa gachua* due to short term exposure to mustard oil cake

Dose of mustard oil cake (mg l^{-1})	Parameters (unit)	Normal range of parameters	Controlled range of parameters	Hour after application			F value
				24hr	48hr	96hr	
50.65	TEC (×10^6/mm^3)	0.58 - 7.06	3.705±0.795	3.294±0.721 (-11.09%)**	2.971±0.902 (-19.81%)**	2.762±0.804 (-25.45%)**	30.22***
253.25				2.571±0.383 (-30.61%)***	2.452±0.353 (-33.82%)***	2.025±0.721 (-45.34%)***	57.80***
50.65	Hb (g/100ml)	8.40-21.20	13.85±1.42	11.759±0.795 (-15.10%)**	10.774±0.824 (-22.21%)**	10.261±0.661 (-25.91%)**	13.56**
253.25				10.691±0.654 (-22.81%)**	9.640±0.727 (-30.40%)***	8.495±0.943 (-38.66%)***	8.79*
50.65	PCV (%)	11.80-60.86	32.875±2.983	30.834±2.574 (-6.21%)*	30.258±1.942 (-7.96%)*	29.781±1.469 (-9.41%)*	25.27**
253.25				28.928±0.956 (-12.01%)**	27.829±0.966 (-15.35%)**	27.009±0.844 (-17.84%)**	54.32***
50.65	TLC (×10^3/mm^3)	5.00-20.00	15.64±1.824	16.87±1.13 (+7.86%)*	17.55±0.95 (+12.21%)**	18.52±1.18 (+18.41%)**	13.35**
253.25				19.76±0.90 (+26.34%)**	20.08±0.92 (+28.39%)***	21.24±0.96 (+35.80%)***	26.15***
50.65	Thrombocytes (×10^3/mm^3)	5.00-10.00	6.82±0.88	7.29±0.72 (+6.90%)*	7.97±0.90 (+16.86%)**	8.26±0.80 (+21.21%)**	0.504***
253.25				7.57±0.38 (+11.00%)*	8.45±0.35 (+23.90%)**	9.02±0.72 (+32.26%)***	6.851*

in mustard oil cake included fed of fish at the end of short term exposure. But, neutrophils 9.00 in controlled samples exhibited progressive and significant diminishing to 7.84 and 6.95 in mustard oil cake included dealt with fish after 96hr. Basophils 12.20 in controlled specimen also demonstrated progressive and insignificant/significant increment to 13.84 and 14.038 in mustard oil cake included fed of fish. Similarly, monocytes 13.34 in controlled fish exhibited progressive and significant ascending to 14.85 and 14.75 in mustard oil cake included dealt with fish after 96hr. Lymphocytes 38.40 percent in controlled *Channa gachua* showed progressive and significant decrease to 39.48 and 39.74 in mustard oil cake added fed fish after 96hours (Table 3). The percentage of eosinophils and neutrophils of *Channa gachua* decreased but basophils, monocytes and lymphocytes increased at different experimental periods in comparison to base ones. Nath et al (2017) also revealed that eosinophils of controlled *Channa punctatus* come down in mustard oil cake treated fish after 28 days. The reduced neutrophil counts probably indicated the absence of bacterial infection (Adesina et al 2017). Conversely, observed rise in basophils, monocytes and lymphocytes from intoxicated *Channa gachua* after 28 days of treatment. Higher lymphocyte value suggests an immunological adaptation of fish under poor water quality. An increase in lymphocyte counts with the advancement of exposure may also be characterized to more production of

Table 2. Variation in relative hematological parameters in *Channa gachua* due to short term exposure to mustard oil cake

Dose of mustard oil cake (mg l^{-1})	Parameters (unit)	Normal range of parameters	Controlled range of parameters	Hour after application			F value
				24hr	48hr	96hr	
50.65	MCV (μm^3)	76.20-203.45	88.73±3.75	93.61±3.57 (+5.50%)*	101.84±2.17 (+14.78%)**	107.82±1.84 (+21.51%)**	3.31^{NS}
253.25				112.52±2.49 (+26.82%)***	113.50±2.74 (+27.92%)***	133.38±1.17 (+50.32%)***	6.15*
50.65	MCH (pg)	30.00-110.00	37.38±1.78	35.70±1.10 (-4.49 %)NS	36.26±1.91 (-3.00%)NS	37.15±1.87 (-0.62%)NS	0.977^{NS}
253.25				41.58±1.71 (+11.24%)**	39.31±2.06 (+5.16%)*	41.95±1.31 (+12.23%)**	9.513**
50.65	MCHC (%)	30.00-85.00	42.13±1.76	38.14±1.09 (-9.47%)*	35.61±1.24 (-15.48%)**	34.45±1.52 (-18.30%)**	7.66*
253.25				36.96±1.16 (-12.27%)**	34.64±1.79 (-17.48%)**	31.45±1.12 (-25.35%)**	2.93^{NS}

Table 3. Variation in differential leucocyte counts in *Channa gachua* due to short term exposure of mustard oil cake

Dose of mustard oil cake (mg l^{-1})	Parameters (unit)	Normal range of parameters	Controlled range of parameters	Hour after application			F value
				24hr	48hr	96hr	
50.65	Eosinophils ($\times 10^3/mm^3$)	1.00-15.00	11.54±1.73	10.07±0.98 (-12.74%)**	10.46±0.89 (-9.36%)*	10.91±0.91 (-5.46%)*	1.639^{NS}
253.25				10.78±0.94 (-6.58%)*	10.58±0.69 (-8.32%)*	10.26±0.84 (-11.09%)**	1.962^{NS}
50.65	Basophils ($\times 10^3/mm^3$)	2.00-15.00	12.20±2.42	12.41±0.92 $(+1.72\%)^{NS}$	13.22±0.85 (+8.36%)*	13.84±0.78 (+13.44%)**	15.76**
253.25				12.54±0.94 $(+2.78\%)^{NS}$	13.87±0.94 (+13.69%)**	14.03±0.82 (+15.00%)**	4.19^{NS}
50.65	Neutrophils ($\times 10^3/mm^3$)	5.00-10.00	9.00±1.34	8.65±0.85 $(-3.89\%)^{NS}$	8.04±0.71 (-10.67%)*	7.84±0.84 (-12.89%)**	0.278NS**
253.25				8.95±0.59 $(-0.22\%)^{NS}$	7.24±0.81 (-19.55%)**	6.95±0.85 (-22.87%)**	7.04*
50.65	Monocytes ($\times 10^3/mm^3$)	2.00-15.00	13.34±2.20	14.38±0.93 (+7.80%)*	14.66±0.88 (+9.9%)*	14.85±0.87 (+11.32%)**	7.82*
253.25				14.08±0.93 (+5.55%)*	14.41±0.96 (+8.02%)*	14.75±0.88 (+10.57%)*	27.01***
50.65	Lymphocytes ($\times 10^3/mm^3$)	15.00-110.00	38.40±1.70	38.62±1.77 $(+0.625\%)^{NS}$	39.04±1.58 $(+1.67\%)^{NS}$	39.48±1.92 $(+2.81\%)^{NS}$	11.63**
253.25				38.87±1.87 $(+1.22\%)^{NS}$	39.15±1.19 $(+1.95\%)^{NS}$	39.74±0.849 $(+3.49\%)^{NS}$	111.5***

antibodies to combat the stressor (Spielman 2004). The elevation in the percentage of basophils, monocytes, lymphocytes and thrombocytes with the increase in the sublethal dose of biofertilizer may be due to stress as these cells actively participate in defense mechanism of fish.

CONCLUSION

The mustard oil cake treated *Channa gachua* shows reduced TEC, Hb, PCV and thrombocytes probably due to cumulative response of sub-lethal dose of mustard oil cake towards excessive erythrocyte destruction. The TLC count was increased due to adaptive responses of the fish to lead stress. Due to the rise in environmental pollution, undesirable consequences are expected to happen soon. Therefore, Safety measures ought to be taken to avoid disposal of wastes of near fish culture ground.

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Investigation of Farm Pond Based Integrated Floating Cage Aquageoponic System under Scarce Rainfall Situation in Andhra Pradesh

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Abstract: The efficiency of farm pond technology used for supplemental irrigations in dry land area can be improved by growing vegetables and fish in the farm ponds by 'Integrated Cage Floating Aqua-geoponic System' (IFCAS) at college farm, College of Agricultural Engineering, Madakasira during March-June, 2018. The main aim of the research was to determine the size of IFCAS structure for floatation on water, growth and productivity of ridge gourd, bitter gourd and fishes. The study indicated that for proper floating of IFCAS structure in the farm pond, the optimum size of IFCAS structure was 6.75 m^2 (2.7 x 2.5 m) with 125 kg weight. The bitter gourd crop resulted in higher fruit yield and economic returns as compared to ridge gourd. Further, growing fish (*Oreochromis niloticus*) in IFCAS structure resulted an income of Rs.600 per structure in three months period. The economic analysis of IFCAS indicated a B:C ratio of 2.2.

Keywords: Farm pond, IFCAS, Agriculture, Fish production

Despite higher levels of agricultural production in India, 15 and 38.5 % of the population is undernourished and malnourished, respectively. This clearly indicates that Indian agriculture is still facing food and nutritional security that warrants the availability of adequate and quality food to feed a healthy and productive life. On the other hand, so far the technologies had more focus on exploitation of soil and water technologies and less in improving, restoring, reclaiming and enhancing the productivity and sustainability. There is a need to increase productivity by efficiently utilizing the available resources to meet the nutritional demand of the burgeoning population on a sustainable basis. In scarce rainfall zone, the availability of water for irrigation is limited and every drop of water need to be conserved and efficiently utilized for crop production, which was achieved by 'Farm Pond Technology' (Reddy et al 2012, Larson et al 2016). This is a low-cost viable technology which includes harvesting of excess runoff water in a farm pond and utilizing the same for giving lifesaving irrigation to crops, thereby increasing the crop yields. Realising the importance of farm pond technology in dry land farming, both central and state governments initiated several measures to promote and encourage taking up farm ponds in farmer fields of dry land areas. Inspite of many advantages farm pond technologies, there is hesitation among farmers that some portion of the productive land gets wasted, for digging the farm pond in their fields. In this situation, any technology that utilises the farm pond for generating additional income besides being a source of irrigation can be a better option for increasing the income of farmer. Increasing the productivity of farm pond for generating additional income on the farm land can be one of the possible ways for increase in the farmer's income. The storage period of water in the farm pond can be increased by arresting the leaching and seepage losses by using various lining materials like using cement and sand mix, stone slabs, polythene sheets etc. The farm ponds offer an opportunity to grow the fish providing for diversification of farm enterprise and reduction of risk through integrated farming system (Ahmed and Lorica 2013). The fish production plays an important role in people's diet which provides micro nutrition. If the water is available in the farm pond for 3-4 months, this water can be efficiently utilized in increasing farmer income through integrated floating cage aqua-geoponics system (IFCAS).

The IFCAS is an aquaculture–horticulture based on the concept of integrated farming system approach developed in Bangladesh in 2013 (Haque et al 2015). In integrated farming system, an output/waste form one sub-system becomes an input to another sub system, there by achieving greater efficiency or output of derived products from the land/water. In IFCAS, fish and vegetables are produced under floating condition, where waste materials like fish faeces and unused

feed from the fish culture dissolved in the pond water are used for vegetable production. The IFCAS has several benefits as compared to aquaculture technology. Unlike traditional aqua ponds, in aqua-geoponics fish and plant grown on soil pits depend on each other and mutual relationship exists between them. Unused fish feed and excrements results in nitrogenous waste in the pond water and mud that are used as nutrients (nitrate) by the plants in IFCAS. Further, some substrates such as fallen leaves from horticultural plants, mud and material in IFCAS favours the nitrifying bacteria that convert toxic ammonia to less harmful nitrate. Plant roots hanging from the pits absorb the nitrates effectively from the water and in return, symbiotically plants provide fish with ammonia free water. The production of vegetables and fish in IFCAS provides nutritional food to the existing farmer's diet. The performance of the IFCAS depends on the floating ability (buoyancy) of the structure, which in turn depends on the size and weight of the material used for construction, type of soil filled in soil pits and the crops grown in soil pits. Hence, there is need for development of IFCAS in farm ponds of dryland area for improving productivity of farm ponds (Rehman et al 2016). The present investigation was taken up to study the feasibility of IFCAS in farm pond-based ecosystem and the growth and productivity of vegetables and fishes.

MATERIAL AND METHODS

The research study was conducted at Madakasira, which is located in Anantapur district of Andhra Pradesh. The mean annual temperature and annual rainfall of the study area are 27.6 ˚C and 532 mm, respectively. Most of the rainfall (~ 80%) is received during South-West monsoon.

Experimental site and preparation of ponds: The research study was conducted in the existing farm ponds at College of Agricultural Engineering, Madakasira. The dimensions of the farm pond were 29.6 m length, 21.2 m width and 1.7 m height. The heavily shaded ponds (HSP) were used for the research study. The advantage of HSP was small water surface area, whole system was covered with plants, sunlight exposure in the middle of the area only. By the first week of the March, fresh water was added to the farm pond. The study was conducted from March to June during the year 2018.

Design of IFCAS structure: The 6.75 m^2 IFCAS was rectangular in shape and made of iron-bars with sixteen concave grooves (upward 3 and downward 1 groove) in its four corners for holding floats of plastic drums (Fig. 1). The structure was prepared as per the procedure explained by Haque et al (2015). A nylon net was covered surrounding the entire bottom portion of the structure. Two soil pits were



Fig. 1. IFCAS with different components

arranged in the system to grow vegetables and pits were filled with a mixture of black soil, red soil and vermicompost. The two soil pits were in contact with the pond water so that roots could easily take up the nutrients. On the top side of structure, a scaffold was arranged to give support for the climbing vegetables crops.

The main components of the IFCAS were main frame, soil pits, plastic drums, concave grooves, fish net, scaffold and mesh wire and main function of the frame to hold the whole system. The total length and width of the IFACS frame was 2.7 × 2.5 m and was made of M.S. Flat and rectangular in shape. The dimensions of each pit were 0.60× 0.50 × 0.20 m of length, width and height, respectively. The whole structure was attached to drums by using concave grooves, made of M.S. steel flat with 0.50 m length. The main function of the concave grooves was holding floats of plastic drums. The plastic drums are used to hold and float (buoyancy) the whole structure of IFCAS in water. The weight of each plastic drum was 2.5 kg. The floatation of the whole system depends upon the buoyancy. These plastic drums should be sealed with cover for drum cap to prevent leakage and air entering into the drums. Red oxide primer is applied to the complete structure with two layers to prevent corrosion followed by aluminium paint, which protects the structure from corrosion.

Determination of buoyancy for IFCAS structure: When a drum floats, the upward buoyant force exerted by the water is greater than the downward force of the weight of the object. When a drum sinks, the weight of the object is greater than the upward buoyant force exerted by the water and its density is greater than 1 g/cm³.When drum is neutrally buoyant, meaning it neither sinks nor floats, and then the weight of the object is equal to the upward buoyant force exerted by the water. When neutrally buoyant in water, the object also has the same density as water. In general terms, this buoyancy force can be calculated with the equation (Shiva 2016) :

$$F_b = V_s \times D \times g$$

Where, F_b is the buoyancy force, V_s is the submerged volume =l×b×h, D is the density of the fluid the drum is submerged and g is the force of gravity

A small storage tank was filled with water to about 2/3 of

its total volume. The initial water level in the tank was noted and the area of the tank was determined. The capacity of the plastic drum was determined manually. The drum was submerged completely under water without any floatation and was rolled around a few times so that all the air bubbles come out. The increased water level in the tank was noted as final height. After removing the drum from the tank, the change in water level was noted as Δh of the water. Based on V= A× Δh (Where V = change in volume of the water, A = area of the base of the drum and Δh = change in height of the water (final height - initial height) the change in volume was calculated. After that, the mass of the drum was measured without floatation mechanism. The buoyancy needed from floatation material= Mass of drum – Mass of water displaced.

Experimental details of IFCAS: Sowing of ridge gourd and bitter gourd was done in the soil by dibbling method. The data pertaining to root length and yield attributes were recorded during the crop growth period. As a prophylactic measure, neem oil was sprayed @ 5 ml l^{-1} of water at 10 days interval during the crop growth period. No major pests and disease were noticed during the crop growth. The Tilapia (*Oreochromis niloticus*) fish was released in the month of April 2018 into the 6.75 m^2 net cage and then fed with rice bran. Tilapia (300 fishes) was fed twice a day in the early morning and evening depending on the body weight of the stock (Ali et al 2016). Weights of fishes were recorded at the initial stage, one month and two months.

Collection of water sample and its analysis: The water sample (1000 ml) was collected from farm pond in College of Agricultural Engineering, Madakasira. The collected samples were analysed by using the water quality analysis guidelines (Bhatnagar and Devi 2013) during the beginning and end of the experiment. The chemical analysis was done to determine values of chemical properties and inorganic compounds of water such as pH, total dissolved solids, chlorides, sulphates and nitrates. The chemical analyses were carried out at I.W.Q.M (Integrated Water Quality Management) lab, Department of rural water supply and sanitation, Madakasira division, Andhra Pradesh.

RESULTS AND DISCUSSION

Buoyancy of plastic drums: At the beginning of the research, buoyancy forces of floating structure (plastic drum) under complete/partial immersion were recorded. Under complete immersion, each plastic drum of weight 2.5 kg and with a capacity of 50 L could exert a total buoyancy force of 50.86 kg. The plastic drum when immersed partially could exert a total buoyancy of 26.29 kg. This indicates that the buoyancy force of floating structure under complete immersion was almost twice as compared to the buoyancy force under in partial immersion. The calculation of total buoyancy forces of the IFCAS with the 4 plastic drums (floating structures) was shown as : Complete immersion : capacity of 4 plastic drums = 200 kg; total buoyancy forces of 4 plastic drums = 203.44 kgf ; Partial immersion : capacity of 4 plastic drums = 100 kg; total buoyancy forces of 4 plastic drums = 109.6 kgf. This shows the higher buoyancy force helps in floating mechanism of IFCAS structure (with the soil in soil pit and vegetable crops grown in the soil pit) on water in the farm pond.

Effect of different sizes of IFCAS structure on flotation and influence of buoyancy: Two different sizes of IFCAS *i.e.,* 9.0 and 6.75 m^2 were evaluated resulting different weights i.e., 145 and 125 kg, respectively. The total buoyancy forces (203.44 kgf) of drums were high compared to the capacity of drums (200 kgf). The IFCAS structure with 9.0 m^2 size resulted in submergence of soil pits portion of the structure and hence, was not possible to grow vegetables (bitter gourd and ridge gourd) in soil pits. However, proper floatation of soil pits was attained with the optimum sized IFCAS structure (6.75 m^2) and hence, vegetable crops could be grown in soil pits.

Growth and productivity of vegetable and fish under IFCAS: The performance of bitter gourd in terms of growth and productivity was better as compared to ridge gourd under IFCAS (Table 1). The root length at 55 days after emergence (DAE) with bitter gourd was higher as compared to ridge

Table 2. Changes of water quality parameters in the farm pond

Parameters	Initial value	Final value (After 90 days)
pH	7.25	7.19
TDS (mg l^{-1})	32.17	27.02
Chloride as Cl (mg l^{-1})	244	216
Sulphate as SO_4 (mg l^{-1})	29	41
Nitrate as NO_3 (mg l^{-1})	0	1.5

Table 1. Root growth and yield attributes of ridge and bitter gourd under IFCAS

Crop	Root length at 55 DAE (cm)	No. of fruits per vine	Average Fruit weight (g)	Yield per plant (kg)	Total yield per IFCAS structure (q ha^{-1})	Gross returns (Rs $structure^{-1}$)
Ridge gourd	40.7	8	200	1.60	19.2	768
Bitter gourd	67.6	55	66	3.30	39.6	1980

Table 3. Economics of farm pond- based IFACS (Size: 2.7 x 2.5 m)

Inputs/Items/Produce	Quantity	Cost (Rs/-)
IFCAS Structure – Iron bar	35 Kg	2500
Drums (50 L volume)	4 Nos.	1600
IFCAS Net a. Nylon net b. Mesh net	1 No 1 No	600 600
Bamboo sticks, threads etc., for scaffold & nuts and bolds	6 sticks	1500
Aluminium and red oxide paint	1.0 L	300
Total cost of structure		7100
Tilapia production in IFCAS Fishes (Tilapia) Feed	300 Nos. 20 Kg	500 500
Seeds of bitter gourd and ridge gourd	50 g	125
Neem oil	1 L	430
Cost of cultivation		1555
Gross returns from vegetables a. Ridge gourd (19.2 Kg @ Rs.40/-per kg b. Bitter gourd (39.6 Kg @ Rs.50/-per kg C. Gross returns from fish (20kg @ Rs.30/- per kg)		 768 1980 600
Gross returns (Rs)		3348
Net returns (Rs)		1943
B:C ratio		2.2

gourd, which clearly showed that there was optimum root growth of the plants grown under IFCAS, thereby improving the growth and development of plants. Ridge gourd resulted in an yield of 1.6 kg plant^{-1}, while bitter gourd yielded 3.3 kg plant^{-1}. The total yield (39.6 kg) and gross returns (Rs.1980 per IFACS structure) with bitter gourd was two times higher as compared to that of realized ridge gourd. The average weight of the fish was 0.4 g/fish at the time of release of Tilapia fish into farm pond. After 30 days and 60 days, the average weight of the fish was 6 g fish^{-1} and 18 g fish^{-1}, respectively. The yield of fish was calculated for the study period *i.e.,* 3 months and after 3 months period the fish yield was 20 kg per structure and resulted in an income of Rs.600 per structure.

Water quality: The analysis of water samples before and after the experiment clearly indicates decrease in pH from 7.25 to 7.19 (Table 2). The pH of optimum growth for tilapia fishes is 7-9. The decrease in pH might be due to increase in acidity of water which could be due to release of faeces containing ammonia and acids by fish into farm pond water. The total dissolved solids (TDS), nitrates and sulphates increased in final water as compared to initial water in the farm pond, while chlorine levels decreased.

Cost economics: The cost economics of farm pond- based IFACS (Size: 2.7 x 2.5 m) was shown in the Table 3. The material used for preparation of IFCAS structure were iron, drums, nylon net and red oxide paint and their specifications; and the particulars of inputs used for vegetable and fish production are mentioned in Table 3. The cost of vegetable and fish production was estimated during three months period. The gross returns from the vegetables and fish was Rs.2,748 and Rs.600, respectively. The net profit from the vegetables and fish was Rs.1943.

CONCLUSION

The results revealed that usage of IFCAS structure (size: 2.7 X 2.5 m; wt.125 kg) in the farm pond resulted higher fruit yield of bitter gourd as compared to ridge gourd and with an additional income from growing fish indicating a B:C ratio of 2.2. Hence, it can be concluded that the productivity of existing farm ponds can be enhanced considerably through IFCAS technology.

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Analysis of Heavy Metals Concentrations in Water Samples Nearby Wadafiea Dumpsite of Solid Waste in the Khartoum North, Sudan

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Abstract: This study was aimed to determine the heavy metals concentrations in water samples around an open landfill site in Khartoum North, Khartoum State, Sudan in the dry and rainy season. The concentrations of various metals like lead (Pb), cadmium (Cd), chromium (Cr), copper (Cu), nickel (Ni) and zinc (Zn) were analyzed employing a Flame Atomic Absorption Spectrophotometer (AAS) with proper digestion method. The heavy metals were within the range of acceptable limits set by Sudanese maximum value (2016), Canadian guideline values (2020) and WHO guideline value (2018) except, the concentrations of Cr in some water samples in the dry season which were above the recommended limits prescribed by Sudanese maximum value (2016) (0.03 mgl^{-1}). The study findings indicated that the open dumpsite of solid waste could adversely affect the water quality in the study area and also the near residential district around and it could become a probable source of risk for human health and the environment in the future due to the expected problems of water pollution.

Keywords: Heavy metal, Landfill, Residential area, Water quality, Pollution, Environment, Sudan

Solid waste is the garbage, refuse, sludge and other discarded materials including solid, liquid, semi-solid, or contained gaseous material, resulting from industrial, commercial, mining and agricultural operations, and from community activities (Kumar et al 2016). Huge amount of municipal solid waste is producing day by day since the generation rate is increasing even faster than the rate of urbanization. The intensification of solid waste production within 10 years was from 0.68 billion tons per year in 2000 to 1.3 billion tons per year in 2010. It is anticipated to reach 2.2 billion tons per year by 2025 and 4.2 billion tons per year by 2050 (Hoornweg and Bhada-Tata 2012). An increase in world population with its associated high industrial activities has resulted in the production of large volumes of domestic, municipal and industrial wastes (Lagerkvist and Dahlén 2019, Twumasi et al 2016). The increased waste generation has however not commensurate with capacity in waste management, especially in developing countries. The result of this is wide instances of improper waste disposal and management have which pose serious threats to the environment and development of major cities around the globe especially Africa (Lebreton and Andrady 2019). Solid waste management is a growing problem in Khartoum city, this is because these wastes are randomly disposed of and as such they one of the main sources of environmental pollution. Wastes disposed of by traditional ways such as burning and uncovered dunghills. These ways lead to many environmental problems there are different factors which contribute to increasing wastes generation in Khartoum, these are changes in food habit and widespread use of disposable containers and packages, improper collection of these wastes and dumping.

The examination of groundwater quality basically refers to the determination of physic-chemical parameters of which various organic and inorganic contaminants, especially the metal pollutants are of utmost significance. The physiochemical environment of groundwater functions in many ways and influences the biotic components. It gives a picture of the environmental suitability of water for maintaining a normal life. Haphazard urbanization, industrialization and improper disposal of solid wastes led to contamination of groundwater. The improper and unscientific solid waste dumps in the unlined sewage drains drive pollutants into the groundwater regime which is an irrevocable loss and literally not possible to bring the quality of the groundwater to its original state. Contaminated wastewater has resulted in the contamination of food crops (Chen et al 2018). When wastewater contains heavy metals (HMs) at low concentrations, they may be useful for increasing productivity in agricultural production, as they are essential to living organism growth. However, high concentrations of HMs have negative effects on the

environment (Muchuweti et al 2006). Many studies have documented that both individual and combined HMs simultaneously expose humans and other organisms to toxic effects but are mediated by leached doses, duration of exposure, and genetic factors (Tchounwou et al 2012). Therefore, this study was carried out with the following objectives: 1- To determine the heavy metals concentration in the selected water samples; 2- to assess the risk of heavy metals pollution of water around the dumpsite; and 3- to compare the seasonal variations in concentrations of heavy metals in the water around the dumpsite.

MATERIAL AND METHODS

Study area: This study has been conducted during October 2019 and August 2020 in the landfill area and the area around it in Wadafiea Landfill which located at the East side of Kafoury, North of Haj Yousif and South of Nabta, Khartoum North (Bahri), Khartoum state, Sudan. It lies between Longitude 32° 603363 E and Latitudes 15° 6762815 N.

Water samples analysis: Twenty samples of water were collected from the dumping area for heavy metal analysis in 350 ml sterilized plastic bottles. The samples were collected from two seasons the dry and rainy season from the landfilling site and the area surrounding it. Ten samples of water were collected from each season. Six samples of drinking water (tap water) were taken from the adjacent area to the landfill, (three) samples were taken from a farm well adjacent to the landfill and (one) sample was collected from a water canal adjacent to the landfill at the northern side. Samples were taken by a specialist technician from the Faculty of Sciences and Technology - Al Neelain University and transferred to the laboratory of Environmental and Natural Resources and Desertification Research Institute, Khartoum State, Sudan, directly for analysis and test.

Data analysis: The data were analyzed with SPSS version (22) general linear model (univariate analysis of variance) to test the difference of variables under consideration**.**

RESULTS AND DISCUSSION

Heavy Metals Concentration in Water Samples

Dry season: The concentration values of Cr in water samples were ranged from 0.01 (Channel North) to 0.050 (East A), while the concentration results of Cu were ranged from 0.029 (South A) to 0.124 (South B). The findings of the concentration of Zn ranged from 0.10 (West B and North A) to 0.072 (Channel-North). The analysis results of all water samples with the AAS could not detect the absorption of any trace of Pb, Cd, and Ni. The metal with the greatest level concentration in all water samples was Cu followed by Cr and Zn (Table 1). These results indicate that the highest metal concentration in the water samples was Cu0.124 (South B) and 0.088 (Channel-North), whereas Zn and Cr 0.010 had the least concentrations.

Rainy season: The results of heavy metal concentrations of Cr, Cu and Zn in water samples were ranged from 0.010 (North B) to 0.015 (West A), 0.010 (South A and West A) to 0.029 (Channel - North) and 0.011 (East A) to 0.095 (West A) respectively. The findings of heavy metal concentrations of Pb, Cd and Ni in water samples from different sources near the dumpsite of solid waste have not detected any trace. The heavy metal with the highest concentrations in water samples was Zn 0.095 (West A)followed by Cu 0.029 (Channel-North) and Cr 0.015 (west A) (Table 2). The concentration of heavy metals in all water samples was

Table 1. Heavy metal concentration (mg l^{-1}) in water samples near the dumpsite of solid waste at dry season

Location	Longitudes E	Latitudes N	Cr	Cu	Zn
Channel - North	32.603047	15.686316	0.011	0.088	0.072
North A	32.604164	15.681920	0.048	0.041	0.010
North B	32.604468	15.688362	0.044	0.051	0.017
West A	32.606744	15.682213	0.043	0.038	0.037
West B	32.604372	15.682435	0.028	0.061	0.010
East A	32.603253	15.688964	0.050	0.055	0.039
East B	32.604423	15.684420	0.019	0.031	0.014
Southern East	32.601584	15.685577	0.010	0.035	0.042
South A	32.605087	15.686337	0.014	0.029	0.014
South B	32.607793	15.686542	0.016	0.124	0.025
Sudanese, 2016			0.03	1.33	3
Canadian, 2020			0.05	2	≤ 5.0
WHO, 2018			0.05	2	4 (taste) -3-5 (greasy)

compared together in the dry and rainy seasons. These results indicated that, the concentration of Cr in water samples in the dry season were below the limits prescribed by the Sudanese maximum value (2016), Canadian guideline values (2020) and WHO guideline value (2018) (0.03mg/l), (0.05mg/l) and (0.05mg/l) respectively, except the values 0.048 and 0.044 (North A and B), 0.043 (West A), 0.11 (channel- North) and 0.050 (East A) were recorded the findings were above the limit prescribed by Sudanese maximum value (2016) and within the limit of Canadian guideline values (2020) and WHO guideline value (2018). These might be due to other environmental factors like soil type or activities occurring close to the wells and sources of water, produces a large quantity of solid waste mixed with the waste of factories, medical healthcare, institutions, market and industrial, all these quantities of waste used to be transported daily without any treatment to be dumped in an open landfill near a residential area and water sources or may due to the heavy metals within the topsoil layer in the dumping site migrate to groundwater and surface water resources. As indicated in the results records the concentration of Cu and Zn in all water samples in the dry season were below the permissible limit values for Sudanese maximum guideline values (2016), Canadian guideline values (2020) and WHO guideline values (2018) while the concentration of Cr, Cu and Zn for all water samples for the same sources in the rainy season were below the acceptable limits of Sudanese maximum guideline values (2016), Canadian guideline levels (2020) and WHO guideline values (2018).

The variation between total heavy metal concentrations mgl^{-1}in the dry and rainy season results in (Table 3), the difference between total metal concentrations Cr, Cu, and Zn (mgl^{-1}) obtained in (Table 4) and variation in total heavy metal concentrations (mgl^{-1}) between sites (Channel - North, North A, North B, West A, West B, East A, East B, Southern East, South A and South B) obtained in (Table 5) for water samples from different locations showing that the means of concentration of elements Cr, Cu and Zn with respect to the Sudanese (2016), Canadian (2020) and WHO (2018) criteria are significantly different ($P < 0.05$) in seasons and locations. Therefore; a general trend in the elemental concentration exists in the water around the Dumpsite accordingly to the results obtained for all water sources. However, the concentration order is Zn > Cu > Cr. No abnormal heavy metal concentration was observed in all of the analyzed water samples. Concentrations of Cu, Zn, Cr, were below the desired limits for the world health organization (WHO), 2018; Sudanese, 2016 and Canadian, 2020 desirable standards. The study revealed that the concentration of heavy metals in water sources in the region is below the desirable limit for the WHO (2018); Sudanese (2016) and Canadian (2020) standards in most of the sites that were sampled and considered suitable for human consumption. However, heavy metal concentrations remained within the permissible limits set by the WHO (2018); Sudanese guideline value (2016) and Canadian acceptable limits standards (2020). The zinc concentration in the study area agreed with the study conducted in Accra (Ghana) where the concentration of zinc nearby stream was below the detection limit (Nartey et al 2012). In Sri Lanka observed range between 0.1 and 9.9 mg/l in leachate water (Nirmala Dharmarathne 2013). The results

Table 2. Heavy metal concentration ($mg\ l^{-1}$) in water samples near the dump site of solid waste at rainy season

Location	Longitudes E	Latitudes N	Cr	Cu	Zn
Channel -North	32.603047	15.686316	0.013	0.029	0.014
North A	32.604164	15.681920	0.011	0.015	0.015
North B	32.604468	15.688362	0.010	0.022	0.058
West A	32.606744	15.682213	0.015	0.010	0.095
West B	32.604372	15.682435	0.011	0.018	0.015
East A	32.603253	15.688964	0.011	0.019	0.011
East B	32.604423	15.684420	0.011	0.013	0.029
Southern East	32.601584	15.685577	0.014	0.008	0.039
South A	32.605087	15.686337	0.013	0.010	0.024
South B	32.607793	15.686542	0.012	0.021	0.035
Sudanese, 2016			0.03	1.33	3
Canadian, 2020			0.05	2	≤ 5.0
WHO, 2018			0.05	2	4 (taste) -3-5 (greasy)

Table 3. The variation of total heavy metal concentration (mg l^{-1}) in dry and rainy season

Season	Mean value	Std. Deviation
Dry season	0.037	0.0235542
Rainy season	00.21	0.0174176

Table 4. The variation between total heavy metal concentrations (mg l^{-1})

Heavy metal	Mean value	Std. Deviation
Cr[c]	0.025	0.0238182
Cu[b]	0.030	0.0202701
Zn[a]	0.031	0.0222142

Means in a column with superscripts letters are significantly different (P<0.05).

Table 5. The variation of total heavy metal concentration (mg l^{-1}) between locations

Location	Longitudes E	Latitudes N	Mean value	Std. Deviation
Channel - North[a]	32.603047	15.686316	0.054	0.0387155
North A[g]	32.604164	15.681920	0.023	0.0155826
North B[c]	32.604468	15.688362	0.034	0.0186227
West A[b]	32.606744	15.682213	0.040	0.0282309
West B[f]	32.604372	15.682435	0.024	0.0181379
East A[d]	32.603253	15.688964	0.031	0.0185310
East B[i]	32.604423	15.684420	0.019	0.0079931
Southern East[e]	32.601584	15.685577	0.025	0.0146708
South A[j]	32.605087	15.686337	0.017	0.0069636
South B[h]	32.607793	15.686542	0.020	0.0082722

Means in a column with superscripts letters are significantly different (P<0.05)

of Cu in this study are consonant with Besufekad Mekonnen et al (2020), which were recently supported by the finding of Nirmala Dharmarathne (2013) that, the concentration of copper in the study sites fall within this range except for the leachate sample. The highest value of copper was above the prescribed by Ethiopian EPA and WHO standards (0.1 mgl^{-1}) and also higher than a similar study conducted in Accra (Ghana) dumpsite which revealed below 0.059 mgl^{-1} but less than another finding in Sri Lanka where copper in surface and leachate water near to dumpsite were between 0.08 and 9.9 mgl^{-1}(Osei et al 2011). During this study, heavy metals were within the acceptable safe range therefore, they didn't affect the environment. The dry season showed higher heavy metal concentrations than the rainy season. Probably, within the rainy season, low-strength leachate was generated; however, during the dry season, the reduced percolation and enhanced evaporation may need to increase the leachate strength and concentration (Tatsi and Zouboulis 2002). The concentration of heavy metals within the landfill leachate was significantly higher than that within the groundwater samples. The changes in heavy metal associations within the groundwater are often attributed to the proportion of several heavy metals from the leachate, which contains high levels of Fe, Pb, and Cd and a comparatively small proportion of Zn, Cr, and Cu. Additionally, to the massive amount of heavy metal pollution originating from leachate, the degradation of an outsized amount of biodegradable material within the landfills also played a task (Liao et al 2016). Biodegradation involves the utilization of an outsized amount of oxidant, for instance, oxygen, within the aquifer matrix, which is during a relatively poorly ventilated groundwater table. This induces reducing conditions within the groundwater table, and the existing state of the affected groundwater by heavy metals is disturbed. This leads to the heavy metals covering unusually high quantities of huge particles, activated and non-activated colloids, and dissolved small particles. This will cause the heavy metals to be adsorbed on the pore of the aquifer. The concentrations of Cd, Pb, Zn, and Cr in the studied groundwater samples were comparable with earlier studies (Nagarajan et al 2012, Wijesekara et al 2014, Aiman et al 2016. Chakraborty and Kumar 2016, Deshmukh and Aher 2016) The concentrations of Cr, Zn, and Cu in groundwater near the dumpsite were less than those recorded in Nigeria, Egypt, India, and China landfills (ElSalam and Abu-Zuid 2015, Han et al 2014).

CONCLUSION

This study revealed that the area study around the dumpsite and the wadafiea dumpsite of solid waste is polluted with commercial products and waste contain Cr in certain sites suggests the possible need for concern with respect to future pollution and human health as the landfill maturation progresses. The analytical results indicated that in the dry season some heavy metals like Cr in water samples were above the literature levels of controls and Sudanese maximum value (2016) and within the bounds of Canadian guideline values (2020) and WHO value (2018). Many negative effects on the environmental factors were found in the study area generated from the landfill.

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Agromeliorative Efficiency of Phosphogypsum Application on Irrigation Saline Soils in the Northern Steppe of Ukraine

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***Abstract*:** The present research represents the influence of chemical reclamation on the saline regime of the soil. Irrigation with limited water suitable for irrigation increased exchangeable sodium in the soil exchange complex to 5% and in the aqueous soil extract by 30%. Phosphogypsum was used as a chemical ameliorant in stock for three years under irrigation conditions and without it. It was applied at rates of 1.4, 3 (in spring) and 6 (in autumn) t/ha. The application of ameliorant in the spring a t the rates of 1.4 and 3 t ha^{-1} under irrigation caused to reducing the ratio of Na/Ca on average from 3 years to 2.53 and 1.51. It was sulfate type of salinity for all period of the time. Sodium exchange was decreased by application rates of phosphogypsum to 2.3% total amount of the exchangeable cations without irrigation (application of ameliorant in autumn) as compared to the control variant. Sodium exchange was decreased to 3.7% with a total amount of the exchangeable cations with irrigation (application of ameliorant in spring). In the first year after the second application of phosphogypsum there were the lowest rates of the density had the variants without irrigation. The density in this period was 1.17-1.2 g cm^{-3}, that was less on 0.04-0.96 g cm^{-3} as compared with the results the first year after first application.

Keywords: Saline composition of soil, Chemical reclamation, Irrigation, Phosphogypsum

It is necessary to use irrigation, for higher yields of crops in the Dnipropetrovsk region, Ukraine. The development and management of modern irrigated agriculture should increasingly be based on environmental orientation. The ecological direction is first of all preservation of soil, increasing fertility and maintain optimum physical and physicochemical properties (Dudiak et al 2019, 2020). The fertile soils of Ukraine are suffering from the different quality of water (Malovanyi 2020).The 23.3% area of irrigated lands of Ukraine (2170.5 thousand hectares) which is irrigated. More than 60% of the area of irrigated land is located in the Steppe zone, excluding the temporarily occupied territories, (1324.1 thousand hectares), of which 461.2 thousand hectares (34.8%) are irrigated (Pichura et al 2018). In particular, in the Dnipropetrovsk region the area of irrigated lands is 198.7 thousand hectares-(14.8%). With the beginning of the application of irrigation reclamation there were changes in the conditions of functioning of all components of the natural environment, in particular, the direction and speed of soil processes changed (Pichura et al 2017, Zelenskaya et al 2018). The results of these changes can have both a positive effect (improved moisture supply, increased productivity, etc.) and negative effect (flooding, salinization, waterlogging, etc.) (Dudiak et al 2019, Pichura et al 2019). Although deficit irrigation (DI) may have the potential to optimize crop yields in water limited environments, the success of such strategies may depend on the ability to manage variability in profile stored soil water during periods of drought. Understanding variability in stored soil water and crop rooting depth is an important component of successfully managing a deficit irrigation strategy. Traditionally, DI is applied at a fraction of the full irrigation (FI) requirement, but managed deficit irrigation (MDI) may optimize yield and irrigation by coordinating irrigation timing with the crop's reproductive stages through the management of soil water depletion and water stress (Bell et al 2020).

Understanding the impacts of desalination treatments on salt migration in saline soil during the farmland abandonment-reclamation process has significance for saline soil development and utilization. The research have shown that in arid climates there is a significant increase in the salt levels in the soil (Choudhary et al 2018, Shi et al 2021). The researches have shown that long-term irrigation with fresh and mineralized waters has a negative effect on the physical and chemical properties of soils (Morozov et al 2008, Baliuk 2012, Vargas et al 2018, Onopriienko et al 2019). It also caused to changes in the soil-forming process. The causes of secondary irrigation salinization vary with different quality of irrigation water (Baliuk 2012). The ameliorants influence physical and physicochemical properties of soils (Onopriienko et al 2019, Lozovitskyi 2010). The main objectives of research were impact of irrigation on the state of saline composition of soil and the effectiveness of chemical reclamation. It was determined the optimal

calculated rates of phosphogypsum application during chemical reclamation.

MATERIAL AND METHODS

The study on agromeliorative efficiency of phosphogypsum application on irrigated saline soils was conducted in the Northern Steppe of Ukraine during five years (2014-2018 at Dnipropetrovsk Research Station of the Institute of Vegetable and Melon NAAS of Ukraine" (Oleksandrivka, Dnipropetrovsk region, Ukraine 48°31,656'N35°13,431'E - 48°31,665'N35°13,428'E, Fig. 1.)

The experiments were in randomized block design with four replications. The oil samples were taken in accordance with the "Instructions for soil and salt surveying on irrigated lands of Ukraine"; sampling to determine water quality was performed according to DSTU ISO 5667-6: 2015. The experiments included two factors: A-humidification conditions (irrigation was with hose-drum sprinklers Irtec; irrigated ration was from 1150 to 1700 m^3 ha^{-1}), and B-application of phosphogypsum. B1 - without the application of phosphogypsum without irrigation (control); B2 - without the application of phosphogypsum with irrigation (control); B3 - application of phosphogypsum under spring cultivation at the rate of 1.4 t/ha without irrigation; B4 - application of phosphogypsum under cultivation in the spring at the rate of 3 t ha^{-1} without irrigation; B5 - application of phosphogypsum in autumn under the main tillage rate of 6 t ha^{-1} without irrigation; B6 - application of phosphogypsum under spring cultivation at the rate of 1.4 t ha^{-1} with irrigation; B7 - application of phosphogypsum under cultivation in the spring at the rate of 3 t ha^{-1} with irrigation; B8 - application of phosphogypsum in autumn under the main tillage rate of 6 t ha^{-1} with irrigation). All application rates of phosphogypsum were for three years with one application in the first year). Application of phosphogypsum was done with and without irrigation. One of the established rate coincided with the recommended agronomic norm (6 t ha^{-1}) and 10.3 t ha^{-1} the ecologically safe rate of phosphogypsum. All of the established rate must be less than ecologically safe rate. The rates of 1.4 and 3 t ha^{-1} were applied for cultivation in spring, and 6 t ha^{-1} was applied in autumn for basic tillage.

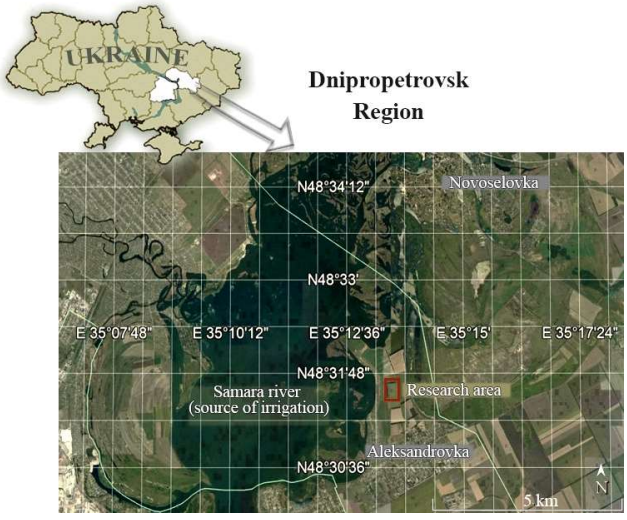


Fig. 1. The place of research

RESULTS AND DISCUSSION

According of soil grading of the experimental plot the soil layer 0-45 cm contains 71.02-74.0% of physical sand and 28.98-26.0% of physical clay, which corresponds to light loamy soil (Makarova et al 2020). The groundwater level is 4-5 m with mineralization up to 15 g l^{-1}. The amount of exchangeable Na is 3.64%; the absorption capacity of the soil exchange complex is 20.1-26.47 meq by 100 g of soil; the content of toxic salts varies up to 0.48%. In the wet state, the soil is viscous, sticky, strongly swollen, easily peptized. According to physicochemical characteristics, salinization processes are observed. There is 2.01–2.50% of humus in the arable layer (0–30 cm). The humus gradually decreases with the depth and it is equal to 0.3% at the depth of 90–105 cm. According to morphological features, the soil belongs to the chernozem of ordinary low-humus leached on the loam. Climatic conditions were characterized by large amplitude of daily and annual temperatures: the predominant amount of precipitation, which was rainy in nature, was recorded in the warm period, which significantly reduced their efficiency in growing crops. The hydrothermal coefficient varied from 0.95 (second year) to 3.52 (fourth year).

Irrigation was done with water from a reservoir on the Samara River with Irtec hose-drum sprinklers. During the research the crop rotation followed were: spring barley, winter wheat, winter wheat, corn for grain, winter wheat. Laboratory tests were conducted on the basis of the Dnipo State Agrarian and Economic University, Dnipropetrovsk branch of the state Institution of Soil Protection of Ukraine, LLC "Center for Radioecological Monitoring". The irrigation water quality belongs to the II class of quality Limitedly suitable (DSTU 2730-2015) according to the danger of its toxic effect on plants and the danger of soil salinization confirmed that water for all years of research. According to agronomic criteria, it was determined the chemical type of water as chloride-sulphate for all years of observation, magnesium-sodium (first, third years) and sodium-magnesium (second, fourth, fifth years). Prolonged irrigation with water of the second class quality Limitedly suitable led to the leaching of calcium carbonates from the arable layer of the soil, which negatively affected the properties of

chernozem, namely: the formation of organic matter and its accumulation, maintaining soil stability, formation of favorable water, air, nutrient, thermal regimes and prevention of salinization processes (Figs. 2, 3).

It have been substantiated the conditions of chemical reclamation to improve the poor physical and chemical condition of irrigated saline chernozems. The sulfate type of salinity was observed according to the chemical composition of aqueous soil extract during the observation period, the experimental plots in all variants with phosphogypsum with irrigation and without irrigation, as well as on control during irrigation by anionic components (ratio, meq Cl/SO_4 and HCO_3/SO_4 less than 0.25). It was registered the soda-sulphate type of salinization in the control without ameliorant application and without irrigation in the first year and it was registered chloride-sulphate in the fifth year in the control with irrigation. In other years of research the sulphate type of salinization was noted. According to the cationic composition, the chemistry of soil salinization was determined taking into account the two cations present in larger quantities. In all samples was fixed sodium type of salinity, with the introduction of phosphogypsum. In the control without irrigation from the fourth year there was a change to the calcium-sodium type, there were processes of stop the salinization.

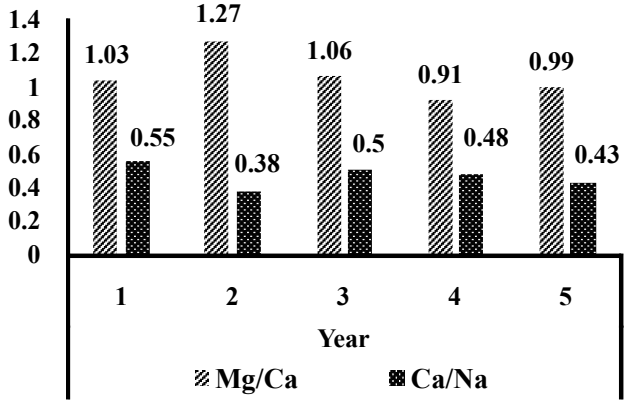


Fig. 2. The changes in the ratio of magnesium, calcium and sodium cations in irrigation water over the years of research

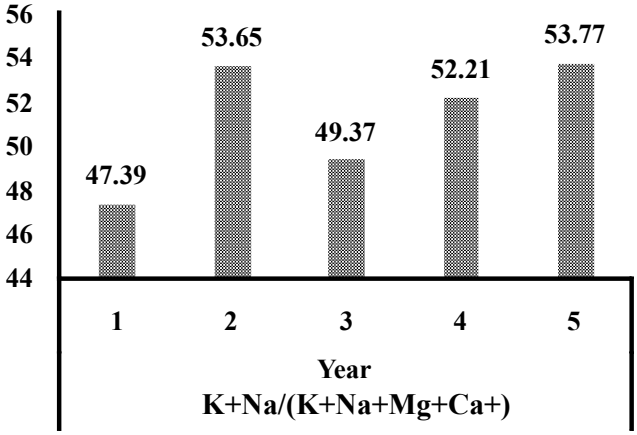
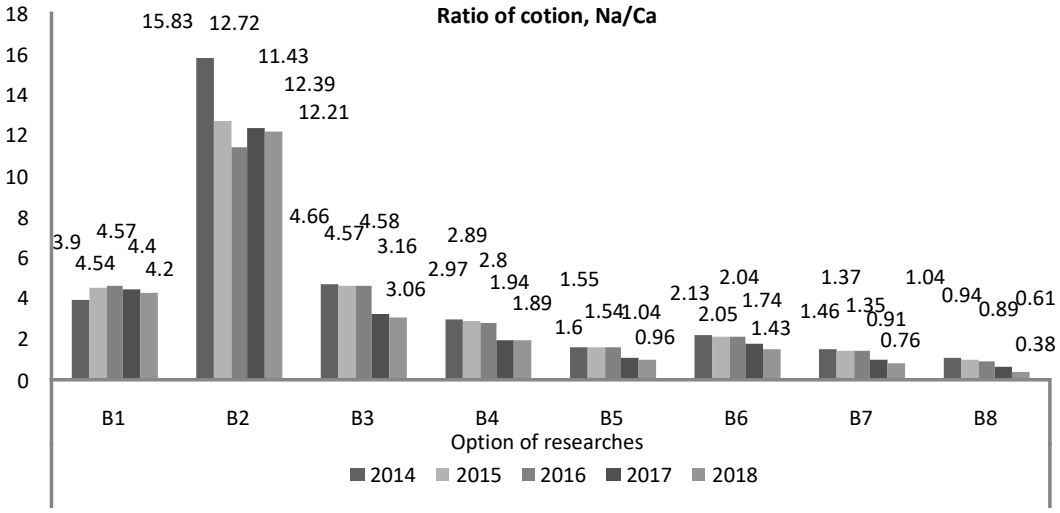


Fig. 3. The changes in irrigation water quality over the years of research

Earlier workers have shown that cationic composition is dominated by calcium and sodium ions. Their ratio was determined and it was established the chemistry of salinity (Fig. 4). The highest Na/Ca ratios were observed in the



B1 - without the application of phosphogypsum without irrigation (control); B2 - without the application of phosphogypsum with irrigation (control); B3 - application of phosphogypsum under spring cultivation at the rate of 1.4 t/ha without irrigation; B4 - application of phosphogypsum under cultivation in the spring at the rate of 3 t/ha without irrigation; B5 - application of phosphogypsum in autumn under the main tillage rate of 6 t/ha without irrigation; B6 - application of phosphogypsum under spring cultivation at the rate of 1.4 t/ha with irrigation; B7 - application of phosphogypsum under cultivation in the spring at the rate of 3 t/ha with irrigation; B8 - application of phosphogypsum in autumn under the main tillage rate of 6 t/ha with irrigation

Fig. 4. The ratio of Na/Ca by years of research in the options

control irrigated variant (15.83-11.43 meq/100 g of soil), which is explained by the influx of sodium ions together with irrigation water. There was a decrease in the ratio in the variants with the introduction of phosphogypsum for all years of observations, which indicates a decrease in the intensity of the salinization process. The best options in this case were 6, 7 and 8, here the average was by 2 times lower than the irrigated option. The application of ameliorant in the spring at the rates of 1.4 and 3 t ha^{-1} under irrigation reduced the ratio by an average of 3 years by 2.53 and 1.51, respectively. The application of 6 t ha^{-1} in autumn under irrigation was reduced by only 0.6 units compared to the non-irrigated option. That was, the amount of precipitation during the autumn-winter period dissolved and removed the resulting sodium sulfate during land reclamation with phosphogypsum less than the amount washed by irrigation for application in the spring.

The degree of salinity in the percentage of toxic salts was established for salinity (Fig. 4). According to the content of toxic salts, all variants (except B1) had a value of 0.3-0.6%, which corresponded to the sulfate (S) type of medium salinity. In B1 for the sulfate type, the values were in the range of 0.15 to 0.3%, which characterizes the slightly saline type (1, 3, 4, 5 years). The "total effect" of toxic ions in chlorine equivalents (mEq) almost always coincided with the degree of salinity, determined by the content of toxic salts (%). In the study, the exception was option B1, where in 4 and 5 years the values fell in the range of 0.3-1.0 it was medium salinity. Research of changes in the salt composition of the soil profile in the third year of the aftermath showed the largest accumulation of salts in the layer 0-15 cm: it was 4.22 meq/100 g of soil in the option with the introduction of phosphogypsum for spring cultivation at 3 t ha^{-1} with irrigation (B7). The option B5 increased the amount of salts by 0.19 meq/100 g of soil relative to the reclamation start data. In the option B7, the amount of salts per 0.022 meq/100 g of soil was higher compared to B5 to the layer 0-30 cm while for B7 layer 75-60cm (3.43 meq/100 g of soil). In the soil layer of 90-105 cm, the amount of salts was equalized to the initial conditions. In all options of the experiments, the concentration of Cl^{-1} and SO_4^{-2} ions decreased in profile, but still exceeded the toxicity limit of 0.3 and 2 meq/100 g of soil. During irrigation, the highest concentration of HCO_3^{-1} ions was observed in the layer of 15-30 cm (0.62 meq/100 g of soil).

The concentration of sodium before the experimenting in the layer 0-15 cm was 3.25 meq/100 g of soil. The application of ameliorant reduced the amount to 2.04 meq/100 g of soil, with irrigation to 2.25 meq/100 g of soil, which is explained by the flux of ions with irrigation water. According to the profile, Na^{+1} ions were pulled up at B7 to a layer of 60-75 cm (2.66 meq/100 g of soil), for B5 to a layer of 45-60 cm (2.03 meq/100 g of soil). In the lower horizons, the concentration gradually leveled off. With the application of phosphogypsum there was a major positive reclamation effect: an increase in Ca^{+2} ions throughout the profile. There were the largest amount in B5 layer 0-15 cm; it was 1.69 meq/100 g of soil. According to the profile during the reclamation for the third year of the aftermath the Ca^{+2} ions were concentrated in the layer 45- 60 cm and was 1.41-1.51 meq/100 g of soil, which overcomes the deficiency of this element in the soil profile. The present study has shown that irrigation with water of class II suitability on ordinary chernozem maintains with the signs of salinity: increased the share of sodium and magnesium exchange (Table 1) and decreased the percentage of calcium exchange. Although the chemical

Table 1. The change of cations exchange under the action of phosphogypsum in the arable layer of the soil

Option of research	First year of the aftereffect, the first application				Third year of the aftermath, the first application				First year of the aftermath, the second application			
	the amount of cations exchange, meq / 100 g of soil	% of the amount of cations exchange			the amount of cations exchange, meq / 100 g of soil	% of the amount of cations exchange			the amount of cations exchange, meq / 100 g of soil	% of the amount of cations exchange		
		Ca^{+2}	Mg^{+2}	Na^{+}		Ca^{+2}	Mg^{+2}	Na^{+}		Ca^{+2}	Mg^{+2}	Na^{+}
B1	28,76	71,28	24,69	4,03	28,34	70,29	25,41	4,24	28,53	70,10	25,38	4,25
B2	28,87	68,90	26,60	4,50	28,27	67,92	26,95	5,13	28,58	68,23	26,59	5,18
B3	29,43	75,77	21,58	2,65	26,79	74,65	22,77	2,58	29,29	77,84	20,48	1,67
B4	30,01	76,31	21,33	2,37	27,28	74,96	22,76	2,27	29,59	77,73	20,75	1,52
B5	30,63	76,40	21,48	2,12	27,88	75,44	22,67	2,08	30,37	78,04	20,71	1,25
B6	27,21	73,87	24,00	2,13	26,76	74,36	23,92	1,72	27,65	75,95	22,82	1,23
B7	28,27	75,70	22,76	1,54	27,88	75,32	23,32	1,36	29,70	77,04	21,91	1,05
B8	29,96	76,28	22,23	1,49	27,57	75,70	23,03	1,27	28,43	77,40	21,70	0,90

characteristics of the soil were not high enough, there were significant signs of salinization visually: the soil was unstructured, sticky, dense, low permeability.

The rapid salinization processes were observed in the control samples (the options 1, 2 of Table 1), especially in irrigated. Over 5 years of research, the amount of sodium exchange under irrigation increased from 4.5 to 5.18% of the amount of cations exchange. In the non-irrigated control, the average value of sodium exchange was 4.28% of the amount of cations exchange, which was 15% lower than this indicator under irrigation, but in this case there are processes of secondary salinization of soils. The ratio of calcium to magnesium exchange in the 2nd option was 2.53, and in the 1st it was 2.76, which indicates the displacement of calcium exchange by magnesium from the soil exchange complex. The amount of cations exchange in the control options did not change significantly and amounted to 28.3–28.87 meq/100 g of soil. With the application of phosphogypsum, the rate of exchangeable sodium decreased by 2.3% compared to the control by 2.3% of the amount of able cations exchange in the absence of irrigation (application of ameliorant in autumn) and by 3.7% of the amount of cations exchange (application of ameliorant in spring). This fact indicates a more significant effect of spring application of phosphogypsum during irrigation. There was tendency to a decrease in metabolic sodium of an increase in the rate of phosphogypsum application. In the options without irrigation, the lowest rates of exchangeable sodium were observed for the application of phosphogypsum in autumn under the main tillage rate of 6 t ha^{-1} and 2.12% of the amount of cations exchange in the first year afterglow and it was 2.08% of the sum of cations exchanging the third year aftertaste. After re-introduction of phosphogypsum in stock, the best indicators were again at the rate of 6 t ha^{-1} (1.25%) for the first year of the aftereffect. The value of sodium exchange decreased from 4.25 to 1.25%, but remained within a weak degree of salinization. As in the options without irrigation, watering was observed a tendency to decrease the sodium exchange with increasing rate of application of ameliorant.

In this case, the best option was the application phosphogypsum for spring cultivation at a rate of 3 t ha^{-1}. The value of exchangeable sodium was 1.49% of the sum of exchangeable cations after the first year of the aftereffect. In the third year of the aftereffect decreased to 1.27% of the amount of exchange cations. Re-application at the rate of 3 t ha^{-1} reduced the presence of exchangeable sodium in the soil absorption complex to 0.98% of the amount of exchangeable cations in the first year of the aftereffect. This indicates that salinization processes in the soil have slowed down. There was significant amount of exchangeable magnesium (25.44-21.65% of the sum of exchangeable cations) which provide negative visual characteristics of the soil (Table 1).Chemical reclamation with phosphogypsum also had a positive effect on the physical properties of the arable soil layer (Table 2).

The application of phosphogypsum affected of the soil density in the improvement direction (Table 2). Even with the application of phosphogypsum, there was a tendency to increase the density with irrigation comparatively to non-irrigated counterparts. Over the years, trend of increasing density in dry years was observed. The lowest densities were without irrigation in the first year of the aftereffect with repeated application of phosphogypsum. The f density in this period was 1.17-1.2g cm^{-3}, which is 0.04-0.96 g cm^3 less compared to the aftereffect of the first year in the first application. With irrigation conditions, the effect of phosphogypsum as a chemical ameliorant on the density of soil formation during spring application was more significant compared to non-irrigated options. In the years of research, the same trend was observed without irrigation. It was the increase in density in dry years and it was the lowest rates in the first year of the aftermath of repeated application of phosphogypsum. The density was 1.18-1.21 g cm^{-3}at the first

Table 2. Change of physical indicators of soil according to soil layer (0-30 cm)

Option h	Density of soil structures (g/cm^3)			Soil porosity (%)			Soil permeability (mm min^{-1})		
	1st year	3rd year	4th year	1st year	3rd year	4th year	1st year	3rd year	4th year
B1	1,37	1,35	1,35	50,20	50,40	50,50	2,14	2,07	2,00
B2	1,36	1,40	1,39	47,28	47,20	47,10	1,10	1,14	1,10
B3	1,24	1,25	1,20	52,00	52,00	52,35	2,48	2,45	2,50
B4	1,22	1,23	1,19	52,41	52,14	52,76	2,50	2,50	2,58
B5	1,21	1,21	1,17	52,83	52,02	53,00	2,51	2,52	2,60
B6	1,27	1,28	1,23	49,45	49,40	49,51	1,70	1,60	1,81
B7	1,25	1,24	1,20	49,98	50,00	49,91	1,73	1,71	1,89
B8	1,22	1,26	1,18	50,00	50,10	50,20	1,79	1,77	1,90

year of the aftereffect with repeated application of ameliorant. The porosity of the soil changed from 50.0 to 50.8% without the application of phosphogypsum and without irrigation over the years of research (Table 2). With irrigation, the average porosity of the arable soil layer in the control was 47.14% and without irrigation 3.24% higher. This was due to the increased of soil density during irrigation. With irrigation, there was the tendency to decrease the porosity and without irrigation the values changed chaotically we didn't observe clear dynamics.

Chemical reclamation (application of phosphogypsum) significantly changed the porosity of the soil. They were improved in all option of the research compared to the control. The best option without irrigation (as in the research of density) was the option with the introduction of phosphogypsum in autumn under the main tillage rate of 6 t/ha. The best results of soil porosity were characterized without irrigation with repeated autumn application of phosphogypsum in the first year of the aftereffect. The porosity increased to 0.17-0.35% compared to the aftereffect of the first application of ameliorant. Irrigation didn't lead to a radical change in porosity. The same trend was observed as without irrigation in the years of research. The best value of porosity was recorded in the first year of the aftereffect with repeated spring application of phosphogypsum as a chemical ameliorant(49.51-50.2%).

The soil permeability was higher in the control without the application of phosphogypsum and without irrigation compared to the irrigation options in our data (Table 2). The application of phosphogypsum significantly increased the soil permeability in the all options of the experiment. It was an increase in the average values of research to 2.46-2.54 mm/min with the application of phosphogypsum without irrigation. The increase of the soil permeability was proportional to the increase in the rate of application of ameliorant. This proves the theory of increasing the soils permeability with irrigation by chemical reclamation with calcium-containing ameliorants due to coagulation of soil colloids by calcium cations. The highest indicators of soil water permeability were observed in without irrigation with repeated application of phosphogypsum in autumn in the first year of the aftereffect. The soil permeability increased to 0.02-0.1 mm/min compared to the aftereffect at the first application in the first year of the aftereffect with repeated application. With chemical reclamation and irrigation there was a decrease in the soil permeability compared with options without irrigation. The first year of the aftereffect was better with repeated application. It was 1.81-1.9 mm/min as in the options without irrigation. This fact confirms the formation of water-resistant aggregation and the reduction of mobility of silty particles with the introduction of calcium with phosphogypsum. This increases the water resistance of the soil, increases filtration. This helps to wash the salts out of the soil. Assessment of soil permeability showed that it has from satisfactorily acquired to the status of good due to the action of chemical reclamation (Kovda 1971).

Phosphogypsum increases the crop productivity and leads to an increase the root residues in the soil, due to which there is an increase in humus. This change indicates a slowdown in the dehumidification of common chernozems during irrigation. The best options for restoring the organic part compared to the control were with irrigation. With irrigation, the best options were the application of phosphogypsum for cultivation in the spring at a rate of 3 t ha^{-1} (increase in humus by 0.35%) and in the autumn under the main tillage at a rate of 6 t ha^{-1} (increase in humus by 0.39%). In present research without irrigation, compared with the control, the best option for the restoration of the organic part was where phosphogypsum was applied in the fall under the main tillage at a rate of 6 t ha^{-1} (increase in humus by 0.29%).

CONCLUSION

Analysis of the content of heavy metals in phosphogypsum proved the possibility of its use in compliance with environmentally safe norm. With irrigation the improvement of the ecological condition of saline soils was registered when applying ameliorant in the spring. Application of phosphogypsum at the rate of 3 t ha^{-1} increased the soil permeability by 0.66 mm/min. It reduced the amount of toxic salts to 0.41% in the third year. It reduced the amount of Na exchange to 1% of the amount of exchangeable cations. Without irrigation the application of spring didn't show positive changes. Without irrigation, the option with the application of phosphogypsum in the fall under the main employer of the soil at a rate of 6 t ha^{-1} was the best. It increased the soil permeability by 0.68 mm/min. It reduced the amount of toxic salts to 0.38% in the third year. It reduced of the amount of exchangeable Na for the third year aftereffect to 2.08% of the amount of exchangeable cations. It was increased the humus content by 0.29%.

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Geographical Assessment of Natural Resources at Abu-Hadair Drainage Basin in Al-Salman Desert, Southern Iraq

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Abstract: The current research dealt with the most important natural resources available in Abu - Hadair drainage basin, one of the most prominent dry valleys in Al-Salman Desert in southern Iraq, including water resources, surface and groundwater, grazing and natural vegetation, as well as the most important mineral resources located in the area of study. Several ways have been discussed in which these resources could be invested by means of development projects for economic benefit, which represent a step towards the development of arid and semi-arid regions in Iraq, particularly in its southern deserts. The research showed that the basin is characterized by the existence of a proper water drainage network, thereby providing a sufficient amount of water to be invested in agriculture, in addition to the available groundwater reservoirs. The availability of such fertile soil leads to the growth of a wide range of natural vegetation, enabling large areas of the basin to be invested for grazing purposes. Rock diversity has proved to be significant in providing various minerals which could be invested in industry and construction.

Keywords: Economic development, Dry valleys, Drainage basin, Natural resources, Geospatial techniques

The human journey began by exploiting the environment and investing its natural resources since the earliest times, and since then many changes have occurred. The rates of population growth and civilization progress have increased, and the nature of their relationship and interaction with the environmental milieu in which they live has varied over the developmental stages through which humanity has been, attempting to make use of the natural resources available. This continuous journey enabled man to produce the materials and commodities he needs, yet the outcome was a range of environmental problems caused by humans. These problems have become the subject of global attention due to the imbalance they cause to the environmental equilibrium. Natural resources outcome of the many interacting forces and factors that are related to the surface of the earth, such as climatic conditions and the associated hydrological conditions and life forms (flora and fauna), the earth's crust and associated mineral resources. The immediate result that can be drawn from the formation conditions of these resources is that their existence is characterized by two main features, namely the variation in their geographical distribution, and their limited presence in nature. The present study is an attempt to understand the characteristics of the natural environment that caused the formation of the natural resources in the Abu Hadair basin, one of the dry valleys in Al-Salman desert, southern Iraq, as well as the characteristics of these resources and their most prominent types and investment possibilities in developing the southern desert of Iraq. The research hypothesis indicates that the natural environment, represented by the climate, soil, terrain, surface and underground water resources, rock structures and their mineral wealth, as well as vegetation, has a clear and distinctive role in the formation of natural resources that can be used as pillars of human development in the study area. The importance of the research lies in shedding light on the most prominent wealth and natural resources that can be invested in developing one of the desert areas with scattered settlements in southern Iraq, where no serious initiative has been made. The main objective of the research is to clarify the spatial relationship between the natural characteristics of the Wadi Abu Hadair Basin and the available natural resources, so as to invest them economically.

MATERIAL AND METHODS

The most important natural resources of the Wadi Abu Hadair basin were analyzed and interpreted through the use of several tools. A number of sources were relied upon, including analysis of aerial photographs, scale (1/50000), topographic maps of scale (1/25000), (1/50000) and (1/100000) and (1/250000) issued by the General Authority for Iraqi Survey, as well as geological maps of scale (1/250000). Additionally, the satellite visual of the American satellite (Landsat ETM + 8) for the year 2016 was relied upon, with the ability to distinguish (30) AD, and the radar board SRTM. These data were analyzed using the Arc GIS 10.8 program, in addition to relying on a number of field studies for

the study area, as well as applying the Berkeley equation to know the expected annual flow:

R = (CIS) 1/2 (W / L) 0.45

Where:

R = expected annual runoff volume (billion m^{-3}).

I = the expected annual rain volume (billion m^{-3}), calculated by multiplying the annual rain rate by the area of the basin and then dividing the result over 1,000,000.

S = slope rate (m/km), calculated as the difference between the maximum and minimum value in the basin height/basin length.

W = rate of duct width.

L = length of valley from upstream to downstream, measured with Arc Map 10.4.1 software.

C = a constant coefficient estimated in the southern desert, being (0.1).

Study area: Wadi Abu Hadair basin is located in the middle of Al Salman desert in the Governorate of Al-Muthanna, within the Lower Valleys region (Fig. 1). It is one of the largest dry valleys that flow into Al-Sulaibat. It is located within longitude and latitude (44°47′45″ - 45°14′4.1″E) and (30°59′49.1″ - 30°11′55.5″N), and it is 29 km away from the city of Al-Batha and 45 km from Ur, which implies that it extends for about one degree of width and about one degree of longitude. The Wadi Abu Hadair basin is bordered on the north side by the Al-Husam, Al-Dawudan, and Abu Muris valleys basins, whereas on the west side it is bordered by the valleys Al-Tayyar, Al-Hawaimi and Al-Faraj, and to the south it is bordered by the Wadi Al-Akarawi basin and its secondary valleys, whereas from the east it is bordered by the Al-Ashali, Al-Arjawi and Al-Kaseer valleys. The basin overlooks the Al-Sulaibat in its northern part through its flood stream.

RESULTS AND DISCUSSION

Water resources: The study area is classified within the hot dry areas, especially in terms of expanding settlement and economic exploitation, as based on agriculture and grazing. The sources can be divided into two types, namely surface water resources and groundwater. Since the annual amount of rain falling over the Wadi Abu Hadair basin is relatively small, changeable from one year to another, and its greater part is lost through evaporation, seepage and drainage towards the Sulaibat depression, no permanent surface water is considered in the area of study. This clarifies that when sudden rains fall with the cold fronts of the atmospheric depressions, the temporary surface water flows in the course of the valley basin and its tributaries in form of violent torrents, in which the water suddenly flows and causes flash floods. Many of these may continue to run in this way for several consecutive days and several times in all the years of relatively heavy rain. During periods of rain retention and after the surface water loses a large part of it through evaporation, leakage and drainage, running water could sometimes be observed in form of thin, threadlike surface water flowing in some of the secondary valleys in the basin. These weak water flows may continue to run for long periods of the year .

The occurrence of surface water was observed which flows over a distance of a few hundred meters in the form of weak runoff water with limited thickness in each of the valleys of the Wadi Abu Hadair Secondary Basin and Wadi Al-Theeb Basin (Fig. 2). Approximately (90%) of the average annual rainwater flowing in the Wadi Abu Hadair basin occurs during the main flood season (winter, from November to March). The study area is devoid of the availability of permanent surface water, except for some springs of limited spread. The valley overflows when the rains fall, and there is no hydrological station to measure the amount of water discharge.

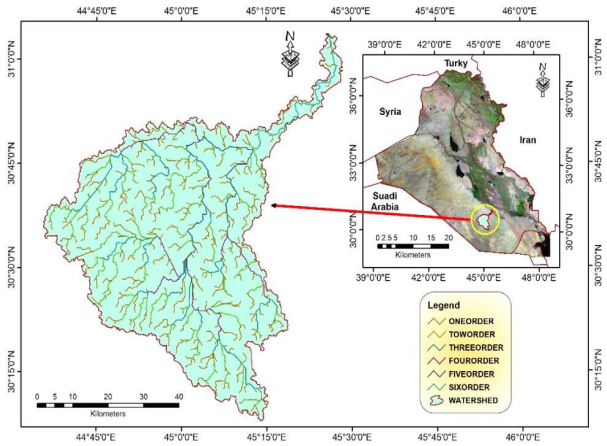


Fig. 1. Location of study area, Iraq



Fig. 2. Seasonal water flow in Wadi Abu Hadair secondary basin

The expected annual flow rate in the basin has reached (0.224) billion m^3 annually, while the secondary basins varied in the size of this revenue, being about (0.138) and (0.042) billion m^3 in Wadi Abu Hadair and Wadi Al-Akraa basins, respectively (Table 1). Despite the modest volume of surface water in the basin, some farmers have succeeded in exploiting it economically and erected deep circular pits in some parts of their farms for this surface water to collect inside them. The farms which were located at a level higher than the level of running water in the Wadi made use of pumps to rise these water so as to be used for irrigation and domestic purposes.

As for underground water resources, these contain water that is infiltrated from the surface through the fragile soil into the earth's crust formations, later to became larger groundwater reservoirs . In spite of the multiplicity of types of groundwater and the variation of its sources in the study area, the biggest source for it is rain precipitation. Despite its smallness, it takes a way towards the interior layers, and the bulk of this receding water settles between the folds of the rocks, filling the interstitial spaces and voids present in the sediments of the debris rocks, and settling in the pores of fused rocks and their joints and cracks, thereby forming the underground water reservoirs. Three reservoirs have been noted in the study area. Sedimentary layers or rock formations that contain this water are known as aquifers, and the availability of groundwater in these rocky areas depends on several natural characteristics, namely the degree of porosity and the degree of permeability .

The wells of the study area were used for human and animal purposes (Fig. 3), which made it a center for attracting population. Due to the decline of the study area towards the northeast towards the Sulaibat depression, large quantities of rainwater descend during its fall season. However, this quantity of water loses a large proportion of it due to evaporation and leakage into the soil, which is then considered wasted and is not used due to the long distance that it crossed to reach the depression. This is clearly visible in the secondary valleys of the basin, therefore, some natural dams can be constructed on the streams of these basins to benefit from the accumulated water to be used for grazing and agriculture purposes and reduce the depletion of well water, in addition to feeding the groundwater reservoirs with large quantities of water, especially since water reservoirs suffer from a lack of nutrition due to drought. The raw materials for creating dams include limestone, sand, gravel and boulders, which are all available in the region. A dam can be built on Wadi Abu Hadair secondary basin, particularly in the narrow area located to the south of the Abu Hadair flood, since the course in this area is characterized by its narrowness, along with the presence of rock cliffs that resist erosion processes. As for the Wadi Al-Theeb Basin, the best place to establish the dam is to the south. In the case of Abu Hadair main basin, the optimal places for constructing a dam is to the south of Ghadir (Lahuj) because of the hardness of the rocks and the narrowness of the valley (Fig. 4).

Grazing: This activity is widely practiced in the basin of Wadi Abu Hadair because it is an important resource in the population's economy, especially in the years of fertility or rain when the growth of woods and pastoral herbs is abundant. This drives the owners of livestock such as the shepherds of sheep, goats and camels to migrate to areas of



Fig. 3. Wells of study area

Table 1. Expected annual flow for the Abu Hadair Basin and its secondary ones

Name of Basin	Area (km^2)	Length (km)	Average width (km)	Average annual rainfall (mm)	Average slope (km/m)	Rain size (billion m^{-3})	Width /length	Expected annual flow (m^3)
Abu Hadair (secondary)	830,02	89,25	9,299	90	2,240	0,074	0,104	0,238
Al-Shikhia	676,68	53,25	12,70	90	1,877	0,060	0,238	0,044
Al-Theeb	1162,50	63,43	18,82	90	1,891	0,104	0,296	0,056
Al-Akraa	708,72	46,66	15,18	90	1,714	0,063	0,325	0,042
Abu Hadair (main)	3377,93	112	30,16	90	1,964	0,304	0,269	0.224

fertility. This activity mainly occurs during the rainy season, being from October to the end of May of each year. Due to the lack of rainfall and its insufficiency for practicing agricultural activity the lands south of the basin have become a major grazing area in which plants grow in the event of rain and include areas as Al-Shawiya, Trak Al Kulaib and Burbak, (Fig. 5). The importance of these areas is linked to the presence of various types of natural plants important for grazing, in addition to wells with potable water that enable the owners and their animals to survive in the area, and farmers may resort to planting some crops, especially fodder nearby.

As for the area to the north of the basin, it is a region with little grazing due to the lack of vegetation growth in it, so it is not considered a significant grazing area. The geographical distribution of livestock numbers indicates that they are mostly located in the southern parts of the basin, due to its many pastures. Yet, the actual numbers that exist within the region are much more, especially in rainy years, as the study area attracts huge herds of animals coming from surrounding areas. The grazing system in the study area is free grazing, as the herdsmen move with their flocks without restrictions, so many pastures in the study area suffer from stress, depletion of their plants and the inability to renew themselves in a way that guarantees them stability, as it is within the natural limits. In terms of exploitation, it takes the pasture to reproduce what it consumes as animal food for a year or less . Excessive grazing led to the disappearance of some of natural plants which are of importance for grazing and the replacement of unpalatable plants such as *(Prosopis farcta, Monotropa and Myrteae)*, and on the other hand it weakened the soil cohesion and exposed it to the risk of erosion and water or air erosion.

Natural vegetation: Natural plants of various kinds are spread throughout the study area, and it is one of the groups of desert plants that have adapted themselves to harsh environmental conditions, especially high temperatures, lack of rain and its fluctuation. The region has rich natural pastures due to its greater share of water and its suitable soil for the growth of herbs, so it is used by shepherds of sheep, camels and goats from many areas, especially from neighboring ones. In many ways, including the large underground root network and needle leaves, these shrubs provide important grazing plants in the summer, when green fodder is scarce, or in places that are not suitable for weeds, as they start to grow in summer and bloom and seed during fall. Among the types of these plants in the study area are *(Tamarix*, *Tamarix aphylla, Haloxylon ammodendron, Zizphus spina and Ranterium epapposum)* (Fig. 6). In addition, perennial weeds and herbs are characterized by their rapid response to the autumn rains, as they begin to

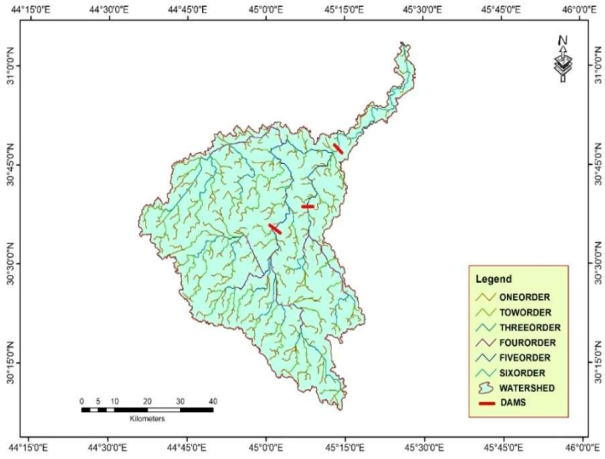


Fig. 4. Locations for the suggested dams within the area of study



Fig. 5. Grazing in the area of study



Fig. 6. Annual weeds in the area of study

form new growth and thus provide early grazing for animals, as well as their importance in preserving the soil from erosion, with their delicate and dense root network, and their types include *(Calligonum comosum, Achillea micrantha, Haloxylon salicornicum and Anabasis)*. As for the second type of desert plants in the study area, annual weeds and herbs are characterized by their short life cycle, as they grow in the rainy season and end when the seeds are formed to re-grow after about a whole year. It has a great pastoral value for its palatability to animals, especially when it is green (Fig. 7).

In general, the study area is considered to be unable to support large numbers of animals that exceed the pastoral energy, which would damage and destroy the pastures and their plants, especially in depressions and valleys, characterized by the presence of many types of perennial plants. Therefore, an appropriate plan must be drawn up to proportion animals according to the amount of production of natural pasture plants, as well as the use of organized grazing in its various ways, such as periodic and postponed grazing, which preserves good and palatable plant species and prevents their extinction. Being one of the essential components of the ecosystem, yet the numbers of these organisms have decreased significantly due to natural factors, including climate change, water resources, and other human practices related to incorrect and negative human practices such as poaching and killing large numbers of them. This led to the extinction of a large number of animals, such as deer, falcons, bustards, partridges, and hares .

Minerals: The study area is rich in mineral resources, which have not been used in a thoughtful and planned manner due to the lack of technologies and research capabilities. Some of these resources are exposed, such as stones and building rocks (Fig. 8A), and some are in the form of sediments, most of which are concentrated in the stomachs of valleys and depressions (Fig. 8B), varying in thickness from one region to another, and consist of large boulders and pebbles that the running water cannot carry. It is transported though stumbling and rolling, which are controlled by several factors including the volume of water drainage, the speed of the water, the severity of the slope, and the distance traveled by the stream. These sediments are spread in multiple areas of the basin. Most of them are of local origin, indicated by their sharp corners and lack of roundness. They originate from the limestone, gypsum, marl, and flint rocks, and vary in size between several millimeters and large crushed stone blocks with sizes of more than 50 inches, which were swept by torrents to the bottom of the valley. These are not clearly separated but mixed with sand and mud due to the large number of sediments that are deposited with it through water erosion processes. The gravel is used in construction works, concrete and brick making, paving work, road and pavement construction, and other uses.



Fig. 7. Annual vegetation



Fig. 8. Types of rocks in the basin

CONCLUSIONS

Wadi Abu Hadair overflows through heavy rain storms which rarely occur in winter season, therefore groundwater is the mainstay of life in the study area. Grazing is widely practiced in the study area because it is an important resource in the population's economy. Different types of natural plants are spread throughout the study area, and it is one of the groups of desert plants that have adapted themselves to harsh environmental conditions, especially high temperatures and a lack of rain. Also, the study area is rich in mineral resources, some of these resources are exposed, such as stones and building rocks, and some are in the form of sediments, most of which are concentrated in the center of valleys and depressions, varying in thickness from one region to another.

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Soil Physical and Hydraulic Properties of Irrigable Lands in the Northern Region of Ghana

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Abstract: The study was carried out to determine soil physical and hydraulic properties of irrigable lands in three selected irrigation schemes in the Northern Region of Ghana. Soil properties estimated were hydraulic conductivity, gravimetric moisture content, volumetric moisture content, soil texture, bulk density, soil infiltration and soil porosity. Data was obtained from both primary and secondary sources with methods used for data collection as detailed survey, desk study, remote sensing and GIS, laboratory and field work. Average hydraulic conductivities recorded were 2.52 x 10^{-6} m/s, 2.28 x 10^{-6} m/s, and 1.87 x 10^{-6} m/s for Bontanga, Libga and Golinga irrigable lands respectively. The average volumetric water content was 0.25, 0.31 and 0.19 cm^3cm^{-3} and with 0.18 [1], 0.15 and 0.18 gg^{-1} average gravimetric water contents for Bontanga, Golinga and Libga, respectively. Bontanga and Libga irrigable areas recorded the same average dry bulk density of 1.8 g cm^{-3} whilst Golinga recorded 1.7 g cm^{-3}. The soil texture was sandy loam for the Bontanga and Golinga irrigable lands whilst Libga was a loamy sand with average soil porosity ranging from 0.31 to 0.35%. There were significant difference for average soil temperature, sand and silt percent and volumetric moisture content of unsaturated soils in different sites. The soil physical and hydraulic properties presented good and desirable qualities for the cultivation of different tropical crops.

***Keywords*:** Hydraulic conductivity, Soil porosity, Gravimetric moisture content, Bulk density, Volumetric moisture content

Physical properties of soil include colour, texture, structure, porosity, density, consistence, temperature, and air. Soil texture, structure, porosity, density, and consistence are related with types of soil particles and their arrangement (Osman 2013). Soil texture and structure together regulate porosity, density, compactness, retention, and movement of water and air in soil. Mangi (2018) noted some key soil physical indicators in relation to climate change to include soil structure, water infiltration rate, bulk density, rooting depth, and soil surface cover. Soil property is the physical, hydraulic or chemical aspects of the soil and these properties can influence its infiltration and thus irrigation and agriculture production. Variation of infiltration–related soil physical properties from different sites in the field presents a challenge to infiltration prediction. Understanding of the behaviour of the soil physical, hydraulic and chemical properties is a challenge to crop production especially in relation to climate change. Soil-plant-water relations are linked to the physical properties of soil and plants that influence the movement, retention and use of water (Saurau and Nkem 2018). The most favourable moisture conditions for any crop depend on a number of factors, including soil type, climate conditions, growth rate and habit (El-Shal and Soad 2012).

Soil hydraulic properties, including soil hydraulic conductivity function and water retention characteristics are influenced by soil texture, bulk density, soil structure, and organic carbon content, many of which are easily influenced by landuse and management even though the soil classification may be the same (Zhou et al 2007). Saturated hydraulic conductivity (Ks) is the movement of water in soil surface when it is at saturated condition (Shukla and Lal 2004, Islam et al 2017). *Ks* is useful in designing irrigation, drainage and wastewater systems, studying runoff characteristics and groundwater recharge, modelling of water in motion and pesticides from agricultural land (Jarvis et al 2013). Soils with similar texture may have quite different *K*-values, due to varied soil structure and also some heavy clay soils have well-developed structures and much higher *K*-values (Ritzema 2006, Stibinger and Labem 2014). The soil texture and structure greatly influence hydraulic conductivity of a given sample of soil. Soil texture, structure, porosity, density, and consistence are related with types of soil particles and their arrangement (Osman 2013). The study assessed soil physical and hydraulic properties of irrigable lands of three irrigation sites in the northern region of Ghana.

MATERIAL AND METHODS

Study area: The study was carried out in the irrigable lands

of three irrigation schemes namely; Bontanga, Golinga and Libga in the Northern Region of Ghana. Figure 1 is a map showing the irrigation schemes whilst the principal characteristics of the schemes are presented in Table 1.

Soil sampling in the irrigable areas: The irrigable area of each irrigation scheme was divided into three zones namely; upstream, midstream and downstream for soil sampling. Nine soil samples were taken at 0-60 cm depth in each irrigable area. Structurally undisturbed soil samples were collected from the field using a 4.1 cm diameter pressure PVC pipe cut to a length of 60 cm and slanted at the outer part of the lower end to make soil cutting easier. Collection of soil samples were carried out by initially excavating a circular trench around an unbroken "pillar" of undisturbed soil which was higher and had a somewhat bigger diameter than the PVC pipe core sampler. The core sampler was then inserted directly into the pillar of the soil by striking a wooden plank positioned across the top of the ring, with a mallet, by this, the edges of the pillar were allowed to fall away from the core as it was inserted. Following complete insertion, the core was removed by hand and labeled as described by Tuffour (2015). A total of twenty-seven soil samples were taken from the three schemes at the locations Figure 2 and Table 2.

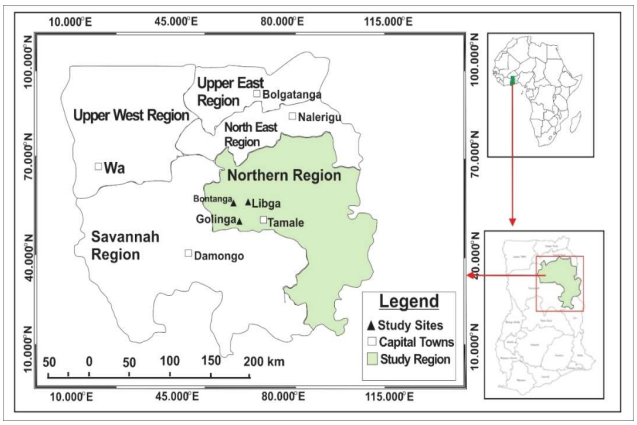


Fig. 1. Northern Ghana showing the study sites. Adopted and modified from Adongo et al (2019)

Soil infiltration test: Double ring infiltrometer was used to test the soil infiltration on the field at the study sites using the following procedure:

- 30 cm and 60 cm diameter rings were hammered at 15 cm into the soil using a mallet. The side of the rings was kept vertical and 12 cm above the ground.
- Polythene sheet was used to protect the soil surface inside the rings before pouring in the water.
- Water was poured into the rings until the depth was approximately 12 cm.
- After 2 minutes, the drop in water level was recorded in the inner ring on the measuring rod and water was added to bring the water level back to the original level.
- The water level inside the inner ring was recorded and water level outside the inner ring was maintained similar to that of the inside.
- Readings were taken at 2 minutes intervals at the beginning of the test and increased to 5 minutes, 15 minutes and 30 minutes as infiltration reduced.

Measurement of soil hydraulic conductivity: Saturated hydraulic conductivity (Ks) of the sampled soils was estimated in the laboratory using the constant-head method

Table 1. Description of study irrigation schemes

Name of scheme	Location			Period of construction		Management	MWD	PIA (ha)	DIA (ha)	Crop cultivated
	Region	District	Coordinates	Start	End					
Bontanga	Northern	Kumbungu	9° 57'N 1° 02'W	1980	1986	GIDA	Gravity	800	495	Rice (*Oryza sativa*), Onion (*Allium cepa*), Roselle (*Hibiscus sabdariffa*), Maize (*Zea mays*), Okra (*Hibiscus esculentus*), Tomato (*Lycopersicon esculentum*), Pepper (*Capsicum frutescens*), Vegetable jute (*Corchorus olitorius*), Garden eggs (*Solanum melongena*), Groundnut (*Arachis hypogea*), Cowpea (*Vigna unguiculata*), Amaranth, 'Alefu' (*Amaranthus spinosus*)
Golinga	Northern	Tolon	9° 22'N 0° 57'W	1976	1980	GIDA	Gravity	100	40	
Libga	Northern	Savelugu	9° 59'N 0° 85'W	1971	1974	GIDA	Gravity	40	16	

Source: GIDA (2017); Adongo (2019). PIA – Potential irrigable Area, DIA – Developed irrigable Area. MWD = Mode of water deliver

as described by Black et al (1965) and calculated using Equation 1 given by Turner (2006) as;

$$k_s = \left[\frac{vp}{A_c \Delta t}\right]\left[\frac{L}{H}\right] = k_s = \left[\frac{Q}{A_c}\right]\left[\frac{L}{H}\right] \qquad (1)$$

Where: K_s – Saturated hydraulic conductivity, A_C - cross sectional area of the sampled soil in [L^2]; L - sampled soil length [L]; H - the hydraulic head [L]; *Q* - V/t, Water flow rate [L^3T^{-1}]; VP - Amount of percolate collected [L^3] and Δt - time for percolate collection [T].

Gravimetric soil water content: The gravimetric approach as used by Gardner (1986) was applied to estimate the initial soil water content for the three study locations. The mass of wet soil samples was taken using beam balance, after which the samples were dried in force-draft oven at 104°C for 24 to 48 hours, and the dry soil then weighed. The gravimetric moisture content of the soil (θ_g) at this point was calculated using Equation 2.

$$\theta_g = \frac{M_w - M_d}{M_d} \qquad (2)$$

Where: θ_g - gravimetric moisture content of the soil; M_w - mass of wet soil and M_d - mass of dry soil.

Soil dry bulk density: The dry bulk density of the soil was calculated using Equation 3 as used by Tuffour (2015) and given as:

$$\text{Dry Bulk Density of Soil (pb)} = \frac{M_d}{V_t} \qquad (3)$$

Where: (ρb) Dry bulk density (g/cm^3); M_d – mass of dry soil (g); V_t – volume of dry soil (cm^3)

Volumetric soil moisture content: Equation 4 as used by Tuffour (2015) was adopted to calculate volumetric soil moisture content using the soil bulk density and gravimetric soil moisture content and the density of water.

$$\theta_c = \theta_g\left(\frac{pb}{pw}\right) \qquad (4)$$

Where: θv – volumetric water content ($cm^3\ cm^{-3}$) ρb – Dry bulk density (g cm-3); ρw – density of water (assumed to be 1.0 g cm^{-3}), θ_g Gravimetric water content M/M

Soil porosity: With particle and bulk densities, the soil porosities were calculated using Equation 5 as given by:

$$f = 1 - \left(\rho_b \Big/ \rho_s\right) \qquad (5)$$

Where: f – porosity; ρ_b – bulk density; ρ_s – density of particle size (assumed to be 2.65 g cm^{-3})

Soil particle size distribution: The hydrometer method as described by ASTM (1985) was used to measure the soil particle size distribution. This method was used because it allowed for the non-destructive sampling of suspensions undergoing settling (Tuffour 2015).

Statistical analysis: Data was analysed and tested for statistical significance among mean variation for the different irrigable areas by analysis of variance. The level of significance was tested at 5% using Minitab 16 statistical software and the results presented in Tables.

RESULTS AND DISCUSSION

Physical Properties of the Saturated Soils

Soil texture: Soil textural class of Bontanga and Golinga was sandy loam with different percentages in particle sizes and with Libga being loamy sand (Table 3). The particle size composition of each texture influences the behaviour of the textural class of the soils, therefore soil hydraulic conductivity, infiltration and porosity of the soil were influenced by the particle size distribution of the sampled soils. Soil with more clay content may exhibit low hydraulic conductivity and infiltration but high porosity. Percent sand at Golinga was significantly different from the other sites at *p*-value of 0.003. While percent silt was significantly different between Golinga and Libga at *p*-value 0.02 (Table 3).

Soil infiltration rates: The cumulative infiltration increases with time, whereas infiltration rates decrease with time. The average range of infiltration rates at Bontanga ranged from 2.66 mm h^{-1} to 65.42 mm h^{-1}, Golinga was 0.4 mm h^{-1} to 55.78 mm h^{-1} and Libga was 5.0 mm h^{-1} to 49.88 mm h^{-1} indicating a characteristic decrease infiltration rate with increasing time (Figures 3 and 4, Table 4). Variation in the infiltration rate may be linked to the variation in saturated hydraulic conductivity and some of the soil physical properties such as bulk density, porosity, moisture content as measured in the surface soil layer of 60 cm deep. The average cumulative infiltration at Bontanga was 33.47 mm followed by Golinga (20.10 mm) and Libga (32.32 mm) as influenced by the percentage clay content of the soils. Soil temperature and compaction could cause difference in the rate of infiltration since increasing temperature reduces surface tension and increases viscosity of water. Wilson (2017) recorded typical infiltration rates for loamy sand as 5 cm h^{-1} (50 mm h^{-1}) and 2.5 cm h^{-1} (25 mm h^{-1}) for sandy loam under low moisture content. The relatively high moisture content brought about lower infiltration rates of 0.4 mm h^{-1}, 2.66 mm/h and 5.0 mm h^{-1} for Bontanga, Golinga and Libga irrigable areas respectively. These differences could be due to difference in the soil moisture content. USDA-NRCS (1985) reported that group 'A' soils have high infiltration rates of >7.5 mm h^{-1}, group 'B' soils have moderately high infiltration rates of 3.8-7.5 mm h^{-1}, group 'C' soils have moderately low infiltration rates of 1.3–3.8 mm h^{-1}; and group 'D' soils have low infiltration rates of < 1.3 mm h^{-}

[1]and based on this classification, soils at Bontanga irrigable area belong to group C, Golinga belongs to D and Libga belongs to B. These results are in line with the basic infiltration rates of 0.4 mm h^{-1}, 2.66 mm h^{-1} and 5.0 mm h^{-1} obtained for Bontanga, Golinga and Libga irrigable areas, respectively.

Bulk density of dry sampled soils: The average dry bulk densities of the soils at the various study sites were 1.8 g cm^{-3} at both Bontanga and Libga and 1.7 g cm^{-3} at Golinga (Table 5). The difference in dry bulk density may be due to different particle size distribution of the soils of the irrigable lands. Course and fine soils of the same quantity may have different densities. These densities correspond well with sandy loam of bulk densities 1.55 - 1.75 g cm^{-3} and loamy sand (> 1.75 g

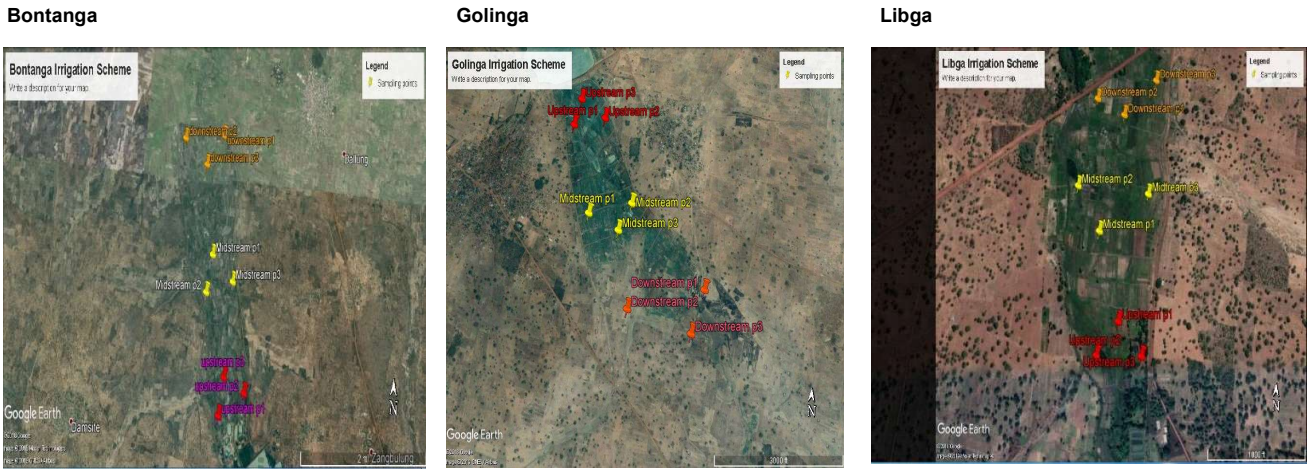


Fig. 2. Sampling points at the study sites

Table 2. Soil sampling points at the irrigable areas of the irrigation schemes

Study site	Soil sampling location	Sampling point	Latitude (°)	Longitude (°)	Altitude (m)
	Upstream (US)	P1	9°35′46.65″N	0°51′13.58″W	156
		P2	9°35′43.97″N	0°51′15.74″W	156
		P3	9°35′44.27″N	0°51′10.89″W	156
Libga	Midstream (MS)	P4	9°35′53.53″N	0°51′16.30″W	155
		P5	9°35′57.09″N	0°51′19.11″W	155
		P6	9°35′56.99″N	0°51′10.94″W	155
	Downstream (DS)	P7	9°36′3.66″N	0°51′14.24″W	154
		P8	9°36′4.91″N	0°51′17.55″W	154
		P9	9°36′7.07″N	0°51′10.64″W	154
	Upstream (US)	P1	9°34′30.39″N	1°1′49.39″W	136
		P2	9°34′42.75″N	1°1′28.18″W	134
		P3	9°34′49.15″N	1°1′45.89″W	133
Bontanga	Midstream (MS)	P4	9°35′50.72″N	1°2′0.43″W	127
		P5	9°35′30.52″N	1°2′4.76″W	130
		P6	9°35′37.77″N	1°1′41.39″W	129
	Downstream (DS)	P7	9°36′58.35″N	1°1′55.07″W	121
		P8	9°36′53.98″N	1°2′31.21″W	122
		P9	9°36′40.20″N	1°2′9.68″W	123
	Upstream (US)	P1	9°21′19.18″N	0°57′9.50W	154
		P2	9°21′21.23″N	0°57′1.37″W	155
		P3	9°21′24.89″N	0°57′8.09″W	155
Golinga	Midstream (MS)	P4	9°21′1.34″N	0°57′3.56″W	154
		P5	9°21′4.16″N	0°56′52.67″W	154
		P6	9°20′58.63″N	0°56′55.67″W	155
	Downstream (DS)	P7	9°20′48.99″N	0°56′33.19″W	155
		P8	9°20′44.02″N	0°56′52.07″W	155
		P9	9°20′40.76″N	0°56′36.11″W	155

cm^{-3}) as reported by Edward (2020). Turner (2006) also reported bulk density of 1.7 g cm^{-3} for sandy loam which corresponds to the bulk density at Libga irrigable land. Variation among average dry bulk densities for the study sites was statistically not significant at *p*-value of 0.63 (Table 5).

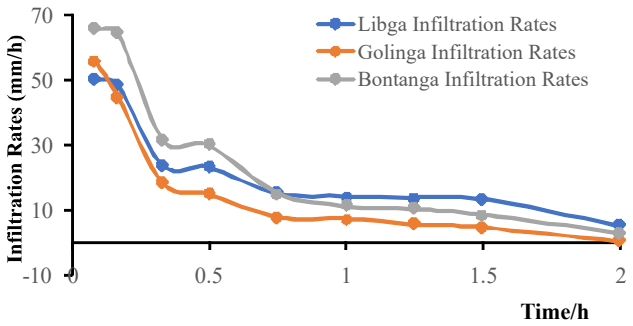


Fig. 3. Infiltration rates of the irrigable areas

Soil porosity: The soil porosity at both Bontanga and Libga irrigable areas ranged from 0.25 to 0.36% with an average porosity of 0.31% whilst the Golinga site recorded 0.32 to

Table 3. Textural class of soils at the study sites

Study site	Sand (%)	Clay (%)	Silt (%)	Textural class
Bontanga	72.59 ±0.99^{a}	6.23 ±3.28	19.5 ± 3.42^{ab}	Sandy Loam
Golinga	65.17 ±2.33^{b}	7.64 ±1.55	27.19 ±1.0^{a}	Sandy Loam
Libga	77.76 ±3.72^{a}	7.21 ±1.57	15.03 ±5.27^{b}	Loamy Sand
ANOVA				
p-value	0.003	0.75	0.02	
LSD	5.19	4.55	7.34	
SED	2.12	1.86	3.00	
CV%	3.60	32.40	17.90	

p-value - Probability value, LSD - Least Significance Difference, SED - Standard Error of Difference, CV- Coefficient of Variation. Means within columns that do not share a letter are significantly different

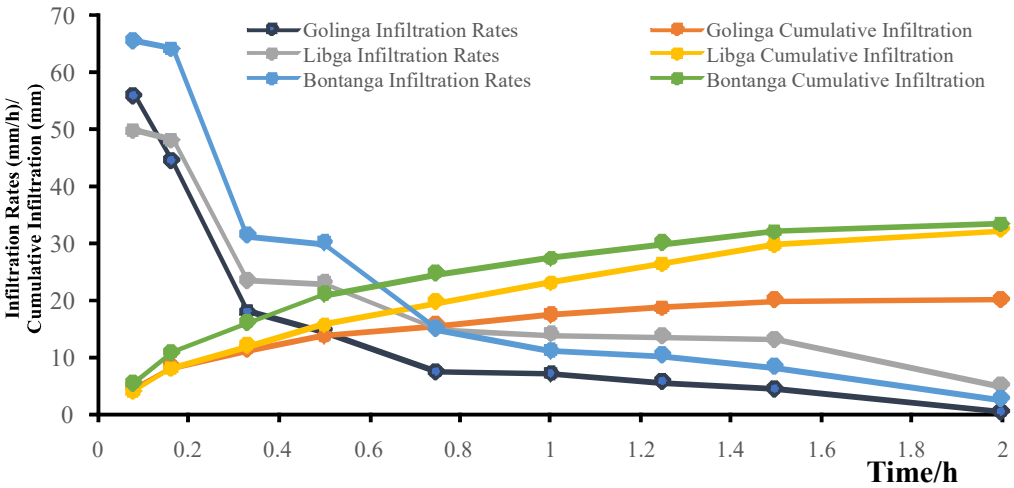


Fig. 4. Infiltration rates and cumulative infiltration at the study sites

Table 4. Infiltration rates at the irrigable areas

Time (min)	Time (h)	Elapsed time(h)	Bontanga irrigable area			Golinga irrigable area			Libga irrigable area		
			AI (mm)	IR (mm/h)	CI (mm)	AI (mm)	IR (mm/h)	CI (mm)	AI (mm)	IR (mm/h)	CI (mm)
5	0.083	0.083	5.43	65.42	5.43	4.63	55.78	4.63	4.I4	49.88	4.14
10	0.167	0.083	5.33	64.22	10.76	3.68	44.34	8.31	4.00	48.19	8.14
20	0.333	0.167	5.22	31.26	15.98	3.04	18.20	11.35	3.91	23.41	12.05
30	0.500	0.167	5.00	29.94	20.98	2.46	14.73	13.81	3.83	22.93	15.88
45	0.750	0.250	3.73	14.92	24.71	1.86	7.44	15.67	3.76	15.04	19.64
60	1.000	0.250	2.77	11.08	27.48	1.77	7.08	17.44	3.51	14.04	23.15
75	1.250	0.250	2.57	10.28	30.05	1.40	5.60	18.84	3.40	13.60	26.55
90	1.500	0.250	2.09	8.36	32.14	1.10	4.40	19.94	3.27	13.08	29.82
120	2.000	0.500	1.33	2.66	33.47	0.20	0.40	2.50	2.50	5.00	32.32

AI=Average Infiltration; IR=Infiltration Rate; CI=Cumulative Infiltration

0.40% porosity with an average porosity of 0.35% (Table 5). Soil porosity amongst other conditions influences the hydraulic properties of the soil. Golinga irrigable area recorded the highest average porosity compared to Bontanga and Libga, but with Golinga irrigable land showing relatively low average hydraulic conductivity of 1.87 x 10^{-6} m/s indicating that high porosity is not directly proportional to soil permeability. The clay content of sampled soil at Golinga was 7.64 % followed by, at Bontanga and Libga . This also indicates that the sampled soil at Golinga site has more clay content than the other two sites justifying its high porosity. This means that clay has high porosity but small pore size thus allowing it to retain water better than sand with low porosity but large pore size. Azuka et al (2013) reported relatively high soil porosity, ranging from 43.14 to 54.34%. Findings by Islam et al (2017) on porosity showed an average range of 33 to 35%, which conforms to the range of average porosity of 31 to 35% in this study. The difference in average soil porosity among the study sites was statistically not significant at *p*-value of 0.64 (Table 5).

Gravimetric and volumetric water contents of saturated soil samples: The average gravimetric water contents were 0.18 gg^{-1}, 0.15 gg^{-1} and 0.18 gg^{-1} for Golinga, Libga and Bontanga irrigable areas respectively. The results of Golinga and Bontanga were the same because of similar soil characteristics (Table 5). Similar to dry bulk density and soil porosity, there was no significant difference for variation of the average volumetric water content among the various study sites at *p*-value of 0.21(Table 5). The average volumetric water content recorded was 0.25 cm^3cm^{-3}, 0.31 cm^3cm^{-3} and 0.19 cm^3cm^{-3} at Bontanga, Golinga and Libga study sites respectively (Table 5). It was realized that Golinga with the highest moisture content had the least average hydraulic conductivity indicating that the moisture content influences the hydraulic property of the soil. Turner (2006) reported mean soil moisture content of the saturated soil samples as 0.368 and 0.339 cm^3/cm^3 on sandy soils at Upper Marlboro and Popular Hill Site respectively. Despite the different volumetric water content recorded at the various study sites, variation among average content showed no significant difference at *p*-value of 0.63 (Table 4).

The moisture content of unsaturated soil 6 indicates that average volumetric moisture content were 0.220, 0.133 and 0.237 cm^3 cm^{-3} for Golinga, Libga and Bontanga respectively and the average moisture content of the saturated soil were 0.318, 0.280 and 0.335 cm^3 cm^{-3} for Golinga, Libga and Bontanga irrigable areas respectively (Table 7). The study sites with similar characteristics such as Bontanga and Golinga had the same available water storage of 5.88 d/cm

Table 5. Physical properties and associated water holding properties of the saturated soils

Study site	$\theta_g(gg^{-1})$	(g/cm^3)	$\Theta_v(cm^3cm^{-3})$	Porosity (%)
Bontanga	0.18 ±0.03	1.8 ±0.15	0.25 ±0.19	0.31 ±0.06
Golinga	0.18 ±0.01	1.7 ±0.12	0.31 ±0.02	0.35 ±0.05
Libga	0.15 ±0.02	1.8 ±0.15	0.19 ±0.14	0.31 ±0.06
ANOVA				
p-value	0.21	0.63	0.63	0.64
LSD	0.04	0.28	0.11	0.11
SED	0.017	0.116	0.278	0.04
CV%	12.00	7.90	55.80	16.40

$p_b(g/cm^3)$ = Bulk Density; $\theta_g(gg^{-1})$ = Gravimetric Soil Water Content; and θ_v = Volumetric Water Content (cm^3cm^{-3}) p-value - Probability value, LSD - Least Significance Difference, SED - Standard Error of Difference, CV- Coefficient of Variation

Table 6. Volumetric water content of unsaturated soils and available water storage

Study site	θi (cm^3/cm^3)	θf (cm^3 /cm^3)	SA = (θf - θi) d/cm
Bontanga	0.237 ±0.003[a]	0.335 ±0.06	5.88
Golinga	0.220 ±0.01 [b]	0.318 ±0.03	5.88
Libga	0.133 ±0.003 [c]	0.280±0.01	8.82
ANOVA			
p-value	0.001	0.24	
LSD	0.01	0.07	
SED	0.01	0.03	
CV%	3.20	11.60	

p-value - Probability value, LSD - Least Significance Difference, SED - Standard Error of Difference, CV- Coefficient of Variation.Means within columns that do not share a letter are significantly different

Table 7. Average temperatures and saturated hydraulic conductivities of sampled soils

Study site	Initial temperature (℃)	Final temperature (℃)	Saturated hydraulic conductivity (m/s)
Bontanga	29.93 ±0.25[a]	30.6 ±0.27[a]	$2.52x10^{-6}$±$2.25x10^{-6}$
Golinga	27.93±0.55[b]	29.6 ±0.27[b]	$1.87x10^{-6}$±$5.61x10^{-6}$
Libga	29.2 ±0.17[a]	29.93 ±0.32 [ab]	$2.28x10^{-6}$±$3.99x10^{-7}$
ANOVA			
p-value	0.001	0.01	0.85
LSD	0.73	0.57	0.00
SED	0.30	0.23	0.00
CV%	1.30	0.90	61.10

p-value - Probability value, LSD - Least Significance Difference, SED - Standard Error of Difference, CV- Coefficient of Variation. Means within columns that do not share a letter are significantly different

which was lower as compared to Libga with d/8.82 cm due to the different textural classes.

The average volumetric moisture content for unsaturated soils was statistically significant at *p*-value of 0.001 while that of the saturated soil was not significant at relatively high *p*-value of 0.24 (Table 6). Northcott (2010) reported that sandy loams and fine sandy loams have moisture content range of 0.10 - 0.15 cm^3 cm^{-3} and medium textured sandy loam, loam and silt loam recorded a range of moisture content of 0.13 - 0.19 cm^3 cm^{-3}. Ogbe et al (2011) reported three different moisture contents at three different sites was 5, 4.7 and 4.4%, which are higher than 2.20, 1.33 and 2.37% in present study with differences largely occurring from the influence differences of environmental and edaphic characteristics.

Saturated hydraulic conductivity of soil: The increasing percentage of clay content resulted in a corresponding reduction in saturated hydraulic conductivity (Ks) for all the study irrigable areas. The upstream of Libga irrigable area recorded the highest hydraulic conductivity of 2.7 x 10^{-6} m/s, followed by 1.23 x 10^{-6} m/s at Golinga and with Bontanga upstream showing the least hydraulic conductivity of 1.2 x 10^{-6} m/s. These differences may be due to the decreasing sand content in the soil samples i.e. 73.48, 71.44 and 66.56% at Libga, Golinga and Bontanga upstream, respectively, as soil texture influences *Ks.* Higher clay content led to strong opposition to water flow by the available micropore, thus the hydraulic conductivity of the various streams for the three study sites were influenced by the clay content of their soils. Al-Shayea (2001) reported that the hydraulic conductivity sharply decreases with increasing clay content up to 40% beyond which the reduction becomes less significant.

The Bontanga irrigable area had the highest average hydraulic conductivity of 2.52 x 10^{-6} m/s followed by Libga (2.28 x 10^{-6} m/s) and Golinga (1.87 x 10^{-6} m/s) (Table 7). Bontanga irrigable area has the least potential amongst the 3 sites when subjected to the same conditions and the high clay content of the irrigable areas and may result in flooding as high percentage of clay content results in less hydraulic conductivity. In a similar study the USDA (2007) obtained a range of hydraulic conductivities of 1.0 x 10^{-6} to 40.0 x 10^{-6} m/s. Also, Tuffour (2015) obtained an average saturated hydraulic conductivity of 2.5 x 10^{-6} m/s from a study on a loamy sand soil which is similar to 2.52 x 10^{-6} and 2.28 x 10^{-6} m/s obtained at Bontanga and Libga, respectively. Islam et al (2017) recorded hydraulic conductivities of 0.53 x 10^{-7}, 6.25 x 10^{-7} and 5.53 x 10^{-7} m/s using different methods and these results are comparably lower than the average hydraulic conductivities recorded in all the three study sites. There was significant variation among average hydraulic conductivity of the various study sites.

The average temperatures of the saturated sampled soils ranged from 29.93 to 30.6^{O}C, 27.93 to 29.6^{O}C and 29.2 to 29.93^{O}C at Bontanga, Golinga and Libga respectively and relating these temperatures to the experimental results on hydraulic conductivity of the study sites, it reflects the assertion that the soil saturated hydraulic conductivity increases with rising temperature of the soil. The difference among average initial and final temperatures were statistically significant. Hongbei and Mingan (2015) reported that rising temperatures increase the soil hydraulic conductivity due to reduction of water characteristics, such as surface tension, density and viscosity. This supported the hydraulic conductivity pattern and temperature dependency (Table 7). There is a linear relationship between *Ks* and temperature increase. Hongbei and Mingan (2015) reported that the temperature dependent growth rate, d*Ks*/ dT was 8.54 x 10^{-5} cm /min/K for loamy soil and 6.3 x 10^{-3} cm/min /K for sandy soil. The *Ks* value for loamy soil at 36°C was about 2.2 times more than at 6°C and 2.35 times larger for sandy soil.

CONCLUSION

A decreasing saturated hydraulic conductivity (Ks) was recorded in all the irrigable areas with increasing percentage (%) of clay content. Soils of Golinga and Bontanga were sandy loam, whilst Libga was loamy sand, however the differences in soil texture did not affect soil hydraulic conductivity and soil gravimetric water content. Very little variation in soil bulk densities were recorded due to the differences in soil particle sizes and percentage composition. Moisture content of unsaturated soil showed that average volumetric moisture of unsaturated soils was lower than saturated soils for study sites. The results of ANOVA among the study sites showed significant difference for average temperature, sand and silt and volumetric moisture content of unsaturated soils.

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Evaluation and Spatial Distribution Maps of Heavy Metals in Soil using Geomatic Techniques

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***Abstract*:** The study was aimed to evaluate and prepare spatial distribution maps of heavy metals in the soil using the geomatic technique. A representative area was chosen which suffers from environment pollution near the oil fields (Ajil and Alas oil fields, Iraq). Nineteen soil samples were taken from the surface layer (0-15)cm and analyzed for the physical and chemical properties and estimation of the heavy metals(Cd, Co, Mo, Cu, Zn, Ni, Fe, Cr, Mn, Ti, As and Pb) using an XRF device. Various Pollution criteria were applied (Contamination Factor-CF, Contamination degree-Cd, Modified contamination degree-mCd, Pollution Load Index-PI, Enrichment Factor -EF, Geo-accumulation index- I-geo, Potential Ecological Risk-PERI and Requested potential ecological risk index-RI The spatial Kriging interpolation tool was used to prepare of maps and prediction of heavy metal content. The results shown that content of heavy metals in soil were higher than the permissible limit. According to pollution criteria, the highest risk was for cadmium element in the soil. The results of PERI and RI indicate that the pollution degree range between high-risk pollution to very high-risk pollution.

Keywords: Heavy metals, Soil Contamination, Pollution Index, Kriging technique

The soil pollution is widespread environmental problems as soil contains high concentrations of heavy metals. Soils are classified as contaminated when becoming toxic to plants, humans, and animals via food chain. It is therefore important to recognize the distribution of heavy elements levels in soils. The accumulation of heavy elements in the surface layer of soil is affected by many factors such as parent material, soil characteristics, human activities, industrial production and agricultural processes. The elements are usually present in different concentrations in soil surface, either from a natural source (lithogenic or pedogenesis) or from many human activities (Luo and Li 2012). The heavy metals are 38 elements, but some of them are toxic such as are Zn, Cu, and Ni, because of precipitation nan adsorption in soil surface. The toxicity with the elements like Pb, Co, As and Cd occur under special conditions (Singh 2005). Al-Farraj and Al-Wabel (2007) conducted a study to evaluation of soil pollution around Mahad AD'Dahab Mine, Saudi Arabia (As, Be, Cd, Co, Cr, Cu, Fe, Mn, Mo, Ni, Pb, Se, Ti, V, Zn, Hg), and concluded that soils are loaded with heavy metals. Miheso (2013) studied of heavy metal (Zn, Pb, Cr, Mn and Cd) in soil and water of Samburu County, Kenya observed that all heavy metals were within the criteria of WHO (2003). Barbieri (2016) used Enrichment Factor (EF) and Geoaccumulation Index (Igeo) to assess of soil contamination in Rome, Italy concluded that the concentration of elements in the soil either a product of the weathering of the natural rocks, or human practices (mismanagement). Khurana et al (2012) mentioned that all the soil samples, in terms of heavy metal of sewage irrigated were found within permissible limits. All the crops had higher concentration of pollution elements in sewage irrigated soils compared with same plant in well irrigated soils. Reddy and Yarrakula (2018) calculated the Ecological Risk Indices for Granite Mining Waste in Chimakurthy, Andhra Pradesh, India and six heavy metals (Cr, Co, Ni, Cu, Zn and Mn) were chosen in soil contamination assessment. According to risk map data, the dump yard soils were highly pollution than stockyard soils. Ahmed (2021) estimated pollution status by cadmium, lead in dumpsite in Kani-Qrzhala - Erbil. The levels of Pb, Cr, Cd and Nit were under the maximum allowable limit of soils used for farming purpose. The element changes from area to another and which due to the difference in the nature of the parent material and its impact on the formation and development of soil. The aims of this research to evaluate and prepare spatial distribute maps of heavy metals in soil using Geomatic techniques.

MATERIAL AND METHODS

Based on satellite images, maps and reference information, the areas most exposed to environmental pollution near the oil fields (Ajil and Alla's fields) were

selected. The study area place between longitudes 43˚48' 0" and 43˚2'30" E and latitudes 34˚ 55' 30" and 34˚ 0' 0" N. It is boundary by the Hamrin mountain range in the east, Al-Dour district in the south and Al-Alam district in the west, and the oil fields of Ajil and Alas in the north. AL-Alem district is characterize by its agricultural activity and diversity in the agricultural crops. The flat topography to undulating with low fertility content. Most of the dominant natural vegetation covers are thorns, macaws, capers and annuals. The total annual rainfall is 169.9 mm and temperatures is highest in July and August, reaching 43.9°C and 43.8°C respectively, while the lowest in January was 14.2°C. The region suffers from continuous environmental pollution from oil fields, especially in recent times, where military operations led to the burning of a large number of oil wells as well as the movement of sand dunes and dust storm in the summer season and the movement of vehicles and machinery (Fig. 1).

Samples collection and analysis: Nineteen (19) soil samples were obtained from the soil surface layer (0-15 cm) and their coordinates were taken using GPSMAP64 (Garmin). The soil samples were air-dried, grind and sieve with a 2 mm diameter sieve to measure the physical and chemical properties of the soil. Soil texture was determined (Gee and Bauder 1986). Electrical conductivity (EC) and soil reaction (pH) were measured (Page et al 1982). Calcium carbonate was determined according to Ryan et al (1996), and organic matter according to (Tandon 1998) (Table 1). The soil content of heavy metals (Cd, Co, Mo, Cu, Zn, Ni, Fe, Cr, Mn, Ti, As and Pb) were estimated using XRF (Spectro X-

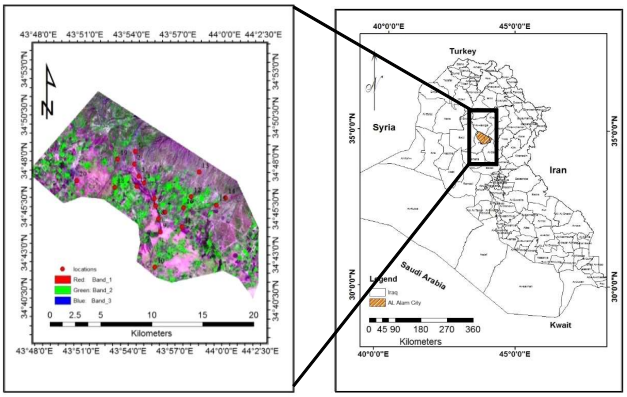


Fig. 1. A map of study area

Table 1. Some of soil physical and chemical characterize

Samples	Coordinates		pH	EC dS. m^{-1}	O.M	$CaCO_3$	Soil partical size distribution		
							Sand	Silt	Clay
	x	y					gm. kg^{-1}		
S_1	399891	3852461	7.80	0.62	4.81	285.00	610.00	255.00	135.00
S_2	399813	3851180	8.10	0.52	8.02	430.00	635.00	230.00	135.00
S_3	400220	3849969	7.91	0.319	14.44	295.00	700.00	160.00	140.00
S_4	400753	3849283	7.90	0.42	17.65	300.00	675.00	185.00	140.00
S_5	401752	3847741	7.70	0.52	10.91	289.00	550.00	360.00	90.00
S_6	401855	3846971	7.60	0.42	11.23	385.00	600.00	285.00	115.00
S_7	402792	3846344	7.80	0.33	16.05	335.00	700.00	210.00	90.00
S_8	402138	3845672	7.80	0.50	8.02	255.00	650.00	235.00	115.00
S_9	402349	3844373	7.90	0.49	4.81	305.00	650.00	235.00	115.00
S_{10}	401803	3840842	7.10	2.90	8.02	330.00	600.00	245.00	155.00
S_{11}	404456	3844881	7.62	2.09	6.90	355.00	400.00	410.00	190.00
S_{12}	405379	3847912	8.10	0.24	11.23	355.00	585.00	230.00	185.00
S_{13}	406130	3850410	7.50	0.21	7.38	315.00	685.00	230.00	85.00
S_{14}	408747	3847789	7.40	0.30	24.07	325.00	685.00	230.00	85.00
S_{15}	407834	3847053	8.10	1.86	19.25	325.00	460.00	355.00	185.00
S_{16}	404637	3846805	8.20	0.76	17.65	317.00	460.00	355.00	185.00
S_{17}	400045	3848937	7.51	0.85	19.25	294.00	650.00	200.00	150.00
S_{18}	397871	3848873	7.50	0.92	11.23	297.00	850.00	100.00	50.00
S_{19}	398150	3851687	7.90	0.65	4.81	310.00	685.00	105.00	210.00

LAB 2000) in the laboratories of the Department of Earth Sciences, University of Baghdad in Iraq according to the standard method.

Application of ArcGIS: The geographic information systems (ArcGIS Ver. 10.2) program was used to prepare spatial distribution maps of heavy metals by the Kriging tool, which is a geostatistical interpolation tool that reflects both the distance and the degree of difference between known points and concentration in unknown areas. The general formula for this technique as following

$$Z(So) = \sum_{i=1}^{N} \lambda i Z(Si)$$

Where Z(si) = the measure value at the i point. λi = an unknown value for the measured value at the i point. s0 = the prediction point. N = the number of measured values.

Pollution indicators: These indicators were classified as in the (Table 2)

1. Contamination Factor -CF = C_{sample} / $C_{background}$ (1)

Where, CF: contamination factor, n = number of metals = 12.

C_{sample}: metal concentrate in soil, $C_{background}$: mean natural background value according to (Lindsay 1979).

2. Contamination degree-Cd= $\sum_{i=1}^{i=n} CF$ (2)

3. Modified contamination degree-mCd= $\sum_{i=1}^{i=n} CF/n$ (3)

(Abrahim and Parker 2008)

4. Pollution Load Index- PLI= $[CF_1 \times CF_2 \times CF_3 \times \ldots \times CF_n]^{1/n}$ (4) (Tomllinson et Al 1980)

5. Enrichment Factor

EF = $[C_{metal}/C_{Fe}]_{samples}$ / $[C_{metal}/C_{Fe}]_{background}$ (5) (Abrahim and Parker 2008). Cmetal and Cnormalizer are the concentrations of heavy metal and normalizer in soil and in unpolluted control, respectively.

6. Geo-accumulation index

I-geo = Log_2 [Cn/ (1.5Bn)] (6)

Cn: Concentration of metals in the soil samples.

Bn: Concentration of metals in the background.

7. Potential Ecological Risk

PERI= (7)

$$PERI = \sum_{i}^{n} Ti \times CFi \qquad (7)$$

Ti: Toxic response factor for metals: Zn=1, Cr = 2, Co = Cu = Pb = 5, Ni = 6, As = 10, Cd = 30.

8. Requested potential ecological risk index –RI

$$RI = \sum_{i}^{n} PERI$$

RESULTS AND DISCUSSION

Total concentration of heavy metal: The concentration of contaminated heavy metals and the exceeded the world average of soil content of heavy elements (Table 3). The

Table 2. Classification of soil pollution indicators

CF < 1	low	(Hakanson, 1980)
1 < CF <3	moderate	
3 < CF < 6	high	
CF >6	Very high	
Cd < 6	low	
6 < Cd < 12	moderate	
12 < Cd < 24	considerable	
> 24	high degree	
mCd < 1.5	nil to a very low	After: Abrahim and Parker 2008
1.5 ≥ mCd < 2	low	
2 ≥ mCd < 4	moderate	
4≥mCd < 8	high	
8 ≥ mCd < 16	very high	
16 ≥ mCd < 32	extremely high	
mCd ≥32	ultra high	
PLI≤1	unpolluted	Qing et al 2015
1-3	Moderate	
3-5	High	
>5	Very high	
EF ≤ 1	Non enrichment	After: Abrahim and) (Parker, 2008
1 < EF ≤ 3	Minor enrichment	
3 < EF ≤ 5	Moderate enrichment	
5< EF ≤ 10	Moderately -severe enrichment	
10 < EF ≤ 25	Severe enrichment	
25 < EF ≤ 50	Very severe enrichment	
EF > 50	Extremely severe enrichment	
I geo ≤0	Non Contamination	(Hakanson, 1980)
0＜I geo≤1	Light to Moderate	
1＜I geo≤2	Moderate	
2＜I geo≤3	Moderate to Strong	
3＜I geo≤4	Strong	
4＜I geo≤5	Strong to Extremely	
I geo>5	Extremely	
PERI< 40	low risk	(Qing et al., 2015)
40 ≤ PERI< 80	moderate risk	
80 ≤ PERI <160	considerable risk	
160 ≤ PERI < 320	high risk	
PERI ≥ 320	very high risk	
RI<150	low risk	(after: Hakanson, 1980)
150≤RI<300	moderate risk	
300≤RI<600	considerable risk	
RI≥600	very high risk	

concentration of cadmium and copper ranged between 0.09-1.90 and 24.21-155.46 mg kg^{-1}, and most of the samples exceed the permissible limit. Cobalt and nickel concentrations ranged from 23.83-153.05 and 116.93-172.40 mg kg^{-1}, respectively. The concentration of Pb and Zn ranged between 9.93-24.63 and 67.40-106.72 mg kg^{-1}, and so that all samples exceeded the world average. The results indicated that concentrations of Mo, Fe, and Mn elements ranged between 8.70-49.05, 29891.12–42167.89, and 550.85-863.4 mg kg^{-1}. The Cr element was in highest concentration of 1568.12 mg kg^{-1}, and most samples exceeded the world average. The Ti concentrations ranged between 5.95 -20.94 and 6287.45-11049.90 mg. kg^{-1}. A Figure (2, 3) shows the spatial distribution maps of the heavy elements in the soil of the study sites using Kriging technique.

Soil pollution indicators: The contamination factor (CF) of elements cadmium, cobalt, nickel, molybdenum, chromium, and manganese ranged between 1.50 -33.33, 2.98-19.13, 2.92-4.29 and 5.5.50-38.55 mg kg^{-1} respectively (Table 4). The contamination factor (CF) of elements Cu, Pb, Zn, Fe, Mn, As, and Ti ranged between 0.81-5.18, 0.99-2.46, 1.35-2.13, 0.79-1.06, 1.14.4.19 and 1.79-2.76 respectively. The sites ranged from low to hazard moderate according to (Table 2). The index of the contamination degree (Cd) ranged between 28.44-76.66 and in most sites were high. The modified contamination degree (mCd) and pollution Load Index (PLI) ranged between 84-7.67 and 2.13-3.88 and classify as moderate to high hazard. The enrichment factor (EF) for the soil of the study sites was in order: Cd> Mo> Cr> Co> Ni> pb> Cu> Mn. The e enrichment factor for Cd, Mo and Cr ranged between 1.68-34.16, 4.64-35.43 and 3.50-15.10 mg kg^{-1}. Most samples ranged from moderate to severe hazardous category, respectively. The enrichment factor for Cu, Pb, and Zn and Mn elements was minor, not more than 3 for all samples (Table 5).

The geological accumulation index varied between the soils of the sites (Table 6) and was in order: Cd> Mo> Cr> Co> Ni> Zn> Pb> Mn> Cu> Fe .Compared to Table 3, the geological index of the cadmium and molybdenum elements ranged from moderate contamination to strong contamination. The geological accumulation index of elements of cobalt, nickel, and chromium was moderate to strong, while the elements of copper, lead, iron, and zinc were unpolluted with low of pollution. The potential ecological risk index indicate that the pollution e range between high-risk pollution to very high-risk pollution where it was high risk to very high. The potential ecological risk index the study sites ranged from very risk to very risk because high of cadmium in the soil (Table 7).

Table 3. Heavy metals concentration in the study soils

Samples	Cd	Cu	Co	Ni	pb	Zn	Mo	Fe	Cr	Mn	As	Ti
S_1	1.00	38.52	38.08	151.13	21.33	91.06	32.20	35449.49	761.22	779.16	16.74	9045.33
S_2	1.02	30.12	29.65	146.86	12.16	78.97	16.10	38342.07	607.06	806.95	6.66	9139.08
S_3	0.70	32.03	31.54	144.66	11.05	79.62	18.90	37817.51	808.00	727.88	8.48	9026.68
S_4	0.80	40.19	39.66	157.85	17.60	85.58	19.95	38211.69	614.74	711.54	14.71	8095.43
S_5	0.60	48.35	47.78	171.04	24.16	91.54	21.00	38605.86	421.48	695.20	20.94	7164.18
S_6	0.70	43.40	42.91	169.08	24.63	106.72	21.40	38004.37	386.10	777.60	19.50	7321.54
S_7	0.60	41.16	40.71	131.52	21.65	75.79	19.50	29891.12	553.11	550.85	20.79	6287.45
S_8	1.60	44.51	43.98	161.97	22.44	98.86	20.60	40093.62	516.56	830.12	17.20	8529.15
S_9	1.30	41.95	41.46	170.07	22.81	98.37	16.70	40128.59	348.53	823.15	17.57	7771.74
S_{10}	1.90	155.46	153.05	147.89	12.53	81.30	11.00	37083.12	475.36	726.80	6.89	7809.29
S_{11}	1.00	38.58	37.99	172.40	13.18	95.68	77.10	41342.58	380.81	858.06	7.20	8157.73
S_{12}	0.30	30.84	30.36	146.63	11.42	80.10	12.70	38782.71	517.78	797.66	7.20	9018.04
S_{13}	0.50	28.76	28.31	141.95	11.79	76.00	10.70	36999.19	507.72	778.14	6.66	8786.75
S_{14}	0.40	27.72	27.29	139.62	11.98	73.95	9.70	36107.43	502.69	768.38	6.40	8671.11
S_{15}	1.20	26.68	26.27	137.28	12.16	71.90	8.70	35215.68	497.66	758.63	6.13	8555.46
S_{16}	0.60	25.44	25.05	127.10	11.05	69.65	13.20	34607.18	924.45	765.98	5.95	9011.55
S_{17}	0.60	43.47	42.89	171.72	18.67	93.61	49.05	39974.22	401.14	776.63	14.07	7660.96
S_{18}	1.09	24.21	23.83	116.93	9.93	67.40	17.70	33998.69	1351.23	773.34	5.76	9467.64
S_{19}	1.26	31.08	30.59	142.94	12.25	84.20	10.30	42167.89	1568.12	863.48	7.12	11049.90
*Av.	0.06	30.00	8.00	40.00	10.00	50.00	2.00	38000.00	100.00	600.00	5.00	4000

*Average in soils (Lindsay 1979)

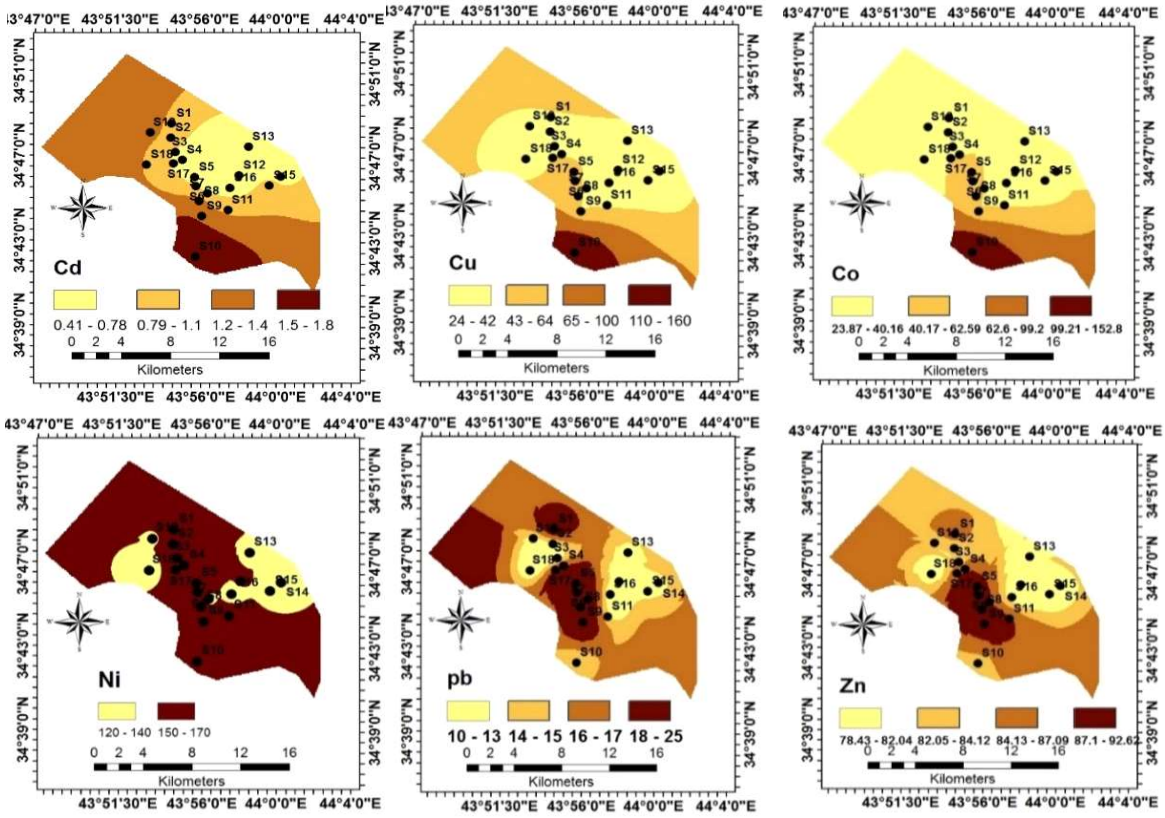


Fig. 2. Spatial distribution maps of heavy metals using Kriging technique

Table 4. Contamination factor (CF), m Cd, Cd and PLI for study soils

Samples	Cd	Cu	Co	Ni	pb	Zn	Mo	Fe	Cr	Mn	As	Ti	Cd	mCd	PLI
S_1	16.67	1.28	4.76	3.78	2.13	1.82	16.10	0.93	7.61	1.30	3.35	2.26	62.00	5.17	3.30
S_2	17.00	1.00	3.71	3.67	1.22	1.58	8.05	1.01	6.07	1.34	1.33	2.28	48.27	4.02	2.59
S_3	11.67	1.07	3.94	3.62	1.10	1.59	9.45	1.00	8.08	1.21	1.70	2.26	46.68	3.89	2.63
S_4	13.33	1.34	4.96	3.95	1.76	1.71	9.98	1.01	6.15	1.19	2.94	2.02	50.33	4.19	2.96
S_5	10.00	1.61	5.97	4.28	2.42	1.83	10.50	1.02	4.21	1.16	4.19	1.79	48.98	4.08	3.07
S_6	11.67	1.45	5.36	4.23	2.46	2.13	10.70	1.00	3.86	1.30	3.90	1.83	49.89	4.16	3.09
S_7	10.00	1.37	5.09	3.29	2.17	1.52	9.75	0.79	5.53	0.92	4.16	1.57	46.14	3.85	2.76
S_8	26.67	1.48	5.50	4.05	2.24	1.98	10.30	1.06	5.17	1.38	3.44	2.13	65.39	5.45	3.38
S_9	21.67	1.40	5.18	4.25	2.28	1.97	8.35	1.06	3.49	1.37	3.51	1.94	56.47	4.71	3.12
S_{10}	31.67	5.18	19.13	3.70	1.25	1.63	5.50	0.98	4.75	1.21	1.38	1.95	78.33	6.53	3.35
S_{11}	16.67	1.29	4.75	4.31	1.32	1.91	38.55	1.09	3.81	1.43	1.44	2.04	78.60	6.55	3.08
S_{12}	5.00	1.03	3.79	3.67	1.14	1.60	6.35	1.02	5.18	1.33	1.44	2.25	33.80	2.82	2.27
S_{13}	8.33	0.96	3.54	3.55	1.18	1.52	5.35	0.97	5.08	1.30	1.33	2.20	35.31	2.94	2.26
S_{14}	6.67	0.92	3.41	3.49	1.20	1.48	4.85	0.95	5.03	1.28	1.28	2.17	32.72	2.73	2.17
S_{15}	20.00	0.89	3.28	3.43	1.22	1.44	4.35	0.93	4.98	1.26	1.23	2.14	45.14	3.76	2.31
S_{16}	10.00	0.85	3.13	3.18	1.10	1.39	6.60	0.91	9.24	1.28	1.19	2.25	41.13	3.43	2.32
S_{17}	10.00	1.45	5.36	4.29	1.87	1.87	24.53	1.05	4.01	1.29	2.81	1.92	60.45	5.04	3.12
S_{18}	18.17	0.81	2.98	2.92	0.99	1.35	8.85	0.89	13.51	1.29	1.15	2.37	55.28	4.61	2.52
S_{19}	21.00	1.04	3.82	3.57	1.23	1.68	5.15	1.11	15.68	1.44	1.42	2.76	59.91	4.99	2.87
Minimum	5.0	0.8	3.0	2.9	1.0	1.4	4.4	0.8	3.5	0.9	1.2	1.6	32.7	2.7	2.2
Maximum	31.7	5.2	19.1	4.3	2.5	2.1	38.6	1.1	15.7	1.4	4.2	2.8	78.6	6.6	3.4
Mean	15.1	1.4	5.1	3.7	1.6	1.7	10.7	1.0	6.4	1.3	2.3	2.1	52.4	4.4	2.8
SD	7.0	0.9	3.4	0.4	0.5	0.2	8.0	0.1	3.2	0.1	1.1	0.3	12.7	1.1	0.4
CV (%)	46.4	66.5	66.5	10.6	32.3	12.8	74.7	7.6	49.9	8.7	49.6	11.9	24.3	24.3	14.1

Table 5. Enrichment factor (EF) for soils

Samples	Cd	Cu	Co	Ni	pb	Zn	Mo	Cr	Mn	As	Ti
S_1	17.87	1.38	5.10	4.05	2.29	1.95	17.26	8.16	1.39	3.59	2.42
S_2	16.85	0.99	3.67	3.64	1.21	1.57	7.98	6.02	1.33	1.32	2.26
S_3	11.72	1.07	3.96	3.63	1.11	1.60	9.50	8.12	1.22	1.70	2.27
S_4	13.26	1.33	4.93	3.92	1.75	1.70	9.92	6.11	1.18	2.93	2.01
S_5	9.84	1.59	5.88	4.21	2.38	1.80	10.34	4.15	1.14	4.12	1.76
S_6	11.67	1.45	5.36	4.23	2.46	2.13	10.70	3.86	1.30	3.90	1.83
S_7	12.71	1.74	6.47	4.18	2.75	1.93	12.39	7.03	1.17	5.28	2.00
S_8	25.27	1.41	5.21	3.84	2.13	1.87	9.76	4.90	1.31	3.26	2.02
S_9	20.52	1.32	4.91	4.03	2.16	1.86	7.91	3.30	1.30	3.33	1.84
S_{10}	32.45	5.31	19.60	3.79	1.28	1.67	5.64	4.87	1.24	1.41	2.00
S_{11}	15.32	1.18	4.36	3.96	1.21	1.76	35.43	3.50	1.31	1.32	1.87
S_{12}	4.90	1.01	3.72	3.59	1.12	1.57	6.22	5.07	1.30	1.41	2.21
S_{13}	8.56	0.98	3.63	3.64	1.21	1.56	5.49	5.21	1.33	1.37	2.26
S_{14}	7.02	0.97	3.59	3.67	1.26	1.56	5.10	5.29	1.35	1.35	2.28
S_{15}	21.58	0.96	3.54	3.70	1.31	1.55	4.69	5.37	1.36	1.32	2.31
S_{16}	10.98	0.93	3.44	3.49	1.21	1.53	7.25	10.15	1.40	1.31	2.47
S_{17}	9.51	1.38	5.10	4.08	1.77	1.78	23.31	3.81	1.23	2.67	1.82
S_{18}	20.30	0.90	3.33	3.27	1.11	1.51	9.89	15.10	1.44	1.29	2.65
S_{19}	18.92	0.93	3.45	3.22	1.10	1.52	4.64	14.13	1.30	1.28	2.49
Minimum	4.9	0.9	3.3	3.2	1.1	1.5	4.6	3.3	1.1	1.3	1.8
Maximum	32.5	5.3	19.6	4.2	2.8	2.1	35.4	15.1	1.4	5.3	2.7
Mean	15.2	1.4	5.2	3.8	1.6	1.7	10.7	6.5	1.3	2.3	2.1
SD	6.7	1.0	3.5	0.3	0.5	0.2	7.3	3.3	0.1	1.2	0.3
CV (%)	43.9	67.3	67.2	7.6	33.6	10.2	68.6	49.9	6.1	52.7	11.9

Table 6. Geo accumulation index–Igeo of soils

Sample	Cd	Cu	Co	Ni	pb	Zn	Mo	Fe	Cr	Mn	As	Ti
S_1	3.47	-0.22	1.67	1.33	0.51	0.28	3.42	-0.69	2.34	-0.21	1.16	0.59
S_2	3.50	-0.58	1.30	1.29	-0.30	0.07	2.42	-0.57	2.02	-0.16	-0.17	0.61
S_3	2.96	-0.49	1.39	1.27	-0.44	0.09	2.66	-0.59	2.43	-0.31	0.18	0.59
S_4	3.15	-0.16	1.72	1.40	0.23	0.19	2.73	-0.58	2.04	-0.34	0.97	0.43
S_5	2.74	0.10	1.99	1.51	0.69	0.29	2.81	-0.56	1.49	-0.37	1.48	0.26
S_6	2.96	-0.05	1.84	1.49	0.72	0.51	2.83	-0.58	1.36	-0.21	1.38	0.29
S_7	2.74	-0.13	1.76	1.13	0.53	0.02	2.70	-0.93	1.88	-0.71	1.47	0.07
S_8	4.15	-0.02	1.87	1.43	0.58	0.40	2.78	-0.51	1.78	-0.12	1.20	0.51
S_9	3.85	-0.10	1.79	1.50	0.60	0.39	2.48	-0.51	1.22	-0.13	1.23	0.37
S_{10}	4.40	1.79	3.67	1.30	-0.26	0.12	1.87	-0.62	1.66	-0.31	-0.12	0.38
S_{11}	3.47	-0.22	1.66	1.52	-0.19	0.35	4.68	-0.46	1.34	-0.07	-0.06	0.44
S_{12}	1.74	-0.55	1.34	1.29	-0.39	0.09	2.08	-0.56	1.79	-0.17	-0.06	0.59
S_{13}	2.47	-0.65	1.24	1.24	-0.35	0.02	1.83	-0.62	1.76	-0.21	-0.17	0.55
S_{14}	2.15	-0.70	1.19	1.22	-0.32	-0.02	1.69	-0.66	1.74	-0.23	-0.23	0.53
S_{15}	3.74	-0.75	1.13	1.19	-0.30	-0.06	1.54	-0.69	1.73	-0.25	-0.29	0.51
S_{16}	2.74	-0.82	1.06	1.08	-0.44	-0.11	2.14	-0.72	2.62	-0.23	-0.34	0.59
S_{17}	2.74	-0.05	1.84	1.52	0.32	0.32	4.03	-0.51	1.42	-0.21	0.91	0.35
S_{18}	3.60	-0.89	0.99	0.96	-0.59	-0.15	2.56	-0.75	3.17	-0.22	-0.38	0.66
S_{19}	3.81	-0.53	1.35	1.25	-0.29	0.17	1.78	-0.43	3.39	-0.06	-0.08	0.88

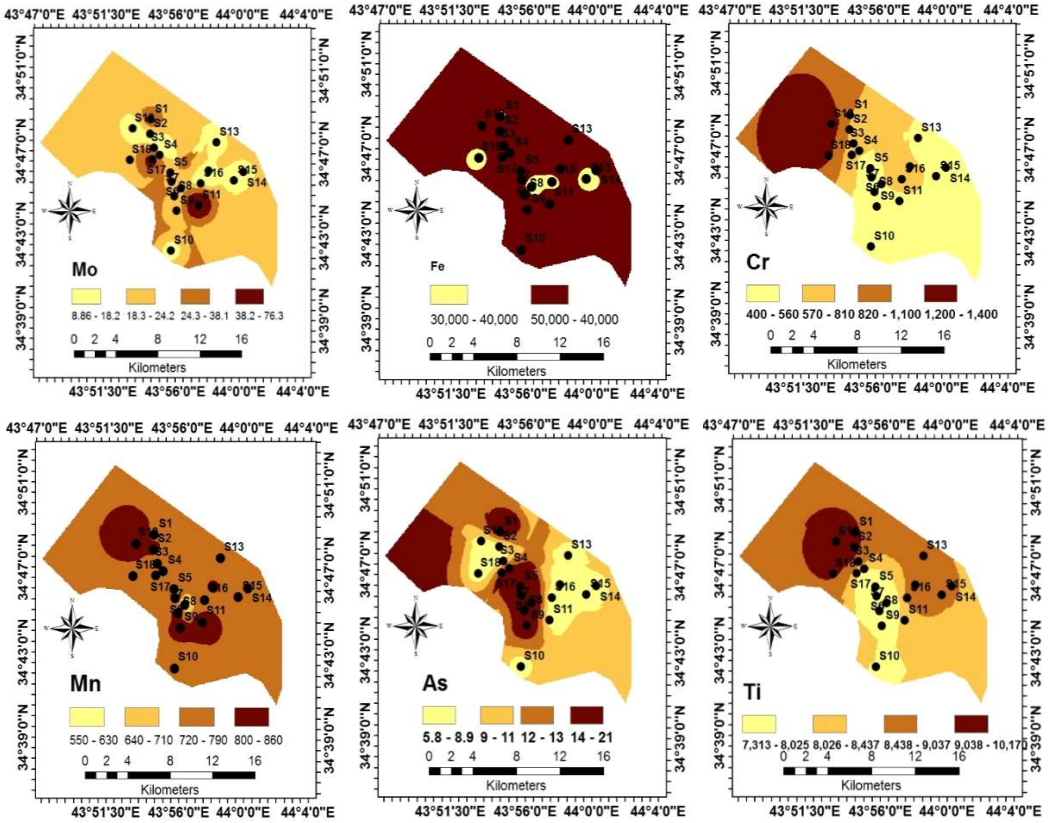


Fig. 3. Spatial distribution maps of heavy metals using Kriging technique

Table 7. Potential ecological risk index PERI and RI in the soils

Samples	Cd	Cu	Co	Ni	pb	Zn	Cr	RI
S_1	500.00	6.42	23.80	18.89	10.66	1.82	15.22	576.82
S_2	510.00	5.02	18.53	18.36	6.08	1.58	12.14	571.71
S_3	350.00	5.34	19.71	18.08	5.52	1.59	16.16	416.41
S_4	400.00	6.70	24.79	19.73	8.80	1.71	12.29	474.03
S_5	300.00	8.06	29.87	21.38	12.08	1.83	8.43	381.64
S_6	350.00	7.23	26.82	21.13	12.31	2.13	7.72	427.35
S_7	300.00	6.86	25.44	16.44	10.83	1.52	11.06	372.15
S_8	800.00	7.42	27.48	20.25	11.22	1.98	10.33	878.68
S_9	650.00	6.99	25.91	21.26	11.41	1.97	6.97	724.51
S_{10}	950.00	25.91	95.65	18.49	6.27	1.63	9.51	1107.45
S_{11}	500.00	6.43	23.74	21.55	6.59	1.91	7.62	567.84
S_{12}	150.00	5.14	18.97	18.33	5.71	1.60	10.36	210.11
S_{13}	250.00	4.79	17.70	17.74	5.89	1.52	10.15	307.80
S_{14}	200.00	4.62	17.06	17.45	5.99	1.48	10.05	256.65
S_{15}	600.00	4.45	16.42	17.16	6.08	1.44	9.95	655.50
S_{16}	300.00	4.24	15.66	15.89	5.52	1.39	18.49	361.19
S_{17}	300.00	7.24	26.80	21.47	9.34	1.87	8.02	374.74
S_{18}	545.00	4.03	14.89	14.62	4.97	1.35	27.02	611.88
S_{19}	630.00	5.18	19.12	17.87	6.13	1.68	31.36	711.34
Minimum	150.0	4.0	14.9	14.6	5.0	1.4	7.0	210.1
Maximum	950.0	25.9	95.7	21.6	12.3	2.1	31.4	1107.5
Mean	451.8	7.0	25.7	18.7	8.0	1.7	12.8	525.7
SD	203.9	4.6	17.1	2.0	2.6	0.2	6.4	218.3
CV (%)	45.1	66.6	66.5	10.6	32.3	12.8	49.9	41.5

CONCLUSIONS

The soil of the study area suffers from a variety of pollution sources, the most prominent of which are the gases emitted from oil fields and the burning of wells in recent times as well as the impact of military operations, and the movement of wind and its speed, which work to transfer quantities of dust and their accumulation in the study area. and most samples exceeded the world average according to heavy metals data The modified contamination degree (mCd) and pollution Load Index (PLI) ranged between7.67-84 and 2.13-3.88 and classify as moderate to high hazard .The enrichment factor for Cd, Mo and Cr ranged between 1.68-34.16, 4.64-35.43 and 3.50-15.10 mg kg^{-1}. Therefore, the study recommends the necessity of conducting periodic studies to determine the impact of pollutants on the soil deterioration of agricultural lands, which threatens the lives of local living, through updating the spatial maps of heavy elements using modern techniques as Kriging interpolation.

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Fertilizer Properties for Design of Tractor Operated Coconut Basin Lister cum Fertilizer Applicator

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***Abstract*:** Study was undertaken to examine the physical properties of fertilizers such as bulk density, tapped density, angle of repose and coefficient of friction which were considered to design and develop tractor operated coconut basin lister cum fertilizer applicator. For urea, muriate of potash and rock phosphate fertilizers; angle of repose values were 32.9°, 38.1° and 40.8°, respectively, bulk densities were 740.6, 1081.6 and 1326 kg m^{-3}, respectively, tapped densities were 834.3, 1167 and 1419 kg m^{-3}, respectively and coefficients of friction were 0.31, 0.47 and 0.55, respectively. Bulk density and tapped density influences the hopper volume and cell or flute volume of fertilizer metering roller in fertilizer applicator. Angle of repose and coefficient of friction affects the flow characteristics of fertilizer in the fertilizer applicator.

***Keywords*:** Fertilizer properties, Angle of repose, Bulk density, Fertilizer applicator, Basin lister, Coconut palm

India is the largest producer of coconut in the world and also ranks first in productivity among major coconut growing countries in 2018-19 (Anonymous 2019). India produced 14.7 million tons of coconut from an area of 2.1 million hectare with an yield of 6769 kg ha^{-1} while Kerala produced 5.2 million tons of coconut from an area of 0.75 million hectare with an yield of 6953 kg ha^{-1} and Kerala accounts for 34.74% of the country's total coconut production leading the other major coconut producing states in 2018-19 (Anonymous 2019). Fertilizer helps in enriching the palms with nutrients that are required for better growth and they need to be applied in correct amounts as per recommendation. Fertilizer is generally applied manually in circular basins at a radius of 1.8 m from base of the coconut palm at a depth of 10 cm. The fertilizer rates to be applied for a coconut palm are; 0.5 kg of N, 0.32 kg of P_2O_5 and 1.20 kg of K_2O for good management (Anonymous 2016). Manual application of fertilizer is a tedious and drudgery prone operation as it is performed with the help of spade. Shortage of labour and non-availability of mechanical fertilizer applicators for coconut palms has made the fertilizer application process a costly operation over the years. Deo (2013) studied the engineering properties of urea viz., size, shape, bulk density, angle of repose and coefficient of friction relevant to design of fertilizer applicator. Pare et al (2009) determined fertilizer physical properties viz., tapped density, granule density, porosity and crushing strength to reduce the number of measurements required by the industry during manufacturing. Shinde (2004) reported that physical properties viz., bulk density, angle of repose and fineness modulus of fertilizers affected the design of fertilizer applicator. Mandal and Thakur (2010) considered the physical properties such as angle of repose and bulk density as important in designing the hopper and metering roller of subsoiler-cum-differential rate fertilizer applicator. Recent studies on physical properties of fertilizers used for coconut are very scarce, therefore a study is put forth to determine the fertilizer properties necessary for designing tractor operated coconut basin lister cum fertilizer applicator.

MATERIAL AND METHODS

The fertilizers used for coconut in Kerala are urea, muriate of potash and rock phosphate. According to the package of practices of Kerala Agricultural University; 0.36 kg urea, 0.67 kg muriate of potash and 0.53 kg rock phosphate per coconut palm should be applied. The fertilizer physical properties viz., angle of repose, bulk density, tapped density and coefficient of friction are required for design of fertilizer applicator.

Angle of repose: Angle of repose is the angle made by material with the horizontal surface when piled from a certain height and it is expressed in degree. The angle of repose of fertilizer influences the design of hopper and fertilizer flow ability in metering roller of fertilizer applicator. Angle of repose of fertilizers was measured by filling sample into a cylinder by keeping it horizontal and then cylinder was raised slowly allowing the fertilizer to flow out and form a heap in the form of cone. The angle of repose was determined by the following equation (Hamzah and Omar 2018):

$$\theta = \tan^{-1}\left(\frac{H}{r}\right)$$

where, θ = angle of repose, deg, H = height of heap, cm , r = radius of the heap, cm

Bulk density: The bulk density of fertilizer helps in deciding hopper dimensions of fertilizer applicator and was estimated by measuring the known weight of fertilizer samples in a container with certain volume. The bulk density of fertilizer sample was calculated as (Basavaraj and Jayan 2020):

$$\rho = \frac{W}{V}$$

where, ρ= bulk density, kg m^{-3}. W = weight of fertilizer, kg, V = volume of container, m^3

Tapped density: Tapped density is the weight per unit volume of a material including voids between particles. Tapped density represents the maximum density to which a material might be reduced by vibration during operation. The test sample is filled into metal box and the box is dropped 15 cm off the floor multiple times. The void created by dropping is refilled and the dropping is continued until compaction is complete. The box with test sample then is weighed, and the weight of the empty box is subtracted to give the weight of the test sample. The tapped density is calculated as (Niveditha et al 2013):

$$D_t = \frac{W_1 - W_2}{V}$$

where, D_t= tapped density, kg m^{-3}, W_1 = weight of fertilizer with box, kg, W_2= weight of box, kg, V = volume of box, m^3

Coefficient of friction: Coefficient of friction apparatus consists of a horizontal plane, bottomless open container and a pan. Known weights of fertilizer in the container are taken. The weights are added in the pan and the instant at which the pan weight exceeds the fertilizer, the container starts to slide. The coefficient of friction measures both external and internal contact of fertilizer with horizontal plane. The coefficient of friction is more important for sliding the fertilizer over a sheet as compared to angle of friction. Following equation is used for determination of coefficient of friction (Singh and Singh 2014):

$$\mu = \frac{F}{N}$$

where, μ = coefficient of friction, F = frictional force (force applied), kg ,N = normal force (weight of the fertilizer), kg

RESULTS AND DISCUSSION

Angle of repose: Angle of repose of different fertilizers namely; urea, muriate of potash and rock phosphate were 32.9°, 38.1° and 40.8°, respectively (Table 1). Angle of repose of different fertilizers was significant (p≤0.05) and coefficient of regression was 0.989. Therefore, inclination of hopper must be set at more than 41° so that the fertilizer flows easily to metering roller and delivery pipe. The values obtained for angle of repose are in close agreement with Deo (2013).

Table 1. Physical properties of fertilizers

Fertilizers	Angle of repose (deg.)	Bulk density (kg m^{-3})	Tapped density (kg m^{-3})	Coefficient of friction
Urea	32.9	740.6	834.3	0.31
Muriate of potash	38.1	1081.6	1167	0.47
Rock phosphate	40.8	1326	1419	0.55

Bulk density: Bulk densities of urea, muriate of potash and rock phosphate were 740.6, 1081.6 and 1326 kg m^{-3}, respectively (Table 1). Bulk density of different fertilizers was significant (p≤0.05) and coefficient of regression was 0.995. Considering the recommended rates of N, P and K fertilizers by Package of Practices of Kerala Agricultural University; the bulk density of mixture of urea, muriate of potash and rock phosphate is 1100 kg m^{-3}. Based on this, the dimensions of hopper are decided to accommodate fertilizer mixture volume for application in field. The values obtained for bulk density are similar to Mandal and Thakur (2010).

Tapped density: Tapped densities of urea, muriate of potash and rock phosphate were 834.3, 1167 and 1419 kg m^{-3}, respectively (Table 1). Tapped density of different fertilizers was significant (p≤0.05) and coefficient of regression was 0.997. The tapped density values are taken into consideration for designing the hopper and metering roller of fertilizer applicator. The values obtained for tapped density are comparable to Pare et al (2009).

Coefficient of friction: Coefficients of friction of urea, muriate of potash and rock phosphate were 0.31, 0.47 and 0.55 respectively (Table 1). Coefficient of friction of different fertilizers was significant (p≤0.05) and coefficient of regression was 0.917. The coefficient of friction values are taken into consideration for designing the hopper and base angle of cell of vertical rotor metering roller. The values obtained for coefficient of friction are in close agreement with Shinde (2004).

CONCLUSION

The physical properties of fertilizers viz., urea, muriate of potash and rock phosphate, affect the design of hopper, agitator, metering roller and delivery mechanisms in fertilizer applicator. The bulk density and tapped density influences the hopper volume and cell or flute volume of fertilizer metering roller. The angle of repose and coefficient of friction affects the flow characteristics of fertilizer in the applicator. The physical properties of fertilizer are taken into consideration in designing the tractor operated coconut basin lister cum fertilizer applicator to obtain the optimum performance.

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Scour Countermeasures at Circular Pier by Using Modified W Weir under Clear Water Conditions

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Abstract: The river spanning W weir can effectively control the scour only at the central pier of the bridge. The author has downscaled the W weir's size, height, and location concerning pier size to countermeasures the scour at each pier. The equilibrium scour morphology of modified W weir is contrasting when compared to river spanning W weir. The depth of the scour hole strongly depends on the structure height and flow depth. At the vicinity of the modified W weir, the maximum and minimum scour depth was 1.64D and 0.96D has occurred. In the modified W weir, one paramount scour hole was found at the weir's center between the upstream apexes to the downstream apex. The maximum and minimum local scour hole depth at the vicinity of the pier is 1.067D and 0.64D. From the observation, the modified W weir can effectively reduce the scour at the vicinity of the cylindrical pier up to 55.14%. The 1.5D sized (D = diameter of the pier) modified W weir with the height of downstream apex is 2D is located 2D distance from the pier, produce the maximum scour control, and this structure configuration is considered as optimum structure configuration of modified W weir.

Keywords: Bridge pier scour, Scour countermeasures, Weir, Scour morphology

The local scour around the pier is one of the prime causes of bridge failure. During the flood, it is difficult to monitor the scour around the pier, and failure occurs during this situation without any prior sign. Around 60% of bridge failures in the USA occurred due to scour, Deng et al (2010). The flow character at a vicinity of the pier was reported by many researchers in the past, such as Graf and Istiarto (2008), Ettema et al (2006), Debnath and Chaudhuri (2012). Das and Mazumdar (2015) have studied the flow structure at two eccentric piers. Kumar and Kothyari (2012) compared the flow structures with circular and compound piers. Ataie-Ashtiani and Aslani-Kordkandi (2012, 2013) studied the flow character at juxtaposing piers and tandem piers. Many researchers are extensively worked on scour protection in the bridge pier's vicinity and found different techniques to control it. Though the designer considers the local scour process in their design, the pier's foundation has been exposed by local scour in many places. It occurred in Kattalai bridge at solaisiramani, Namakkal district in Tamil Nadu (The Hindu -8/11/2018) Saravanan (2018).The vanes and cross vanes like U, V, and A weir are primarily used to control the bank erosion as it helps to redirect the erosive flow from bank to the center of the channel. The jet-like flows, which flow from the upstream side to the downstream side of the structure through the drop, cause the scour pool at the downstream side of the structure. The W weir reduces the center pier foundation scour and increases the sediment transport at the bridge location (Rosgen 2001).

The river spanning W weir serves many purposes, including grade control, stabilizing the banks, bridge pier protection, improving irrigation storage at upstream, etc. The detailed design guidelines of W weir are given by Rosgen (2001). Further study has been done on this W weir periodically by the bureau of reclamation. Bhuiyan et al (2007) have studied the complexity of W weir's flow structure in a meandering channel. Thornton et al (2011) has given the stage-discharge relationship for W weir. Bhuiyan et al (2009), Scurlock et al (2011), Pagliara et al (2014) were studied the downstream scour profile of W weir in straight and meandering channels. Johnson et al (2002) have analyzed the scour control at the vicinity of the pier by using W weir and have given the design guidelines, which is constrained with channel size. As articulated by Rosgen (2001), this W weir can reduce the scour at the center pier of the bridge effectively than others. In India, the River Brahmaputra is more than 1 km wider near Guwahati, and the bridge at the location has 10 nos. of piers. The river spanning W weir cannot protect the number of piers from scouring in such a situation. The main objective of this study is to protect each pier from scour, so the author have downscaled the W weir concerning the pier size and study the structure's effectiveness to control the scour at the pier's vicinity.

MATERIAL AND METHODS

Design of modified W weir: The W weir comprises four Arms with a Centre apex facing the downstream side; the

upstream sill points are lower than the downstream sill points. The downscaled W weir has been designed mainly to protect the pier, so the weir size is restricted to pier size instead of the channel width. Three different widths of the weir have been designed, B = 1D, 1.5D, and 2D, where D is the pier's diameter.

Fixed parameters: The modified W weir's width is done as tantamount partitioning following Rosgen (2001) guidelines and the Bureau of Reclamation (2016). The angle at the bank (θ) should be 25 degrees while the angle in the central apex (α)should be 40 degrees for river spanning rock weir as per Johnson et al. (2002), the same has been adopted in the modified W weir in order to perform the less number experiments. In the modified W weir, the central apex's height is kept as 2D, 1.5D from a bed to the apex's crest. The upstream apexes' height is kept as 1D, 0.5 D from the bed, and the throat height is kept as 0.5D and elevation bed invert, the Figure 2 showing the top and cross-sectional view of modified W weir

$$L_{T-W} = 2L_{AA-out} + 2L_{AA-in} \quad (1)$$

$$L_{T-W} = 2\left(\frac{B/4}{\sin\theta/\cos\varphi}\right) + 2\left(\frac{B/4}{\sin\theta/\cos\gamma}\right) \quad (2)$$

The formula for the length of the modified W-weir (Ahmed 2011).

Experimental methods: The experimental runs were performed at a rectangular flume situated in the Hydraulic Engineering laboratory at NIT Silchar. The waterway has a length of 20.45 m and a cross-sectional size of 0.8 m X 0.8 m, width, and depth. A perforated steel plate with a porosity of 0.7 covered the entire width, placed at the waterway inlet to diminish the flow disturbances and stabilize the flow that entered into the flume. The Figure 3 illustratesing the cross-



Fig. 1. The Kattalai bridge at across river Cauvery, Tamil Nadu (The Hindu -8/11/2018)

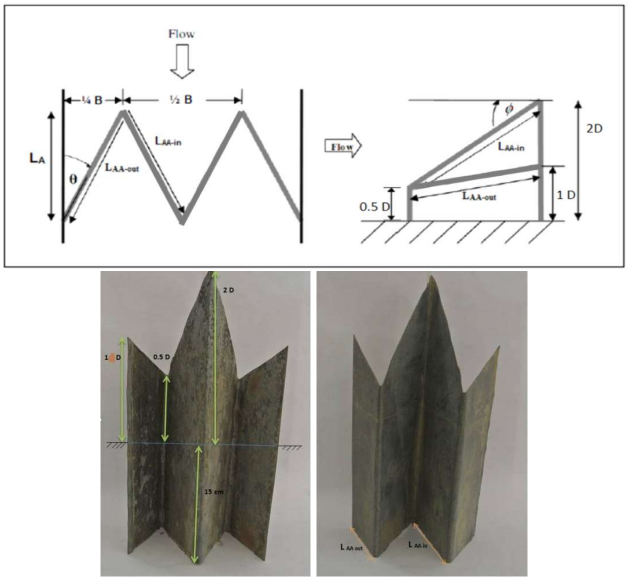


Fig. 2. The plan and cross-sectional view of modified W weir

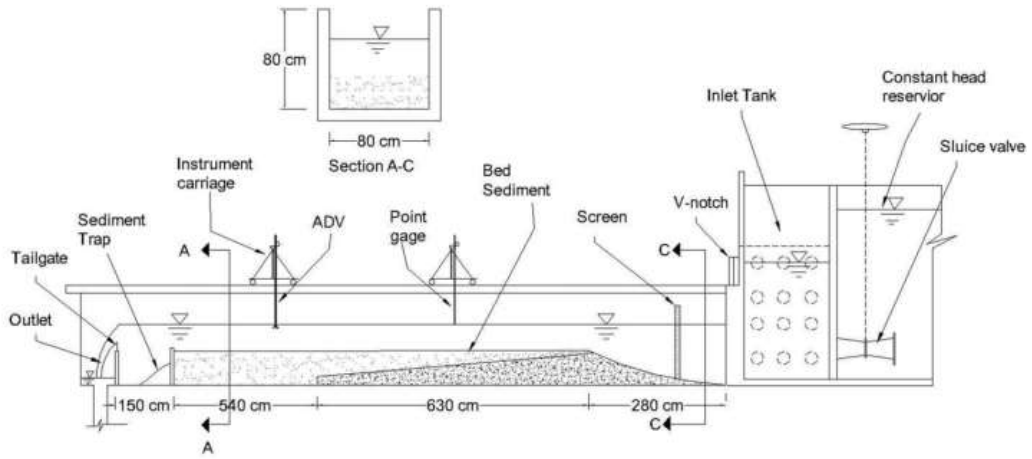


Fig. 3. Crosse section view of flume with the experimental setup

sectional view of the flume with an experimental setup. The flume was filled up to 40 cm with a uniform sand particle with a median size and geometric standard deviation of sediment particle distribution (σ_g)0.2 mm and 1.31, respectively. A gate valve can control the flume's discharge, and the release of water is calculated by measuring the flow depth with a point gauge at a calibrated V notch. At the end of the flume, a sediment trap is provided to arrest those scoured particles. The flow depth was controlled by a tailgate, which is situated at the end of the waterway. The flume is capable enough to generate 3-Dimensional flow. The flow is fully turbulent before it reaches the test location, which is ensured by the formula of boundary layer thickness on smooth flat plate $\delta=0.37L_d(UL_d/\upsilon)^{-0.2}$ where, δ = thickness of bBoundary layer, L_d = Distance along the stream wise direction.

To design and optimize the control structure to effectively control the scour at the pier's vicinity, we need to study the scour profile at the cylindrical pier's vicinity. To compare the efficiency in terms of scour control of modified W weir, local scour profile, and maximum scour depth at the vicinity of the pier is found experimentally for the condition of u_*/u_{*c} is at 0.98. Different experimental runs have performed the effectiveness of modified W weir in scour control at proximity to the circular pier. These parameters have been changed for each experimental run to obtain the effective configuration like the weir's height, the weir's size, and the distance from the pier to the weir. To obtain the various factors that are inducing the scouring process at the vicinity of the smooth cylindrical pier and the components of downscaled W weir, which helps control the scouring process at the vicinity of a pier, the dimensional analysis performed. For a smooth circular pier (d) protected by modified W weir, placed on a rectangular flume with movable bed under steady and uniform flow conditions, the maximum depth of local scour at the vicinity of the pier ds concerning time t is,

$$f(d_s, \rho, g, \mu, d, U, U_*, \rho_s, y_0, C, y, K_s, K_r, K_\infty, t, L_w, h_w, d_{p-w}, d_{50}, \sigma_g) = 0. \quad (3)$$

$$\frac{d_s}{d} = f\left(\frac{\mu}{dU\rho}, \frac{gd}{U^2}, \frac{\rho_s}{\rho}, \frac{d_{50}}{d}, \sigma_g, \frac{y_0}{d}, \frac{y}{d}, K_s, K_r, K_\infty, \frac{U_*}{U}, \frac{C}{U^2\rho}, \frac{t}{dU}, \frac{L_w}{d}, \frac{h_w}{d}, \frac{d_{p-w}}{d}\right) \quad (4)$$

The flume breadth (y) and pier diameter (d) are constant throughout the study; the term y/d is not considered. The circular pier having constant diameter is used for all the experiments, so the shape factor Ks for circular is 1. The smooth circular pier is used, and the angle of approach flow to the axis is zero for all the experimental runs, so Kr and K∞ are not considered. The sediment particle used in all the experiments are cohesion-less soil, so the cohesion term $C/U^2\rho$ is ignored. Throughout the experiments, the same uniform bed materials have been used, so σ_g is remaining unchanged. The density of water and bed materials is the same for all the experiments, so ρ_s/ρ term is dropped. All the experimental runs were performed under the flatbed condition with constant bed material size; therefore, U_*/U is explained through y_0/d; moreover, the velocity term is subjected to flow depth. The experimental run time is sufficient to exhibit the dynamic equilibrium state of the scour profile. All the experimental runs are conducted with the same duration, so the term t/dU is ignored. The median bed material size (d_{50}) is 0.2 mm, and the circular pier diameter (d) is 75mm, so the term d_{50}/d is neglected as the effect of $d/d_{50} > 50$. With the exclusion of those considerations mentioned above, the expression of equilibrium scour depth at a cylindrical pier with modified W weir is refined as in equation 5. From equation 5, the parameters that influence the scour control at the pier are considered for this experimental study.

$$\frac{d_s}{d} = f\left(\frac{\mu}{dU\rho}, \frac{gd}{U^2}, \frac{y_0}{d}, \frac{L_w}{d}, \frac{h_w}{d}, \frac{d_{p-w}}{d}\right) \quad (5)$$

The flume bed was levelled carefully before the experiment begins, and the pier was placed on the center of the flume at the test location. The modified W weir made out of mild steel sheet was placed at mid of the channel at the desired location from the pier. The alignment of the pier with modified W weir has been shown in Figure 4. All the experimental runs, the modified W weir is under submerged condition. The thin sheet flow of water was allowed to pass through the downstream end of the waterway to avoid the water's erosive action on a bed. The water was filled at a low rate until it reached the desired depth; after that, the experiment will begin when the main pump is started. From the temporal analysis of scour depth at vicinity of pier is found that the changes of scour depth rate are minimum after 360

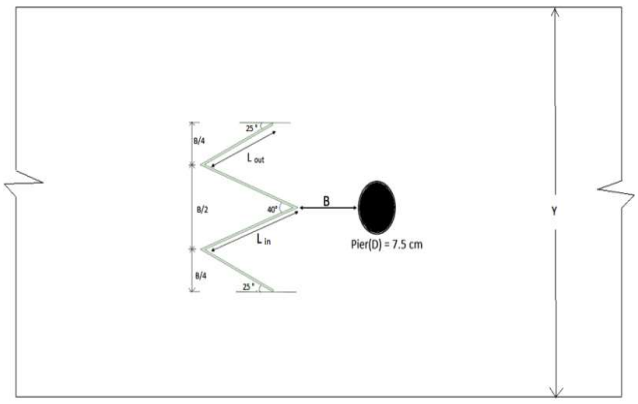


Fig. 4. Top view of modified w weir with the pier

minutes. From the observation is found that is more than 95% of equilibrium scour depth is occurred within first 4 hours. With this findings decided to conduct all the experiment runs up to 12 hours. Once the scour profile reached equilibrium, the pump stopped, and the water is allowed to be released from the flume at a low rate without disturbing the scour profile. The depth of the equilibrium scour profile at the vicinity of the weir and pier was measured by a vernier point gauge with a 5cm square grid range.

RESULTS AND DISCUSSION

Scour morphology at the vicinity of river spanning W weir and pier: The river spanning W weir has the scour pattern, which comprises two dominant scour holes downstream of the weir, as previous researchers mentioned. There were three unique scour patterns downstream of W weir, including one scour hole with two ridges, two ridges with two scour holes, and one scour hole with one ridge. These scour pattern changes when changes in the height of the structure and ratio of water level upstream and downstream of W weir by Pagliara et al (2014). In the river spanning W weir, the upstream apex's drop height is less than the height of the weir's sidearm as it mostly full bank depth. These sidearm deflect the flow towards the center, and the downstream apex deflects the flow from center to sides. These deflected flows pass through the opening at the upstream apex, which is known as drop and the height of the drop is bed invert. The flow is not obstructing normal flow direction by the river spanning W weir due to that the scour at an upstream side of W weir is very minimal. The flow through the opening of the upstream apex is impinging jet type of flow due to it is dropping, due to that the scour depth is high at the downstream side of river spanning W weir. Due to this flow scenario, on the upstream side of the river spanning W weir, the scour is minimal compared to the downstream side due to the flow in the river spanning W weir. However, in the modified W weir, the flow is obstructed by the upstream apexes. Inside the downstream apex, the backflow occurs due to the blockage of the main flow, and this helps to form the predominant vortices at upstream apexes of W weir, which initiate the scour process. Due to this, the scour at an upstream side of the modified W weir is predominant compared to the downstream side. These vortices erode the particle at the upstream side of the weir and stretch downstream around the structure due to the main flow and converge at the structure's downstream side. At this convergence, vortices' strength is getting diminished, and the eroded particle cannot carry forward, getting deposited at the downstream apex and form a point bar. In the modified W weir, one paramount scour hole was found inside the W weir near the downstream apex. The Figure 5 shows the contour of the scour profile in the vicinity of the cylindrical pier. The scour depth of quasi equilibrium at the cylindrical pier's upstream face is 1.43 D at the end of the 12th hour. The scour hole resembles the inverted cone shape as previous researchers found it. At the end of the scour hole at a downstream side of the pier, dune formation occurred due to sediment particles deposition. Due to the power fluctuation, the pump discharge may vary bit time to time; thus, u*/u*c may reach from 0.98 to 1. As a consequence of the fluctuation inflow, the general scour taken place along with local scour.

Scour morphology at the vicinity of a cylindrical pier with modified W weir:

The modified W weir of size 1.5D with the height of downstream apex 2D (from the crest of downstream apex to bed) is placed at a 2D distance from the pier. From Figure 6, the scour profile is evident that the magnitude of the scour hole at an upstream side of the modified W weir is higher than the pier. The height of the downstream apex is ample enough to block the longitudinal flow at an upstream side of the pier. Due to this, the magnitude of down flow and horseshoe vortex is minimized, which is the primary driving force of local scour at the pier. The magnitude of scour at the vicinity of the pier is less when compared to the weir. However, the height of the upstream apex is petite, so the strength of the primary vortex is minimal, which can reveal through the magnitude of scour. The culmination of scour depth at an upstream side of the W weir is 1.093D, which is located in between the upstream apexes at the center of the W weir. The maximum depth of local scour at the vicinity of the pier is 0.64D, the extension of the scour is 2.4D and 1.973D in the longitudinal and lateral directions. In this structural configuration, the efficiency of the modified W weir with regard to scour control at the pier is 55.14%.

Table 1. Flow properties of the different experimental run

Exp. no	Sediment size (d_{50}) mm	Depth of flow (h) m	Discharge (Q) m^3/s	Avg. approach Velocity (U) m sec^{-1}	Intensity of flow (u^*/u^*_c)	Froude No. (F_r)	Reynolds No. (Re)
1-10	0.2 mm	0.20	0.043	0.2718	0.98	0.19	54360
11	0.2 mm	0.18	0.037	0.2573	0.95	0.188	45000
12	0.2 mm	0.18	0.035	0.2442	0.9	0.183	43920

In the experimental run 3, the 1.5D sized modified W weir having the depth of 1.5D is located at a distance of 2D from the pier. In this configuration, the height of the upstream apex is small, and ample main flow can flow through the throat. As a result, the greater scour hole formed at the vicinity of the pier. The maximum depth of the scour hole at the modified W weir is 0.973D and is found inside the downstream apex. At this structure configuration, the maximum depth of local scour at the vicinity of the pier was found to be 1.067D, and the scour hole extent in the longitudinal and lateral direction is 3.93D and 3.64D, respectively. The modified W weir with this configuration could effectively control the scour up to 25.23% at the vicinity of the pier when compared to the maximum scour depth of the pier without any control measures.

The experimental run was performed on the 2D sized modified W weir with the height of 2D is placed at a distance of 2D from the pier to study the effectiveness in terms of scour control at the cylindrical pier. The size of the W weir is larger than the previous cases of modified W weir. The equilibrium scour morphology of the modified W weir is illustrated in Figure 8, which resembles the inverted cone shape at an upstream side of the W weir. The maximum scour was at both the upstream apexes of the W weir with slightly different magnitude. The maximum depth scour at the right side apex is 1.24D, and on the left side apex, the scour depth is 1.373D. In the previous cases, the maximum scour was found at the center of the downstream apex, but in this case, the maximum scour depth was found in the vicinity of the upstream apex. The scour hole extended from the upstream apex in the upstream direction around 2.933D. The size of local scour at the cylindrical pier has reduced considerably when compared to the scour profile at the pier without any control measure, and also at the rear side of the pier no distinct local scour profile due to deposition. The maximum scour at the pier is 0.8133D, which was near the upstream face of the pier. The efficiency of the modified W weir with this structure configuration with respect to scour countermeasures at the pier is 42.99%.

In the experimental run 5 is performed on the 2D-sized modified W weir, which is located at 2D from a pier with the height of central apex is 1.5D from the bed. In this condition of modified W weir, the maximum scour occurred is 1.133D, and at inside the vicinity of the downstream apex. Compared to previous cases of modified W weir, the maximum scour occurred inside the downstream apex as the height of the downstream apex is higher than the upstream apex and throat of W weir. Due to this, the upstream apex cannot block much flow than the downstream apexes of W weir, and the maximum scour modified W weir occurs inside the vicinity of the

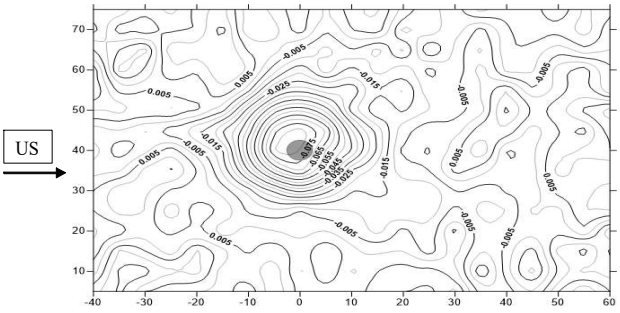


Fig. 5. Contour of scour profile at the cylindrical pierof experimental run 1

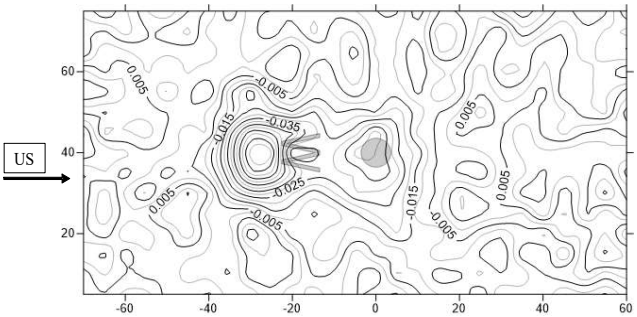


Fig. 6. Contour of scour profile of experimental run 2

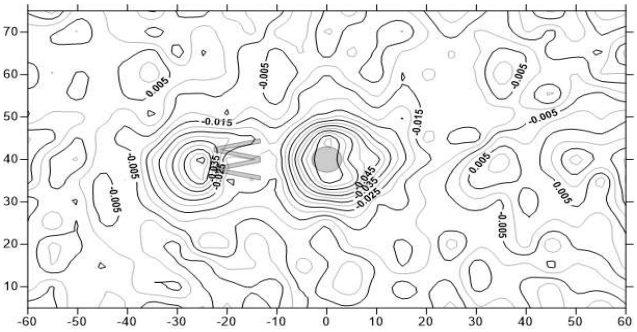


Fig. 7. Contour of scour profile of experimental Run 3

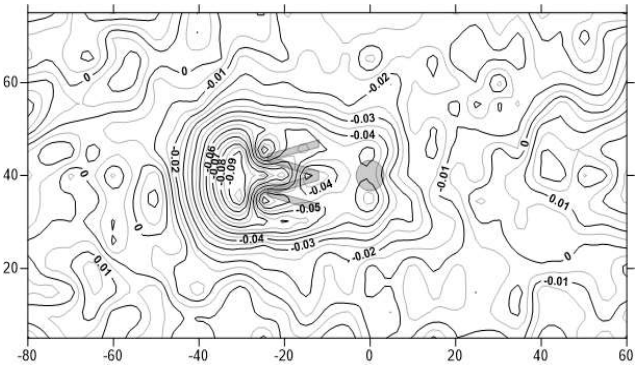


Fig. 8. Contour of scour profile of experimental Run 4

downstream apex instead of the upstream apexes. The scour hole stretch along the upstream direction around a 2D distance from the upstream apex. The maximum depth of scour at the vicinity of the pier is 1D, and the local scour hole around the pier is distinct. The efficacy of modified W weir on scour countermeasures on pier with this configuration is 29.90%.

The modified W weir of size 2D placed at a distance of 1D with the height of downstream apex is 1.5D from the bed is investigated as the experimental run 6, to study their capabilities of scour countermeasures at the pier. The equilibrium scour profile of a modified W weir with a cylindrical pier is shown in Figure 10. The depth of maximum local scour is 1.5867D, which is occurred at inside the modified W weir close to the downstream apex, which is visible from the depiction. The scour hole extension at an upstream side of W weir is 1.733D from the upstream apex. The depth of maximum scour at the vicinity of the cylindrical pier is 1.04D, and the scour hole extends up to 2.333D from the upstream face of the pier. However, there is no distinct local scour profile on the pier's downstream side, to the pier's side and upstream face. Concerning the scour control at the pier, the modified W weir's effectiveness with this configuration is around 27.10%.

In laboratory test 1D sized modified W weir is place a distance of 1D from a pier with the height of 1.5D, which is from bed to central apex. The above figure shows the equilibrium scour profile of experimental run 7. The maximum scour at modified W weir is 1.0267D, which is found at the center point between the W weir's apex. On the upstream side of W weir, the scour hole extended to 1.333D from the upstream apex. The length of the scour hole at an upstream side of the W weir is petite as the size of the weir is less. The maximum scour depth at the vicinity of the pier is 0.8933D, the efficiency of scour control of modified W weir with this configuration is 37.38%. In experimental run 8th performed on the modified W weir of size 2D, a height of 1.5D from central apex to bed is placed at 1.5D from the pier. Figure 12 is showing the equilibrium scour profile of modified W weir of the aforementioned structural configuration. The maximum depth of local scour at W weir is 1.48D, which is occurred at the center of the downstream apex. Inside the downstream apex, the scour depth is increasing from the downstream apex, reaches the maximum at the center, and again reduces towards the edge of the upstream apex. The scour hole from the upstream apex extended towards the upstream direction around 2.267D. The equilibrium scour depth at the upstream face of the cylinder is 0.9467D, the length and width of the scour hole is 3.067D and 2.933D. The scour hole extended longer on the downstream side of the pier than the upstream side and also shows the distinct profile of local scour at the

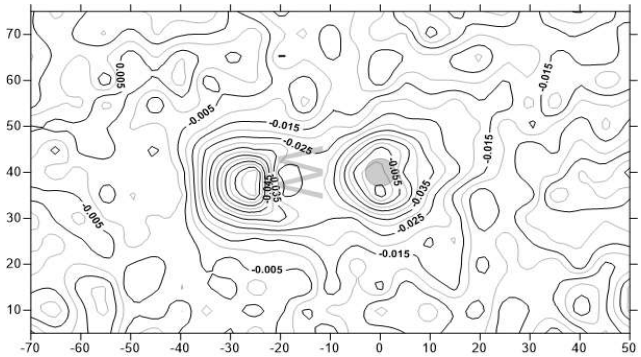


Fig. 9. Contour of scour profile of experimental Run 5

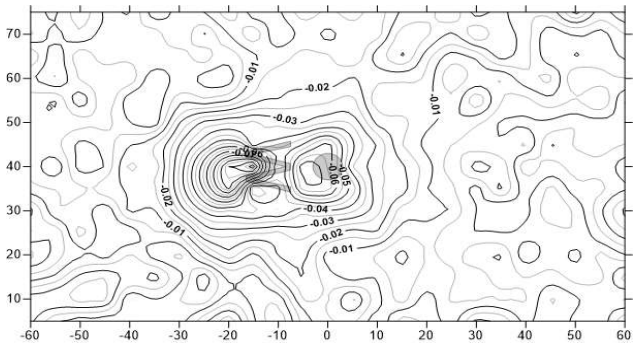


Fig. 10. Contour of scour profile of experimental Run 6

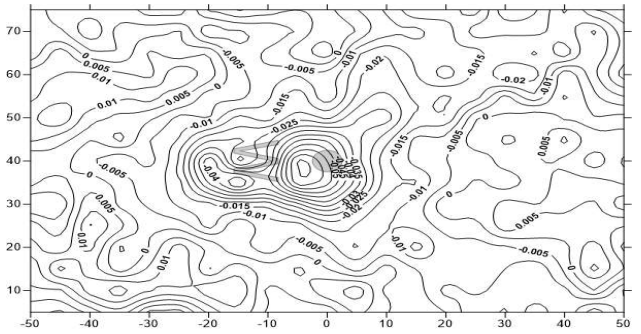


Fig. 11. Contour of scour profile of experimental Run 7

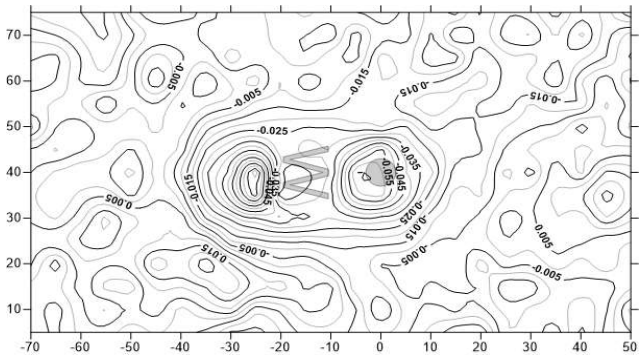


Fig. 12. Contour of scour profile of experimental Run 8

downstream side of the pier. The efficiency of this structural configuration of modified W weir on scour control at the vicinity of the pier is 33.64%.

The modified W weir of size 2D having a height of 1D located at a 1.5D from a pier is analyzed as experimental run 9. The equilibrium scour profile of a modified W weir with a cylindrical pier is shown in the above figure. From the manifest of the figure that, the maximum scour of W weir is occurred at the center of the downstream apex, and the magnitude is 1.6533D. The scour hole is expanding in the upstream direction around 3.2D, which is larger than the previous cases. At next to the upstream apex, the scour hole converged as the particle started to deposit due to the weakening of the primary vortex; at the downstream apex of W weir, the ridge formed with the length of 1.067D. The depth of maximum scour at the vicinity of the pier is 0.9467D at the upstream face of the pier. The size of distinct local scour around the pier is very small when compared to the size of the scour hole without any control measures, and on the rear side of the pier, the scour hole is faint due to the deposition. The ability of modified W weir with this configuration regarding the scour control at the pier is 34.57% compared to the magnitude to scour depth at the pier without any control measures.

The test was conducted on a modified W weir of 1.5D size is placed at 1.5D by the upstream face of a pier with a 2D height between the bed to center apex crest. The above figure shows the distinct profile of equilibrium scour at modified W weir with a pier of experimental run 10. The maximum depth of local scour at modified W weir is 1.52D, and it has occurred at the center of the weir around 0.533D from the downstream apex. The scour hole extended in the upstream direction around 2.3467D from the upstream apex. The tiny but distinct local scour found between the downstream apex of W weir to the ridge formation almost occurs in all the experiments. The depth of maximum local scour at the vicinity of the pier is 0.9467D, and the size of the distinct scour hole is smaller, with no distinct scour formation at the rear side of the pier, which is evident from the scour profile. The downscaled W weir with the aforementioned structural configuration can reduce the scour at the cylindrical pier by around 33.64% compared to the scour depth of pier with devoid of control structures.

Among all the experimental runs in the modified W weir, experimental run 2 shows the maximum scour control on the cylindrical pier's vicinity. The experimental run 11 performed on the optimized structure configuration of experimental run 1 to analyze the effectiveness against scour control under the condition of u_*/u_{*c} = 0.9. The equilibrium scour profile of modified W weir with a pier of experimental 11 is shown in

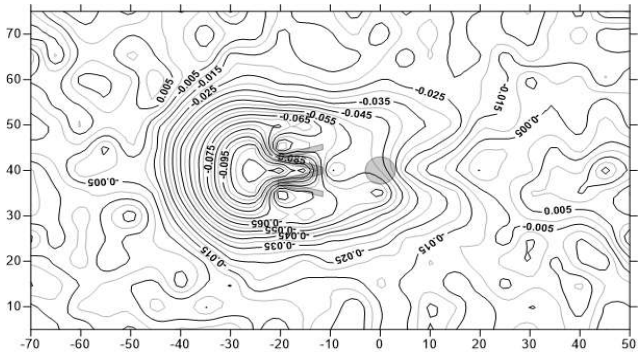


Fig. 13. Contour of scour profile of experimental Run 9

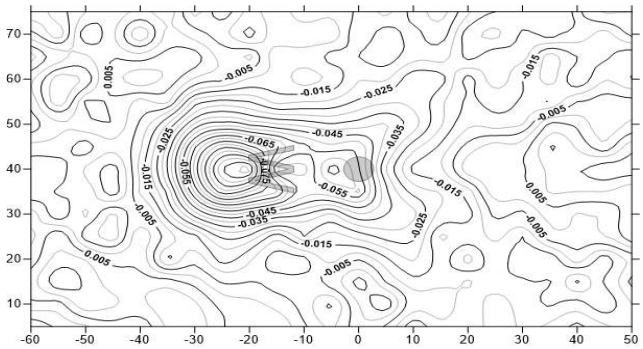


Fig. 14. Contour of scour profile of experimental Run 10

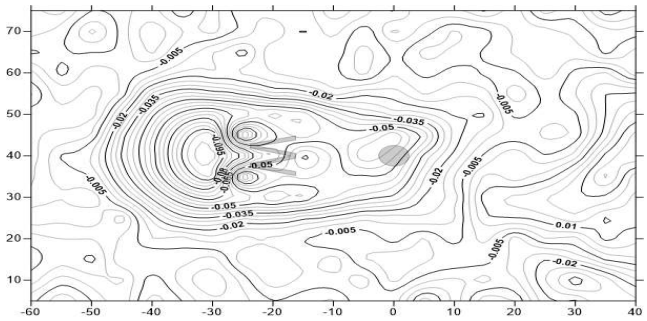


Fig. 15. Contour of scour profile of experimental Run 11

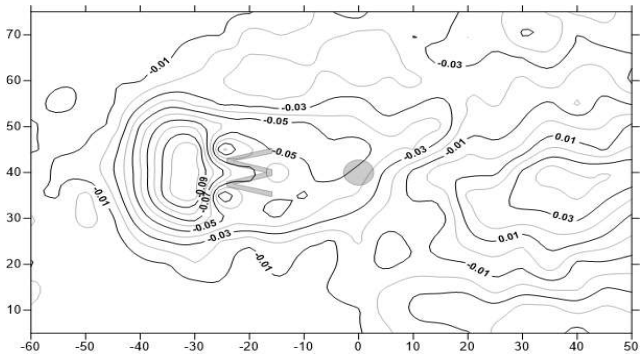


Fig. 16. Contour of scour profile of experimental Run 12

Figure 15. The maximum depth of the scour hole at the modified W weir is 1.5467D, and it is occurred at on the vicinity of upstream apexes. From inside the downstream apex, the depth of local scour is increasing towards the upstream apex, and it reaches the maximum at the vicinity of upstream apexes. The equilibrium scour depth at the cylindrical pier is 0.9067D, the size of the distinct local scour hole is almost similar to experiment 2, and also the rear side of pier shows the distinct local scour. Compared to the experimental run 2, the maximum depth local scour at both of modified W weir and pier is higher in the experimental run 11. The maximum depth of scour at W weir of experimental run 11 ought to be lesser than experimental run 2, as per the condition of u_*/u_{*c}. Nevertheless, the maximum depth of local scour at W weir of run 11 is contrary. Flow depth is another critical parameter that needs to be considered; the depth of flow for experimental run 11 is 18cm. The ratio of flow depth to the structure's height plays a vital role in the W weir's equilibrium scour profile, as mentioned by Pagliara et al (2014). The ratio of the depth of flow to a height of W weir of run 11 is lesser than experimental run 2. It may cause to increase in the magnitude of a primary vortex, which develops at the upstream apex, and due to this vortex, the scour depth is increasing at W weir than the experimental run 2. The experimental run 12 was also performed on the optimum configuration of modified W weir of run 2 under the condition of u_*/u_{*c} = 0.95, and the flow depth is 18cm. The equilibrium depth of local scour at modified W weir is 1.4533D, which is occurred at the vicinity of upstream apexes with almost the same magnitude. The local scour hole enlarges up to 2.4D in the upstream direction from the upstream apex. The maximum depth of local scour at the cylindrical pier is 0.8133D. The maximum depth of local scour for experimental runs 11 and 12 is almost having a similar magnitude at a pier as well as W weir. The depth of equilibrium scour at the pier and modified W weir is higher than the experimental run 2, as the flow depth is lesser.

The Figure 17 showing the variation in scour depth at the vicinity of W weir, pier along the longitudinal direction at the center of the channel. Point zero indicates the pier's location, and from zero, the left side is the upstream side, and the right side of zero is the downstream side of the pier. From the figure is evident that the experimental run 2, showing the minimal scour depth among all experimental runs. The experiment at the pier without a weir showed the maximum scour depth compared to all the experimental runs. Likewise, the section from – 5.33 to -1.33 shows the scour depth at W weir's vicinity. The experiments scour depth at the pier without weir showing very little scour depth at these sections due to W weir's absence. Figure 18 show the

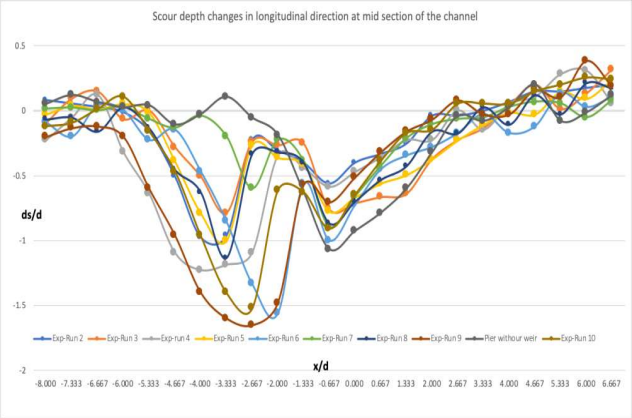


Fig. 17. Scour depth variation along longitudinal direction at centre of the channel

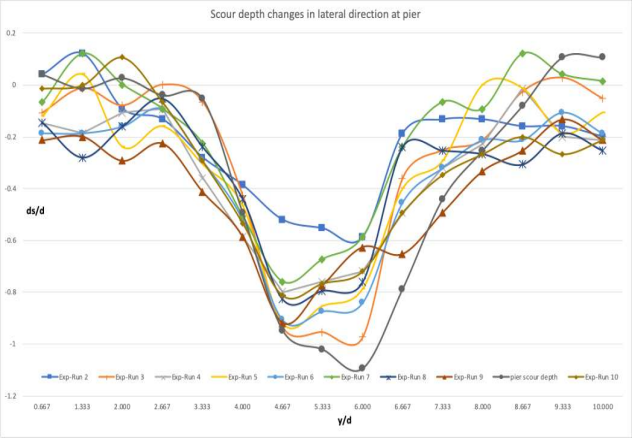


Fig. 18. Scour depth variation along lateral direction at the pier location

variation in scour depth in a lateral direction of the channel at the pier location; section 5.333 is the center of the channel where the pier is located. From the figure is evident that, experimental run 2 shows the minimal scour depth at the pier. The experiment pier without weir showing the maximum scour depth at the pier among all the experimental runs.

CONCLUSION

The modified W weir can effectively reduce the scour at a pier's vicinity. It can be the best alternative to the river-spanning rock weir at were it necessary to protect each pier from the scour. The maximum scour control is obtained at the experimental run 2. W weir's optimum structure configuration is 1.5D size with the height of center apex 2D is located at a 2D distance from a pier can provide the maximum scour control. At this structure configuration, the modified W weir can reduce the scour at the vicinity of a circular pier virtually up to 55.14% compared to the scour at the pier without any control measures. The downscaled W weir, two paramount

scour holes at the upstream apex, but in modified W weir, one paramount scour hole was found. The maximum scour hole is found at the center of the W weir, close to the downstream apex when the upstream apex's height is less, and the scour hole occurs at the near upstream apex when the upstream apex height is higher. This modified W weir can be installed on existing bridges also which is not feasible in the pier slot. Moreover, debris accumulation can be eliminated around the pier, a problematic scenario in the slot. With the combination of rip-rap with modified W weir, the scour has been eliminated in the vicinity of the pier and a weir. Further study has to conduct in order to study the effectiveness of modified W weir under live bed condition and to study the flow structure at the vicinity of the weir to design the effective control structure to reduce the maximum scour in the upstream of the weir.

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Soil Loss Assessment for Palair Reservoir Catchment Area Based on Geoinformatics Approach

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***Abstract*:** This study has attempted to quantify the soil loss rate in the Palair reservoir catchment area, Khammam district, Telangana, India. A Digital Elevation Model (2.5 m by 2.5 m spatial resolution), rainfall data over 16 years, soil and land cover/land use extracted were used as an input to compute soil loss rates. GIS-based USLE factors were integrated and analyzed in the ArcGIS 10.8 platform. The large spread of soil loss is mainly associated with a change in the R-factor. The results showed that yearly soil loss in the study area ranges up to 11591.91406 t ha^{-1} $year^{-1}$ with a mean annual soil loss of 1095.242479 t ha^{-1} $year^{-1}$. The overall yearly soil loss in the study area is 12695956.6 tonnes. Approximately 111.2 ha of the area is within the extreme and very extreme erosion clusters that demand immediate controlling measures. The primarily responsible factors for soil loss are identified as LULC and terrain characteristics.

***Keywords*:** GIS, Palair reservoir, Soil Erosion, Soil loss, USLE

India is estimated to lose about 5 billion tonnes of soil per year, with an average of 16 tonnes/ha (Saroha 2017). Soil loss in India is more common in the western Ghat and Himalayas (Pandey et al 2007). Currently, soil loss and erosion from severe water impacts are considered significant environmental hazards in the world as they significantly affect the environment and human economy (Kalita and Sarmah 2016, Sharma 2010). Therefore, detailed and quantitative assessments are needed to assess the extent and nature of erosion in sustainable planning and land management (Chen et al 2019).

Since the late 20th century, a lot of research has been done to understand the dynamics of soil loss. As a result, many empirical and mathematical models have been developed to estimate soil loss (Chen et al 2019, Benavidez et al 2018). Which would help the policymakers in the decision-making process and helps the local community whose livelihood depends upon a soil (Agarwal and Kumar 2020, 2021). This study used a general model of the soil loss equation to estimate soil loss in Palair reservoir catchment area and prepare a soil loss map. The Universal Soil Loss Equation (USLE) contains a more extensive and improved methodology and database (Chen et al 2019). Due to its reliability and accuracy, several researchers have used the USLE on a GIS platform to estimate the land loss in specific regions, especially India (Pandey et al 2017, Ganasri and Ramesh 2016, Patowary and Sarma 2018, Srinivasan et al 2019, Jaiswal and Amin 2020). The results of this study can help surveyors and decision-makers deal with the damage caused by soil loss by providing adequate information about soil loss and the level of soil loss.

MATERIAL AND METHODS

Study area: The Palair Reservoir is located near the village of Palair in the Khammam district of Telangana, about 30 km from the district's headquarters. Palair is a large artificial reservoir up to 16 m deep. The lake is a balancing reservoir of the Lal Bahadur Canal, the Nagarjuna Sagar project's left bank. The lake's water is used for irrigation, and the lake itself is a famous fish farm. The present study area was located between latitude 17º 9' 33.93" - 17º 48' 30.92" N and longitude 79º 19' 48" - 79º 58' 52.75" E covering a total area of 1923.38 km^2 (Fig. 1). The dominant culture in the study area is paddy. Erosion is expected in the study area due to rolling topography and inappropriate farming practices.

Data collection: Rainfall records were downloaded from the open data portal Telangana website for 16 years (2004-2019) (Table 1). Soil map downloaded from National bureau of soil survey and land use planning, Nagpur. For slope, length-steepness data, and land use/cover data, downloaded 2.5m*2.5m resolution DEM from Cartosat-1 and 23.5m*23.5m resolution LULC from IRS LISS-III satellite images from the BHUVAN website.

Soil loss estimation: Universal soil loss equation was used to determine the annual average soil loss and the spatial distribution over the watershed. USLE predicts soil loss per site as the product of six important erosion factors are shown in Eqn. (1) that can be quantified at a given area (Pandey et al

2007). These erosion factors values vary considerably with the mean value from event to event, but the effects of these fluctuations are average over the long term. One of this model's limitations is that it does not estimate precipitation, sediment runoff, canal erosion, or destruction. Therefore, the USLE is suitable for predicting the long-term average, and the soil erosion is calculated as:

$$A = R \times K \times LS \times C \times P \quad (1)$$

Where A is the annual average soil loss rate (t ha^{-1} $year^{-1}$), R is the rainfall erosivity factor (MJ mm ha^{-1} $hour^{-1}$ $year^{-1}$), K is Soil erodibility factor (metric t ha^{-1} MJ^{-1} mm^{-1}), LS is slope length-steepness factor, C is cover and management factor (dimensionless), and P is erosion support practice factor (dimensionless). As shown in the conceptual diagram is shown in Figure 3.

RESULTS AND DISCUSSION

Rainfall erosivity factor (R-factor): Soil loss estimates were affected by precipitation and runoff affected by rainfall erosion (Yue-Qing et al 2008). In a GIS environment, the R-factor map for the study area was prepared using the following steps.

- Prepare the annual average rainfall (P).
- Inverse weighted interpolation (IDW) method applied on the ArcGIS 10.8 platform.
- Calculating the corresponding factor by considering India's condition using Eqn. (2) developed by (Pandey et al 2007) and see Table 2 below.
- $R = 79 + 0.363 \times F$ (2)

Table 2. Mean annual rainfall and corresponding R-factor value

Stations	Latitude (m)	Longitude (m)	R-values
Gudur	79.3983	17.742317	428.085756
Palakurthi	79.4209	17.6704	327.206241
Kodakandla	79.502815	17.52835	296.131853
Nagaram	79.47996	17.38192	285.9463
Thungathurthi	79.58763	17.425484	289.37665
Noothankal	79.69673	17.340067	269.44795
Atmakur_S	79.71405	17.231234	263.199813
Mothey	79.85595	17.245417	197.139258
Thirumalayapalem	79.84002	17.306883	335.207442
Peddavangara	79.55476	17.52665	156.326167
Maddirala	79.677704	17.414597	267.81445

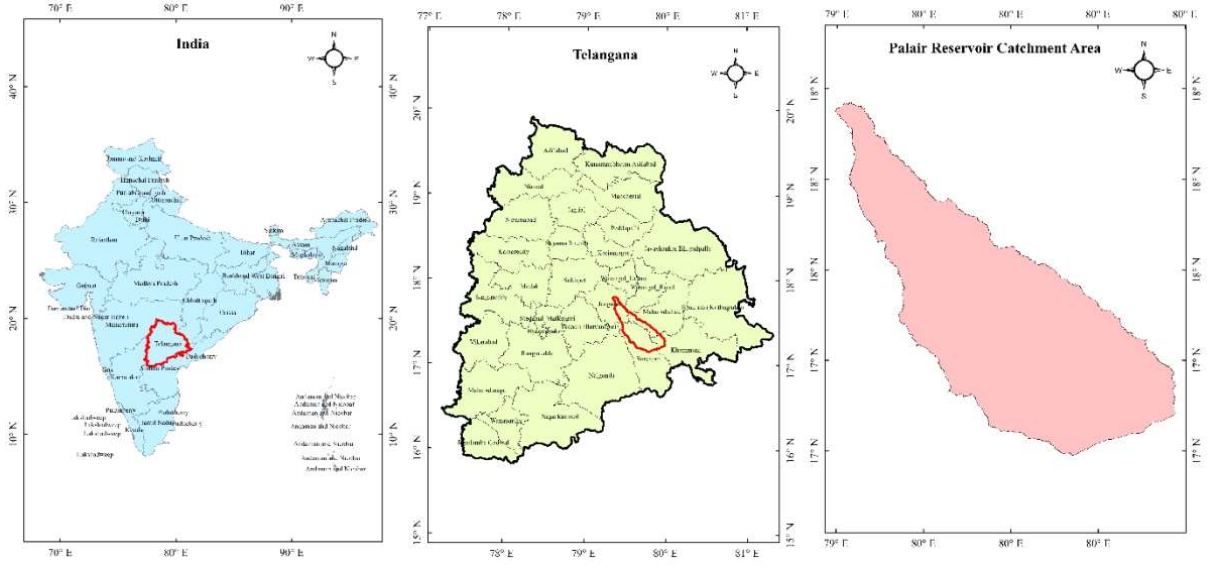


Fig. 1, Study area

Table 1. Data collection

Data type	Source	Description
Rainfall records	https://data.telangana.gov.in/	Precipitation data for 16years (2004-2019) of 11 AWS.
Soil data	NBSS&LUP Nagpur	The soil map prepared by NBSS&LUP (2000)
Slope length-steepness data	https://bhuvan.nrsc.gov.in/bhuvan_links.php	2.5m*2.5m resolution DEM from Cartosat-1
Land use/cover data	https://bhuvan.nrsc.gov.in/bhuvan_links.php	23.5m*23.5m resolution LULC from IRS LISS-III

In the current study, the average annual rainfall is shown in Eqn. (2) was used to calculate the R-factor. R values range from 156.326167 to 428.0857563 MJ/mm/ha/h/year. Inverse distance weighted (IDW) was used to distribute average precipitation in the study area. The IDW process considered annual precipitation data 16 (2004-2019) for 11 collection stations in and around the study area. Figure 4 shows a map of rainfall erosion activity prepared from precipitation data of the study area.

Soil erodibility factor (K-factor): This coefficient is used to quantify ground resistance to transfer shear stress to ground flow and rainfall. Based on other researcher's recommendations (Tirkey et al 2013) and other literature sources, the researchers redistributed the soil in the study area and assigned k-valuesaccording to the soil colors (Table 3). Coefficient K values were obtained for that soil type to get

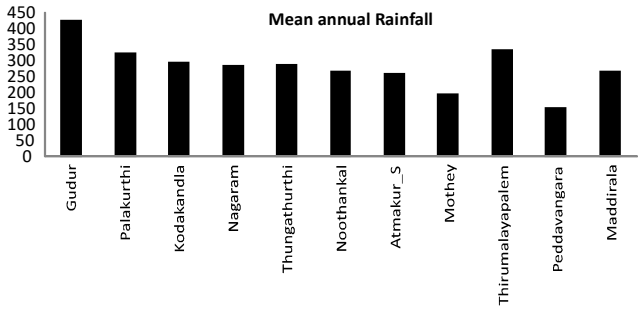


Fig. 2. Mean annual rainfall of Palair reservoir catchment area (year)

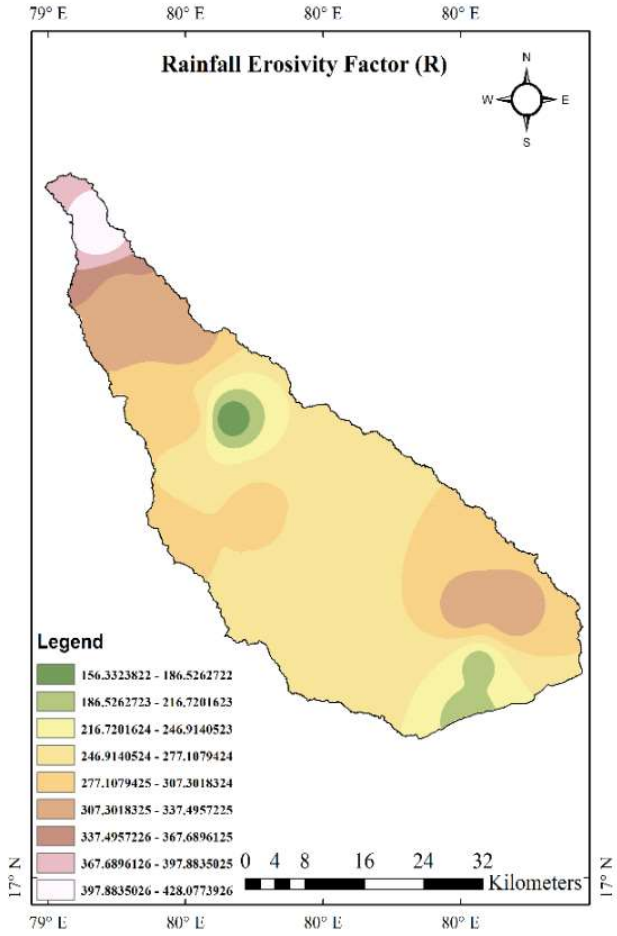


Fig. 4. Rainfall erosivity factor map

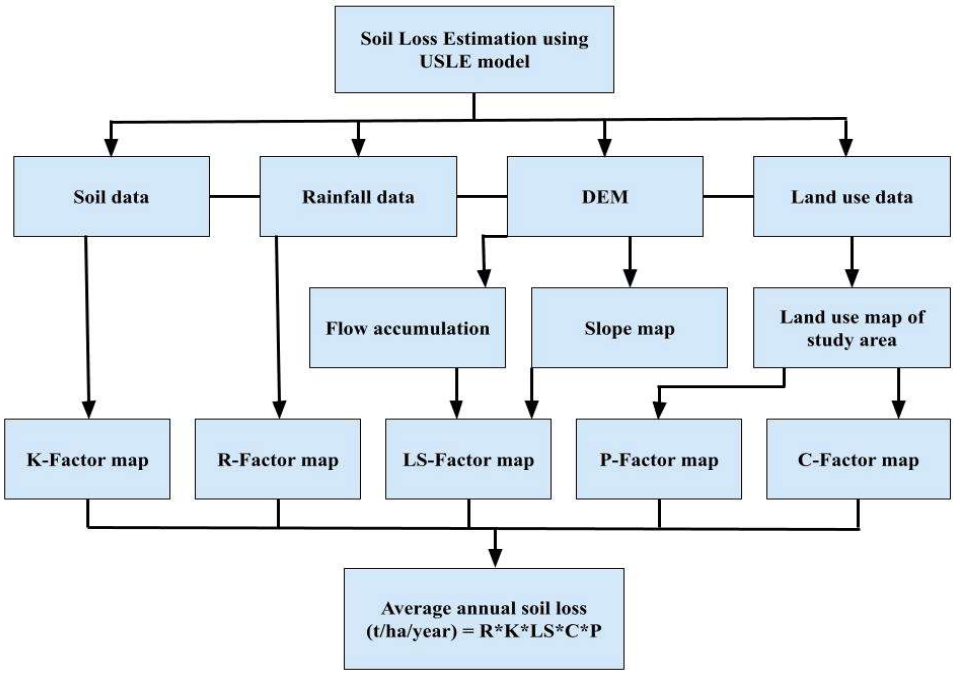


Fig. 3. Conceptual diagram of soil loss analysis by USLE model

a soil erosion map of the Palair reservoir catchment area. The lowest K values are associated with soils with low moisture content and low permeability. Therefore, the Palair reservoir catchment area for the soil map is reclassified to the target value K is shown in Figure 5. K values are prepared from 0.15 to 0.34, and values close to zero are less sensitive to soil erosion.

Slope length-steepness factor (LS-factor): The study area's Slope length-steepness factor has been generated from DEM using the following steps in the GIS environment.

- Filling of sinks of DEM of the study area.
- Generation of S factor using filled-in DEM as an input.
- Generation of flow direction using filled DEM as an input.
- Computing flow accumulation raster using flow direction raster as an input.
- Generating the slope of the study area in degree
- Calculating LS factor using flow accumulation slope raster as an input.

The output slope length-steepness factor raster map of the Palair reservoir catchment area is shown in Figure 6. As indicated by (Pandey et al 2007), the LS coefficient is an essential parameter in USLE for measuring the flow capacity containing sediments. To estimate the LS coefficient for the spatial distribution of soil erosion in each watershed, it is essential to consider the area contributing to the increase. Therefore, this study used the following advanced method to calculate the LS coefficient in an ArcGIS environment is shown in Eqn. 3.

$$LS = (Flow\ accumulation \times \left(\frac{Gridsize}{22.16}\right))^{0.4} \times (sin(slope) \times \frac{0.01745}{0.09})^{1.4} \times 1.4 \quad (3)$$

The topographic aspect reflects the length of a particular slope and its steepness on the erosion process. The LS coefficient was estimated in terms of the flow rate and slope accumulation. According to the analysis, as the flow accumulates and the slope increases, the terrain coefficient's value increases in the range of 0 to 36.893. The minimum and maximum slopes for each pixel were calculated with the fishnet (Fig. 6).

Cover and management factor (C-factor): Depending on

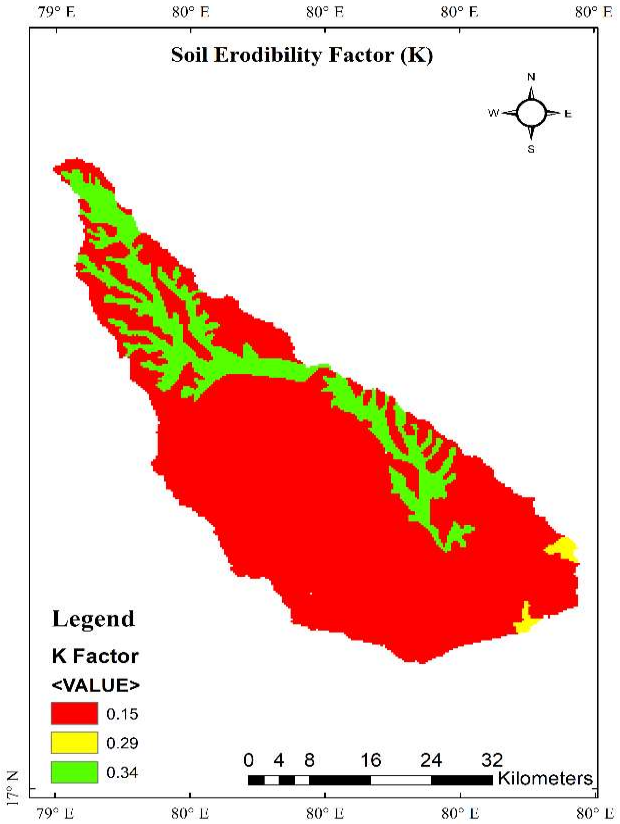


Fig. 5. Soil erodibility factor map

Table 4. C factor developed by Ghosal et al 2020

Land use and land cover class	C value
Agricultural land	0.400
Built-up	0.000
Barren land	1.000
Dense Vegetation	0.004
Waterbody	0.000

Table 5. P factor developed by Ghosal and Bhattacharya 2020

Land slope percentage (%)	P-value
1 – 2	0.6
3 - 5	0.5
6 - 8	0.5
9 – 12	0.6
13 - 16	0.7

Table 3. K values are based on colors

Soil color	Description	K values
Black	Moderately deep, well-drained, gravelly loam soils with low AWC, on undulating lands, severely eroded; associated with: Moderately deep, well-drained, gravelly clay soils.	0.15
Red	Moderately deep, moderately well-drained, gravelly loam, calcareous soils with low AWC, on very gently sloping plains, slightly eroded; associated with Deep, well-drained, loamy soils.	0.29
Yellow	Very deep, moderately well-drained, cracking clay, calcareous soils with very high AWC, on nearly level valleys, salinity in patches; associated with Deep, well-drained, loamy over sandy, calcareous, stratified soils.	0.34

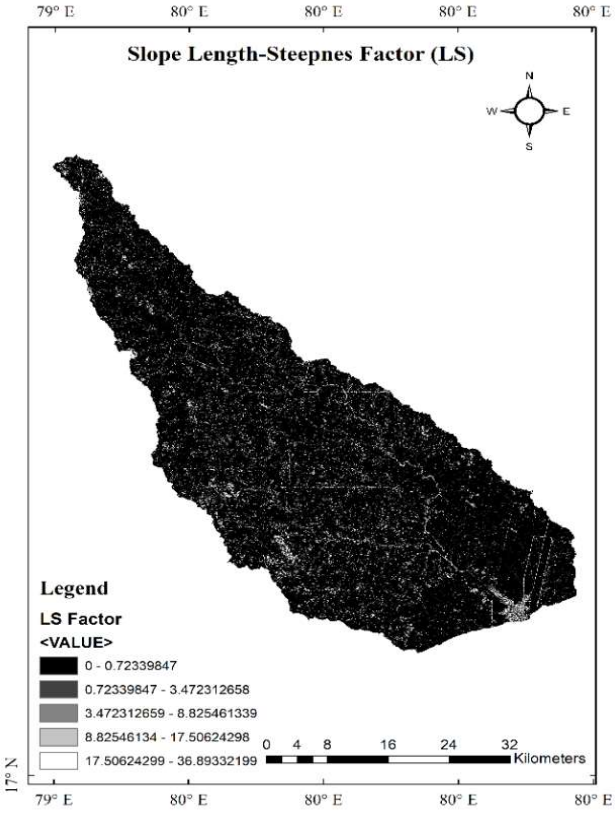


Fig. 6. Slope length-steepness factor map

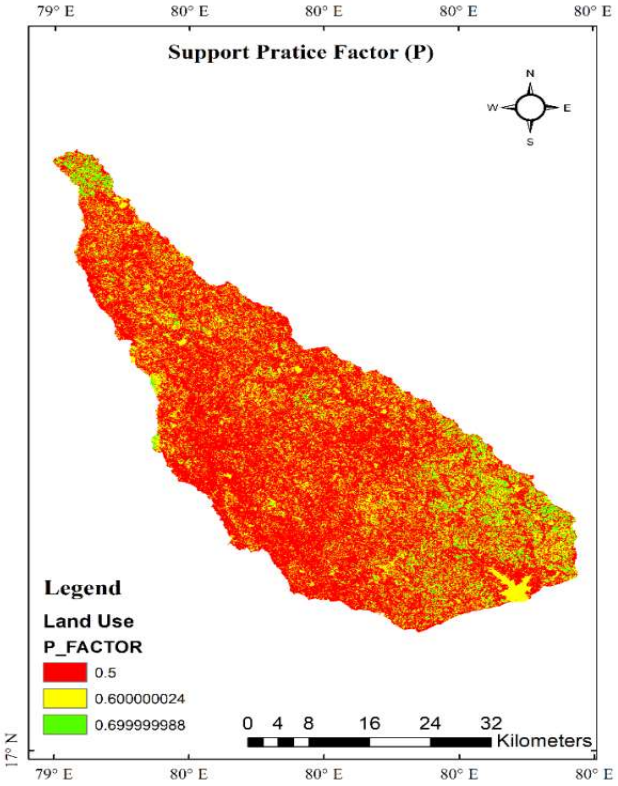


Fig. 8. Support practice factor map

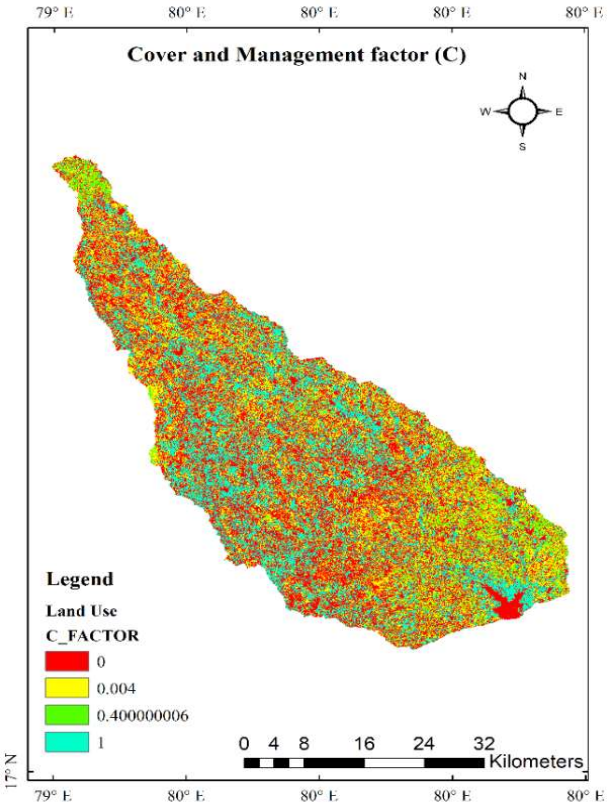


Fig. 7. Cover and management factor map

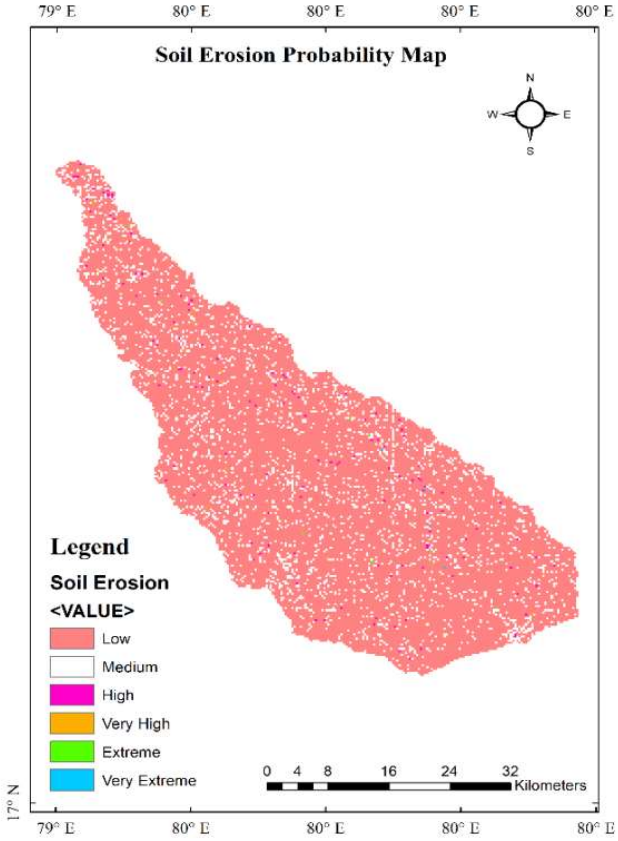


Fig. 9. Soil erosion probability map

Table 6. Numeric soil loss summary

Numeric range of soil loss (t ha^{-1} year^{-1})	Soil erosion risk class	Area (ha)	Area (%)	Annual soil loss (t year^{-1})	Percentage of total soil loss
0 - 90.91697304	Low	168080	93.85331	7640662.414	60.18185632
90.91697304- 500.0433517	Medium	9642.7	5.384335	2849226.561	22.44199968
500.0433517 - 1454.671569	High	1032.5	0.576576	1009121.578	7.948369726
1454.671569 - 3227.552543	Very high	222.4	0.124186	520663.3213	4.101016835
3227.552543 - 6546.022059	Extreme	79.429	0.044352	388152.6285	3.057293262
6546.022059 - 11591.91406	Very extreme	31.771	0.017741	288130.1842	2.269464139

sparse vegetation, dense vegetation, water bodies, barren land, built-up land, and agricultural land (Ghosal and Bhattacharya 2020) first developed a cover and management factor (Table 4). Land- use information provides a good understanding of land-use characteristics such as water bodies, bare soil, built-up area, dense vegetation, and agricultural land required for soil erosion research or development planning. C-values are shown in Table 4. C-factor values are determined using a land-use map is shown in Figure 7.

Support practice factor (P-factor): The development of the support practice factor (P) has not yet been implemented. In general, researchers applied (Ghosal and Bhattacharya 2020) the P-factor concept to their study field. Ghosal and Bhattacharya (2020) developed the P-table factor that considers all preservation. Researchers can easily use this table for specific research areas. They first identified the P-factor for the contour area of plowing and over slope planting along the contour line. Cracks created by these contours reduce current and the formation of gutters in case of excessive spillage. This is the leading cause of soil erosion (Table 5).

The P factor describes a mechanism that reduces the risk of runoff erosion by affecting runoff concentration, hydraulic power, and runoff velocity, which are the drainage patterns applied by surface runoff. The P-factor ranges from 0.5 to 0.7, and values close to 0.5 indicate good defensive practice. Conversely, importance relative to 1 shows a low level of protection (Fig. 8).

Soil loss probability zones in catchment area: The leading cause of soil loss, an essential input to the USLE model for soil erosion calculations, was performed using several methods documented by many researchers (Pandey et al 2017, Ganasri and Ramesh 2016, Patowary and Sarma 2018, Srinivasan et al 2019, Jaiswal and Amin 2020). The map is shown in Figure 9 is generated by transferring a raster map of the six input USLE factors (rainfall erosivity, soil erodibility, slope length-steepness, cover and management, support practice) from cell to cell. The Palair reservoir catchment's overall results area shows that soil loss values were obtained between 0 and 11591.91406 t/ha/year. All maps were categorized into six potential erosion classes, ranging from low erosion risk (≤ 90.91697304 t/ha/year) to very extreme erosion risk (Table 6). Nearly 93.85331% of the watershed causes low erosion of 7640662.414 tonnes per year. In comparison, the very extreme probability zone accounts for about 0.017741% of the watershed. It provides 288130.1842 tonnes of soil erosion per year.

CONCLUSIONS

This study was designed to assess soil loss and assess the Palair reservoir catchment area's susceptibility to erosion. The study results focused on assessing areas prone to erosion and assessing soil loss in the study area by applying a USLE model linked to a geographic information system (GIS). The survey indicated that the average annual soil loss estimated by the USLE model is 1095.242479 t ha^{-1}year^{-1} in the area. The large spread of soil loss is mainly associated with a change in the R-factor. It has been proven that precipitation and soil loss characteristics are closely related. An increase in precipitation generally coincides with an increase in soil loss. We found that the erosion rate was mainly due to LULC and terrain characteristics. The overlapped map showed that nearly 111.2 hectares (0.062093%) of the area focus on extreme and very extreme erosion. As a result, the study area's annual soil loss value exceeded the soil loss allowance, and appropriate water and soil conservation methods must be used in the study area. The faster the farmland grows, the higher the risk of soil erosion from farming methods. Comparing potential soil loss with soil loss can identify the effectiveness of several conservation measures and treatment systems on erosion. The findings suggest that the need to use the contextual soil and water conservation method of 111.2 hectares has an extreme and very extreme impact on the research catchment area.

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Assessment of Biological Water Quality Based on Functional Feeding Groups of Benthic Macroinvertebrates: A Case Study of Pampa River

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Abstract: The present study was focused on the biological monitoring of the Pampa river in the Perunad region using Biological Monitoring Working Party (BMWP) and also evaluated the functional feeding groups of benthic macroinvertebrates communities. Benthic macroinvertebrates were sampled for one year from February 2016 to January 2017. Two sampling stations were selected and out of this one station was a disturbed sand mined area. On the abundance and tolerance values, BMWP index of the invertebrates was determined to evaluate the water quality of Perunad area. A total of 1251 individuals of benthic macroinvertebrates belonging to 24 families were collected from the locality during the study period. BMWP score of the study area varied from 53 to 96, which showed that the water quality of the stations was clean but slightly impacted and moderately impacted. The five major functional feeding groups were represented as collector gatherers, shredders, predators, collector filterers and scarpers and dominant functional feeding group was collector gatherers and collector filterers were the least representative. The pollution tolerant benthic macroinvertebrates are dominantly inhabited in the study area.

Keywords: Pampa river, Biomonitoring, BMWP, FFG, Collector gatherers

Benthic macro-invertebrates are important component of the ecosystem because they act as an intermediate pathway for the transportation and utilization of energy and matter, they can indicate water quality because individual taxa respond differently to a variety of pollutants (Wallace and Webster 1996). Aquatic insects are differently sensitive to many biotic and abiotic factors in their habitats. The benthic invertebrates can be used to monitor the quality of the aquatic ecosystem because this community plays a central role in the food web (Salgado et al 2007). Macroinvertebrates are sensitive to different physicochemical condition and any change in the water quality as a potential effect on the community structure of macroinvertebrates living in a water body. Therefore, they are used as an indicator of water quality (Ajuzie 2012). Commonly the health of stream or rivers were analysed based on water quality assessments. The problem is that water quality parameters reflect only the conditions at the moment the sample is taken and only a limited set of parameters. In contrast, macroinvertebrates possess a life cycle in the water of at least a year or more and do not move great distances and are more or less confined to the area of a stream being sampled. These organisms live with the stress and changes occur in the aquatic environment, including those that are due to human activities or natural events such as flood, drought etc. Therefore, macroinvertebrates are ideal representatives for biotic measures of river health. Biotic indices are an effective tool for assessing the quality of aquatic environment based on the different response of the organism to environmental changes (Borisko et al 2007). Freshwater macroinvertebrates are divided into various groups based on feeding habits, called functional feeding groups (FFG). Animals which consume algae and associated materials are Scarpers. Animals which feed leaf litter or coarse particulate organic matter (CPOM), including wood. Animals which collect fine particulate organic matter (FPOM) from the river bottom are collector-gatherers. Animals which collect FPOM from the water column using a variety of filters include collector filters and predators. The objective of this study is, to list out the composition of benthic macroinvertebrates up to order and family. To analyse the functional feeding groups and thereby determine the biological water quality. The application of BMWP score system is also evaluated in this study.

MATERIAL AND METHODS

The present study was carried out in Pampa River at Perunad area situated between latitudes 9° 22'0" N and longitudes 76°50'30"E. This station is located below the place where Kakkadu river and Pampa river joins. Two sampling sites were selected from this area. Site 1 is unmined area and

station 2 is disturbed sand mined area (Fig. 1). Benthic samples were collected from two selected sites of the river between February 2016 and January 2017. Form each sites quadruplets sample were taken using Van Veen grab with an area of 0.1m^2 and sieved through 0.5 mm mesh sieve to separate the organisms. The samples were stored in plastic jars with 5% formalin solution. Macroinvertebrates specimens were identified up to family level. The biological index used in this study is to assess the riverine ecosystem health based on Biological Monitoring Working Party (BMWP) scoring system (Uherek and Gouveia 2014). The distribution of each taxon to the FFG depended mainly on the mouthpart morphology. FFG assignment is done based on the previous works (Tomanova et al 2006, Arimoro 2007). Family abundance of benthic macroinvertebrates are represented by using ArcGIS software.

Data analysis: The BMWP score is the sum of the tolerance value of all macroinvertebrates families present in a study area. A river with good water quality has a BMWP score of 100. This index allocates a single score value to benthic macroinvertebrates at the family level. The score values of individual families reflect their pollution tolerance based on their abundance and distribution. The pollution tolerant families have high BMWP score and intolerant families have low score value and assigned a score between 1 and 10 accordingly. The BMWP requires taxonomic identification of the invertebrates only to the family level (Uherek and Gouveia 2014). For BMWP calculation macroinvertebrates from each station were identified up to family level and allocate them with the scores following the BMWP scoring system (Table 1). BMWP classes, scores, categories and interpretation of the result are showed in Table 2.

Table 1. Biological Monitoring Working Party Score (BMWP) taxa scores: class, order, or family

Taxa	Score
Ephemeroptera: Leptophlebiidae ,Leptohyphidae	
Plecoptera: Perlidae	10
Trichoptera: Brachycentridae,Leptoceridae, Odontoceridae and Sericostomatidae	
Odonata: Coenagrionidae, Calopterygidae, Cordulegastridae,Gomphidae, and Libellulidae	
Trichoptera:Calamoceratidae, Glossosomatidae, Philopotamidae, and Psychomyiidae	8
Plecoptera:Nemouridae	
Trichoptera:Polycentropodidae	7
Crustacea	
Trichoptera:Hydrobiosidae, Hydroptilidae	6
Coleoptera:Elmidae, Dryopidae	
Diptera:Simuliidae, Tipulidae	
Ephemeroptera:Euthyplociidae,Polymitarcidae	5
Platyhelminthes	
Trichoptera:Helicopsychidae,Hydropsychidae	
Arachnida:Hydracarina	
Coleoptera:chrysomelidae,Curculionidae and Haliplidae	
Diptera:Anthomyiidae, Ceratopogonidae, Chaoboridae, Dixidae, Dolichopodidae, Empididae, Limoniidae, Psychodidae, Stratiomyidae and Tabanidae	4
Ephemeroptera: Baetidae, Caenidae	
Megaloptera: Corydalidae, Sialidae	
Annelida: Hirudinea	
Coleoptera: Dysticidae, Gyrinidae, Helodidae,Hydrophilidae and Noteridae	
Hemiptera: Belostomidae, Corixidae, Gerridae, Hydrometridae	3
Mesoveliidae,Naucoridae, Nepidae, Notonectidae, Pleidae and Veliidae	
Mollusca	
Diptera: Chironomidae, Culicidae, Ephydridae, Muscidae and Thaumaleidae	2
Annelida: Oligochaeta	
Blattaria: Blattidae	1
Diptera: Sciomyzidae, Syrphidae and Rhagionidae	
Lepidoptera	

Source: Uherek and Gouveia (2014)

RESULTS AND DISCUSSION

A total of 1251 individuals belonging to 10 orders and 25 families were collected from the two stations. Of these, order diptera contributed the largest share (59.55%) of the total benthic macroinvertebrate fauna, followed by the class Oligochaeta (13.58%). The highest number of families was among Dipterans (five). Site 1 consisted of 23 families of which family chironomidae were most abundant group. Tubificidae were the second dominant family and least dominant was Hydrachnidae with only one individual. Organisms belonging to pollution sensitive taxa (EPT) such as Ephemeroptera and Trichoptera showed its representation in this site but Plecoptera were absent. Site 2 consisted of 16 families of which family chironomidae were most abundant group. Tubificidae were the second dominant family and dominant was Gerridae. Organisms belonging to pollution sensitive taxa (EPT) such as Ephemeroptera and Trichoptera showed its representation in this site but Plecoptera was not observed (Table 4). Based on the Biological Working Party Score (BMWP), site1 is in class II (96), category of 'acceptable' with an interpretation of 'clean but slightly impacted' aquatic habitat and site 2 is in class III (53), category of 'questionable' with an interpretation of 'moderately impacted' habitat (Table 3). The slow diversity and less BMWP score were observed in site 2 which is a disturbed sand mined area. The site 1was dominated by collector gatherers (43.39%) followed by predators, scrapers, shredders and collector filterers (Fig. 2). The main families of collector gatherers were Tubificidae, Nereidae, Chironomidae, Elmidae, Ceratopogonidae, Hydrophilidae and Baetidae, Caenidae, Leptophebiidae. While Chironomidae, Limnoniidae, Ceratopogonidae, Gerridae and Gomphidae were the predators in this site. Elamidae, Corixidae, Bithyniidae, and Thiaridae were the scrapers. Chironomidae, Lepidostomatidae and Leptoceridae were the shredders. Collector filterers were the least dominant groups includes Hydropsychidae and Chironomidae.

Site 2, the most dominated group was collector gatherers (56.2%) followed by predators, scrapers, collector filterers and shredders (Fig. 2). The predominant families of collector gatherers in this site were Tubificidae, Nereidae, Chironomidae, Ceratopogonidae, Baetidae, and Caenidae. Predators were Dysticidae, Gyrinidae, Chironomidae, Dolichopodidae, Limnoniidae, Ceratopogonidae, and Gomphidae. Corixidae and Thiaridae were scarpers. Hydropsychidae and Chironomidae were the collector filters in this area. Tipulidae and Chironomidae were the shredders in the site.

The Diptera contributes a large number compared to other orders. Diptera can be found in a clean stream to polluted streams (Abbasi et al 2020). Macroinvertebrates

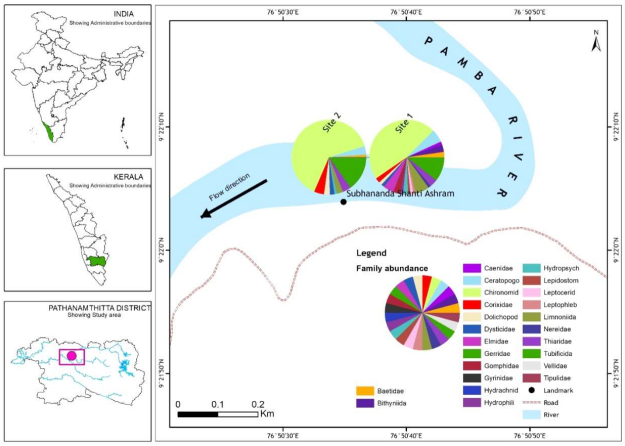


Fig. 1. Study area with family abundance

Table 2. BMWP classes, scores, categories and interpretation of the result

Class	BMWP score	Category	Interpretation
I	>150	Good	Very clean water
	101-150		Clean or not significantly altered
II	61-100	Acceptable	Clean but slightly impacted
III	36-60	Questionable	Moderately impacted
IV	15-35	Critical	Polluted or impacted
V	<15	Very critical	Heavily polluted

Table 3. BMWP index of two sites in the Perunad area

Sites	Class	BMWP score	Category	Interpretation
1	II	96	Acceptable	Clean but slightly impacted
2	III	53	Questionable	Moderately impacted

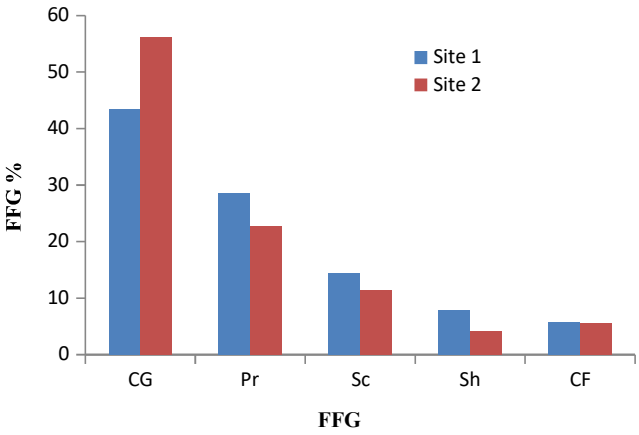


Fig. 2. Overall percentage representation of the different functional feeding groups in the study area

belong to pollution sensitive groups such as families hydropsychidae and baetidae are present in the study area. These two families are known to be tolerant of organic pollution and other human activities (Selvakumar et al 2012). Family Chironomidae was the dominant group and recorded its highest number in the two sites. Family Chironomidae belongs to order Diptera is considered to be a pollution tolerant group may be due to the presence of haemoglobin pigment that helps them to collect oxygen directly from the atmosphere (Davason and Henry 2007). Pollution sensitive group such as EPT (Ephemeroptera, Plecoptera and Trichoptera) show less abundance in the study area compared pollution tolerant groups. Order Plecoptera was not observed at both sites. Among EPT taxa, Oder Plecoptera have long been as the most pollution intolerant of the aquatic insect orders compared to the other two groups in this category such as Ephemeroptera and Trichoptera (Ab - Hamid 2017). According to the BMWP scoring system, the scores of the study area varied from 53 - 96. During the sampling period, site 1was categorized in to 'clean but slightly impacted' according to the index. On the other hand, the site 2 was categorized as 'Moderately impacted'. Low index value indicates the study area was physically disturbed and which results from the low abundance of aquatic organisms (Bhandarkar and Bhandarkar 2013).

Community structure of benthic macroinvertebrates and ecosystem functioning revealed that collector gatherers (CG) being the most dominant group during the period of study. The dominant functional feeding group of the study area was collector gatherer and similar findings were reported by Butakka et al (2014). Collector gatherers directly utilizing the fin particulate organic matter (FPOM) generated by shredders therefore collector gatherers should be co-dominated with a shredder in the headwaters areas (Makaka et al 2018). Collector gatherers are more tolerant to disturbances because they exhibit generalist feeding habits, whereas shredders and scrapers are exhibited the highest level of feeding specialization because of that they are considered to be more sensitive to environmental disturbances (Min et al 2019). Loss of biodiversity and major

Table 4. Benthic macroinvertebrates of the study area and BMWP score allocates to each taxon

Class/Oder	Family	Site 1	Site 2	BMWP score	FFG
Oligochaeta	Tubificidae	61	99	1	CG
Polychaeta	Nereidae	7	2		CG
Acarina	Hydrachnidae	1	0	4	Pr
Coleoptera	Dysticidae	8	13	5	Pr
	Elmidae	26	0	5	CG/Sc
	Gyrinidae	5	4	3	Pr
	Hydrophilidae	6	0	3	Pr
Diptera	Chironomidae	269	414	2	CG/Pr/CF
	Dolichopodidae	8	16	4	Pr
	Limnoniidae	34	18	4	Sh
	Tipulidae	0	4	5	Sh
	Ceratopogonidae	33	24	4	CG/Pr
Ephimeroptera	Baetidae	13	7	4	CG
	Caenidae	8	5	4	CG
	Leptophlebiidae	6	0	10	CG
Hemiptera	Gerridae	2	1	3	Pr
	Corixidae	12	28	3	Sc
	Vellidae	1	0	3	
Odonata	Gomphidae	18	5	8	Pr
Trichoptera	Hydropsychidae	13	7	5	CF
	Lepidostomatidae	6	0		
	Leptoceridae	7	0	10	CG/Sh
Gastropoda	Bithyniidae	18	0	3	CF
	Thiaridae	19	23	3	Sc

CG - Collector Gatherers, Sh- Shredders, Pr- Predators, CF- Collector Filters, Sc- Scrapers

shifts in the structural and functional organization of macroinvertebrates in streams are mainly due to the changes in land use, particularly the loss of riparian vegetation (Allan 2004).

CONCLUSION

The water quality of study area is not very clean because its aquatic environment is moderately polluted. The most dominant FFG group in study area was collector-gatherers, followed by predators, scrapers, shredders and collector filterers. These changes were due to difference in distribution abilities of various organisms in accordance with their traits. The benthic community is generally dominated by pollution tolerant taxa compared to pollution sensitive taxa. This clearly indicates the deterioration of water quality status of river.

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Determining Ground Water Quality for Irrigation in Varahanadhi River Basin, Tamil Nadu, India

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Abstract: Identifying polluted areas using groundwater quality index is a prerequisite for sustainable water resource management. An attempt has been made in this study by overlay various irrigation water quality parameters to identify the irrigation water quality index (IWQI) using GIS for the Varahanadhi river basin of Tamil Nadu. Secondary data and relative weights for each parameter using standard value were adopted. High salinity and low sodium hazard class (C3-S1) based on Wilcox plot, Gibbs plot indicates hydro geochemistry is controlled by rock water dominance. Northern and southern parts are suitable meanwhile north eastern parts of the basin are unsuitable for agriculture activities and accounts for 20 and 30 percent of pre and post-monsoon samples respectively.

Keywords**:** GIS, Wilcox, SSP, MAR, IWQI

The increasing population, industrialization and limited water resources, the demand for domestic as well as agriculture is increasing day by day (Keesari et al 2016). Because of anthropogenic activities, the quality of water is degraded increasingly around the world (Causape et al 2004) and the geological formation of an area also influences the quality (Subramani et al 2005, Chin 2006). Groundwater plays a vital role in arid and semi-arid regions for irrigation (Sanjeev Kumar Pal et al 2018). The utilization of groundwater for various purposes based on quality and quantity should be determined continuously (Arslan 2017). Based on the geochemistry of groundwater, the suitability of water for domestic and irrigation is determined (Kumar et al 2014). The agricultural based country like India, a high amount of freshwater is essential for irrigation (Nandal et al 2020). Various researchers studied the groundwater quality for irrigation (Singaraja 2017 for Thoothukudi; Naseem Akhtar and Shive Prakash Rai 2019 for Jhansi district of Uttar Pradesh; Kumar and Balamurugan 2019 for Sarabanga River region; Vinothkanna et al 2020 for Dindigul region).

Generally, a small quantity of soluble salts always presents in groundwater, normally determined by the source of recharge and strata through which it flows. A high amount of soluble salts present in groundwater is harmful to major food crops as well as affects the physical and chemical properties of soil (Jalali 2010), so it is essential to evaluate the quality of groundwater for irrigation (Karunanidhi et al 2013). Also, excessive application of chemical fertilizers and manures to increase crop production leads to degrading the quality of groundwater (Getahun and Keefer 2016). Water quality indices (WQI) are great tools or methods which combine a set of water quality parameters to a single value that determine and classifies in terms of water quality (Alexakis et al 2016). The interpolation technique in GIS allows identifying the unknown values from the known values (Shabbir and Ahmad 2015, Rabeiy 2017). The study WQI along with GIS would provide a better understanding of hydro geochemistry spatially and results could be more useful for policymakers to take necessary steps (Latha and Rao 2010). By keeping the above views, the present study was carried out to identify the suitable area for irrigation based on groundwater quality parameters.

MATERIAL AND METHODS

Study area: Varahanadhi river basin is one among the 17 river basins of Tamil Nadu originates in the north-western part of Pakkammalai hills covering an area of 4498.5 sq km. This basin is located in the Villupuram, Kancheepuram, Thiruvannamalai and Cuddalore districts of Tamil Nadu and union territory of Pondicherry state and extends between 11° 50' 00" to 12° 28' 00" north latitude and 79° 08' 00" to 80° 10' 00" east longitude. Topographically, the entire basin is plain terrain having altitudinal range from 10 to 100m above MSL.

Geologically, the majority of the basin is covered by a hard crystalline rock of *Archaen* age group. The study area is also covered by sedimentary rocks of Upper *Gondwana*, *Cretaceous*, Teritary and Quatenary age groups (Fig. 1).

Methods: The data collected from the state ground and surface water data centre, Tharamani, Chennai were used and common wells for both post and pre-monsoon season were identified (Table 1). The parameters such as Kelly ratio (KR), sodium absorption ratio (SAR), permeability index (PI), electrical conductivity (EC), fluoride (F), magnesium absorption ratio (MAR), total hardness (TH), sodium percent (Na %), Total dissolved solids (TDS) and soluble sodium percentage (SSP) were integrated to develop irrigation water quality index (WQI). The relative weights for each parameter were calculated and classified based on Meireles et al (2010) and Hussain et al (2017). The following formula was used to calculate the irrigation water quality index (IWQI),

$$Qrv = \frac{(Cv)}{(RSv)} \times 100$$

$$W_{cv} = \frac{1}{RS_v}$$

$$IWQI = \frac{\sum_{1-0}^{n} W_{cv} \times Q_{rv}}{\sum_{i=0}^{n} W_{cv}}$$

Where, Qrv indicates quality rating value, Cv denotes observed concentration values, RSv for recommended standard values, Wcv is a relative weight and IWQI stands for Irrigation water quality index. N denotes the number of variables. Finally, the data are attributed and the interpolation technique mainly Inverse Distance Weight (IDW) method is used for spatial mapping in the platform ArcGIS. The following formulas were adopted for chemical parameters to identify the irrigation quality.

$$\%\,Na = \frac{(Na + K) \pm 100}{(Ca + Mg + Na + K)}$$

$$RSC = (CO^{-}_{3} + HCO_3) - (Ca^{2+} + Mg^{2+})$$

$$SAR = \frac{(Na^{+})}{\sqrt{Ca + \frac{Mg}{2}}} \times 100$$

$$MAR = \frac{(Mg^{2+})}{(Ca^{2+} + Mg^{2+})} \times 100$$

$$PI = \sqrt{\frac{Na^{+} + HCO_3}{Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}}} \times 100$$

$$SSP = \sqrt{\frac{(Na^{+} + K^{+})}{Ca^{+} + Mg^{2+} + Na^{+} + K^{+}}} \times 100$$

$$KR = \frac{(Na^{+})}{(Ca^{2+} + Mg^{2+})}$$

RESULTS AND DISCUSSION

Mechanism controlling groundwater chemistry: Hydrogeochemical compositions of groundwater in the aquifer are determined by several factors which can be better studied using the Piper tri-linear diagram and Gibbs plot. The majority of the samples in anions fall in no dominant types and it constitutes HCO_3^-, SO_4^-, Cl^- which are present in the lower right triangle (Fig. 2). The cations (Ca^{++}, Mg^{++}, Na^{+}) in the lower-left triangles were dominated by sodium and potassium ions followed by Mg^{++}. The sodium chloride type water was highly dominated in the study area followed by magnesium bi-carbonate type and mixed type of water. The diamond shapes indicate that strong acids exceeds weak acid in both monsoon seasons. The relative concentration of anions and cations were in the order of Cl> HCO^3> SO_4^{2} and Mg^{++}> Na^{+}>Ca^{++} respectively. The groundwater chemistry is altered mainly due to rock - water interaction/weathering of rocks which was depicted by Gibbs plot (Fig. 3). It indicates that groundwater chemistry is controlled by rock dominance (Vinothkanna et al 2020).

Soluble Sodium Percentage (SSP): SSP values indicate that 43 percent of the samples during pre-monsoon and 55 percent in post-monsoon season are under permissible limit and 57 percent of samples in pre-monsoon and 45 percent of post-monsoon samples are above the permissible limit as prescribed by (Todd 1980) for irrigation water quality. SSP value below 50 is considered suitable for irrigation (Table 2, Fig. 4). The SSP mean was 49.16 and 46.06 meq l^{-1} for pre

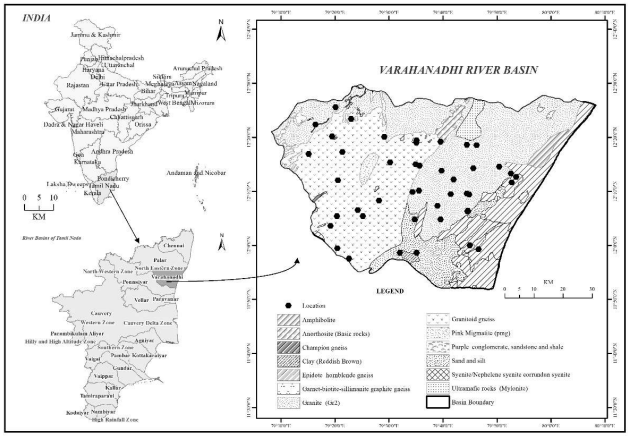


Fig. 1. Location of study area - Varahanadhi River Basin

and post-monsoon seasons respectively. The spatial map indicates that the southern and north eastern part of the basin and a patch in the central part during pre and post-monsoon season are above the standard value, not suitable for irrigation and need remedial measures (Fig. 4a).

Kellys's ratio and total hardness: The Kelly's Ratio (KR) ranged from 0.02 to 4.1 epm and 0.01 to 5.26 epm for pre and post-monsoon seasons respectively. KR value <1 is considered as a recommended value for irrigation. Among the 44 samples (43 percent) falls under the permissible limit (Fig. 4b). The samples which fall above the permissible limits (>1) were 25 (57) and (43 percent) during pre and post-monsoon seasons respectively, are unfit for irrigation. The spatial map portrays that the western and southern parts of the basin are above the recommended limit. Hence, not suitable for irrigation and requires curative measures. The total hardness indicated that 93 and 43 percent samples during pre and post-monsoon seasons are above the permissible limit. The mean was 766 and 866 in pre and post-monsoon seasons respectively. In the majority sample TDS values werewithin the permissible limits, suitable for irrigation. Piper plot confirms that the groundwater samples present in the study area is described as strong acids (SO_4 + Cl + F) which exceed week acids (CO_3 + HCO_3).

Magnesium Absorption Ratio (MAR) and Na%: Magnesium Absorption Ratio (MAR) indicate that 57 percent of pre-monsoon samples 75 percent of post-monsoon samples are acceptable for irrigation. About 19 and 11 samples in pre and post-monsoon seasons are above the permissible limit. A high amount of magnesium in water increases alkalinity in soil and reduces crop yield (Joshi et al 2009). The mean values of MAR are 49 and 52 meq l^{-1} for pre and post-monsoon seasons respectively (Fig. 4c). Northern and south western parts during pre-monsoon and dispersed patches during the post-monsoon season were not suitable for irrigation during the study period revealed by the spatial map. During pre and post-monsoon seasons, 36 and 40 samples are under the permissible limit and 18 and 9 percent are above recommended respectively. High sodium content water arrests plant growth and reduce soil permeability (Joshi et al 2009). The average was 39.75 and 34.8 meq l^{-1} for pre and post-monsoon seasons respectively (Fig. 4d).

Table 1. Location of samples

S. No.	Well No.	Locations	Latitude	Longitude	S. No.	Well No.	Locations	Latitude	Longitude
1	33002	Chinnanolambai	12°25'35"	79°20'10"	23	HP31566	Nadukkuppam	12°11'40"	79°52'45"
2	33005	Melmalayanur	12°20'10"	79°19'33"	24	HP31569	Thiruchitrambalam	11°59'20"	79°46'40"
3	33007	Melolakkur	12°20'06"	79°29'11"	25	HP31570	Kottakkarai	12°40'40"	79°48'20"
4	33008	Vadasiruvalur	12°19'29"	79°35'11"	26	INV31458	Kayathur	12°01'00"	79°44'31"
5	33011	Nagar	12°14'38"	79°50'31"	27	LabVpm04	Endiyur	12°12'12"	79°42'00"
6	33012	Kilsevur	12°14'17"	79°45'41"	28	LabVPm05	Kodima	12°10'10"	79°35'35"
7	33014	Salai	12°15'00"	79°35'00"	29	LabVpm06	Alathur	12°13'20"	79°52'40"
8	33015	Nattarmangalam	12°15'22"	79°30'15"	30	LabVpm07	Kurumbaram	12°12'40"	79°53'35"
9	33018	Melpappampadi	12°16'57"	79°15'13"	31	LabVpm08	Karasanur	12°04'25"	79°40'25"
10	33024	Omandur	12°09'29"	79°41'29"	32	Labvpm10	Athanapattu	12°06'21"	79°44'37"
11	33025	Peravur	12°09'26"	79°44'54"	33	MWS31519A	Vairapuram	12°13'50"	79°39'49"
12	33029	Kiliyanur	12°06'28"	79°44'40"	34	MWS31602	Hanumandapuram	12°03'04"	79°22'47"
13	33031	Padhirapuliyur	12°05'43"	79°35'29"	35	MWS31606	Periyamur	12°12'06"	79°20'36"
14	33033	Kalyanampundi	12°05'25"	79°25'25"	36	MWS31610	Kappalambadi	12°22'23"	79°16'27"
15	33034	Pudukaruvatchi	12°04'43"	79°21'06"	37	MWS31611	Sevalapurai	12°17'18"	79°21'28"
16	33040	Karanai	11°59'29"	79°20'31"	38	MWS31613	Kollar	12°14'47"	79°35'43"
17	33010A	Padhiri	12°19'02"	79°35'08"	39	MWS31614	Veliyanur	12°07'21"	79°39'02"
18	33021A	Karai	12°08'20"	79°02'50"	40	MWS31617	Thevadiyarkuppam	12°01'58"	79°04'01"
19	33023A	Alagramam	12°09'56"	79°34'26"	41	MWS31624	Kambur	12°18'33"	79°46'18"
20	33044A	Vanur	12°01'55"	79°44'28"	42	MWS31627	Mel Karanai	12°23'27"	79°23'04"
21	HP31517	Mambalapattu	11°57'35"	79°22'40"	43	OW11106	Kappiyampuliyur	11°58'38"	79°32'04"
22	HP31524	Sangeethamangalam	12°06'35"	79°24'15"	44	OW11107	Pagandi	11°58'38"	79°35'13"

Permeability Index (PI): Continue use of irrigation water on land affects the soil permeability as it is influenced by sodium, calcium, magnesium and bicarbonate ions (Karunanidhi et al 2013). The majority of samples (93 and 95 percent in pre-monsoon and post-monsoon season) were under the suitable category for PI. The values ranged from 12.87 to 87.95 and 13.7 to 86 meq l^{-1} for pre and post-monsoon respectively. PI values <80 meq l^{-1} is considered suitable for irrigation. The majority of samples are suitable for irrigation with respect to PI values (Fig. 4e).

Electrical conductivity and SAR: Electrical conductivity (EC) shows that majority of the study area falls under moderate to severe. Among the samples, 8 and 12 samples in pre and post-monsoon season have high salinity and mostly in the south western part of the study area (Fig. 4f). If

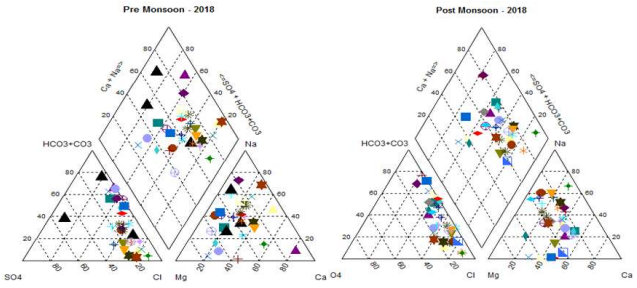


Fig. 2. Piper diagram for pre and post-monsoon seasons

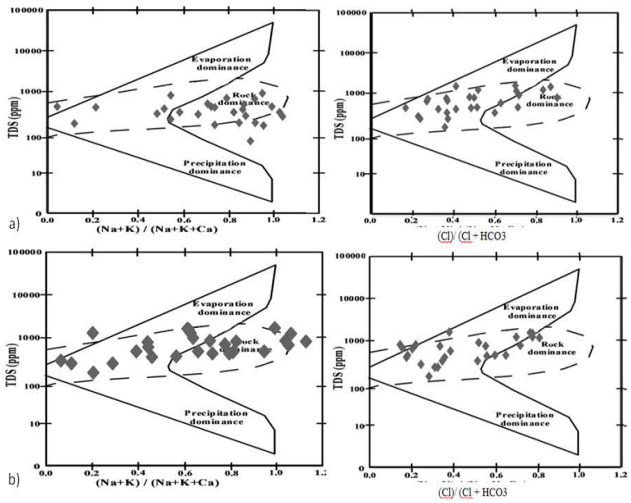


Fig. 3. Gibbs plot for Pre (a) and Post-monsoon season (b)

Table 2. Statistical summary and quality indices of groundwater quality for irrigation

Water quality parameters	Pre-monsoon		Post-monsoon		Suitability classes (NP - Not Permissible P - Permissible)		Pre-monsoon		Post-monsoon	
	Min	Max	Min	Max			Samples	%	Samples	%
SSP (meq l^{-1})	2.25	80.89	2.36	84.67	P	< 50	19	43.2	24	54.5
					NP	> 50	25	56.8	20	45.5
KR (epm)	0.02	4.18	0.01	5.27	P	< 1	19	43.2	25	56.8
					NP	> 1	25	56.8	19	43.2
Total Hardness	100.00	1640.00	150.00	920.00	P	< 150	3	6.8	1	2.3
					NP	> 150	41	93.2	43	97.7
MAR (meq l^{-1})	6.32	79.92	12.64	83.97	P	< 50	25	56.8	33	75.0
					NP	> 50	19	43.2	11	25.0
SAR (epm)	0.05	9.55	0.03	10.96	P	< 26	44	100.0	44	100.0
					NP	> 26	0	0.0	0	0.0
Na% (meq l^{-1})	1.47	72.42	0.84	74.66	P	< 60	36	81.2	40	90.9
					NP	> 60	8	18.2	4	9.1
PI (meq l^{-1})	12.87	87.95	13.73	85.92	P	< 80	41	93.2	42	95.5
					NP	> 80	3	6.8	2	4.5
EC (µS/cm^{-1})	220.00	3850.00	310.00	3730.00	P	< 2250	36	81.8	32	72.7
					NP	> 2250	8	18.2	12	27.3
F (meq l^{-1})	0.05	1.52	0.10	1.65	P	< 1.5	43	97.7	43	97.7
					NP	> 1.5	1	2.3	1	2.3
TDS (meq l^{-1})	115.00	2165.00	150.00	2044.00	P	< 2000	25	56.8	20	45.5
					NP	> 2000	19	43.2	24	54.5

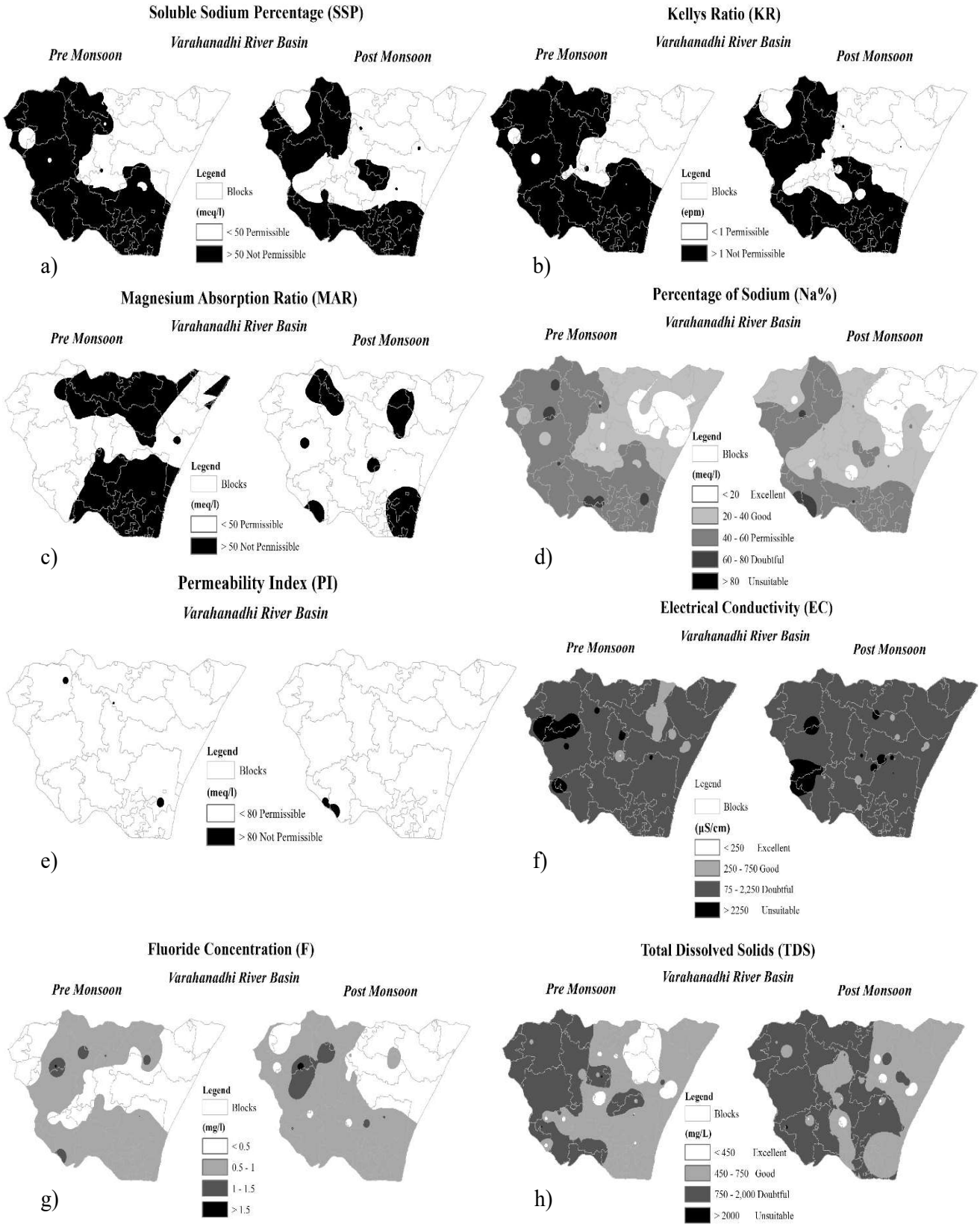
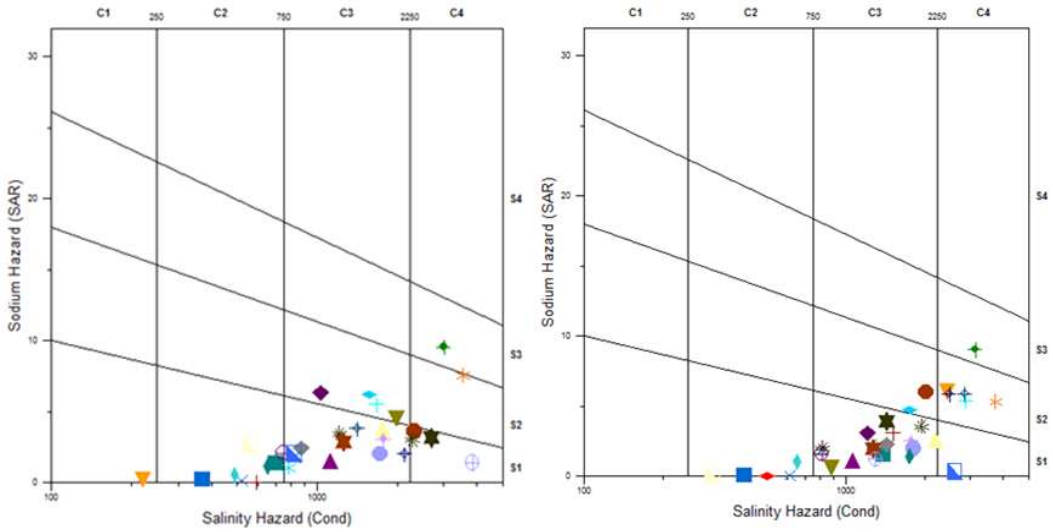


Fig. 4 (a to h). Spatial distribution of groundwater quality parameters for suitability of irrigation

the EC values are higher, it reduces the intake of water by plants even though the soil may wet (Kumar et al 2014). The EC values were 1365 and 1533 µS cm^{-1} during pre and post-monsoon seasons. Wilcox plot portrays that majority of the samples are fallen in high salinity and low sodium hazard class (C3-S1) for both monsoon seasons. Four samples in pre and 2 samples in the post-monsoon season are fall in the C3-S2 category indicates high salinity and medium sodium hazard (Fig. 5). Some samples fall in C4-S1 that indicate very high saline and low sodium in pre-monsoon season but not noted in the post-monsoon season. In the post-monsoon season, 5 samples are fall in the C4-S2 category indicating very high saline and medium sodium hazard. One sample in both monsoon seasons is under very high saline and high sodium hazard (C4-S3). All the samples in pre and post-monsoon seasons of SAR values are suitable for irrigation activities. All the samples in pre and post-monsoon seasons of SAR values are under the permissible limit. Irrigating land with high SAR values breakdown the soil's physical structure (Salifu et al 2017).

Fluoride and TDS: Fluoride value in both monsoon seasons was permissible and suitable for irrigation. Only 1 sample in both monsoon seasons is not under the permissible limit. The mean values of fluoride were 0.55 and 0.64 mg/l for pre and post-monsoon seasons respectively (Fig. 4g). TDS values are varied from 115 to 2165 and 150 to 2044 meq l^{-1} for pre and post-monsoon seasons respectively. The TDS value can be classified as slight to moderate and severe (Ayers and Westcott 1985). The mean values of TDS were 766 meq l^{-1} for pre-monsoon and 866 meq l^{-1} for post-monsoon season indicates TDS values are under the doubtful category and are mainly distributed in the eastern part of the basin (Fig. 4h).



a) Pre monsoon **b) Post monsoon**

Fig. 5. Wilcox diagram for pre (a) and post monsoon season (b)

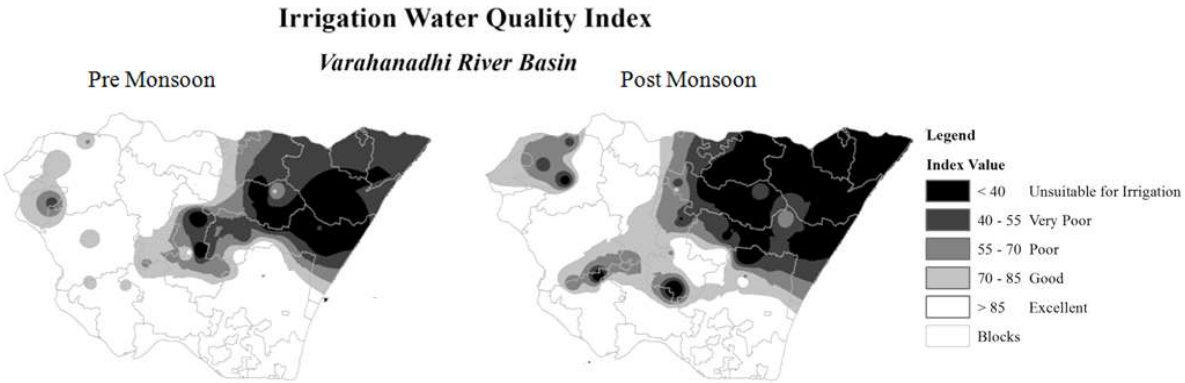


Fig. 6. Spatial distribution of irrigation water quality - Varahanadhi River Basin

Table 3. Irrigation water quality index classification - 2018

Irrigation water quality	Classes	Limitations	Pre-monsoon	Per cent	Post-monsoon	Per cent
Excellent	> 85	No	21	47.7	17	38.64
Good	70–85	Low	6	13.6	3	6.82
Poor	55–70	Moderate	5	11.4	5	11.36
Very poor	40 - 55	High	3	6.8	6	13.64
Unsuitable for irrigation	< 40	Severe	9	20.5	13	29.55

Irrigation water quality

The suitability of groundwater for irrigation purposes has been evaluated using IWQI. The majority of the samples fall above the category (>85), indicated highly suitable for agriculture. During pre-monsoon, 48 percent and in post-monsoon season 38.6 percent were excellent, suitable for agriculture. IWQI indicates that 20.5 percent in pre-monsoon and 29.5 percent during the post-monsoon season are not suitable for agriculture (Table 3). The blocks such as a part of Mailam, Marakanam, Olakkur, Chithamur, Achaapakkam, Madhuranthagam and Lathur are found in the north eastern part of the study area are not suitable for agriculture in both monsoon seasons revealed by the spatial map (Fig. 6). Keelpannathur block in pre-monsoon and Gingee, Melmalaiyanur, Vallam in post-monsoon season are under very poor and unsuitable category for irrigation activities. The northern and southern parts of the basin are suitable for agricultural activities.

CONCLUSION

The study on groundwater chemistry provides reliable information about the suitability of groundwater. The hydro geochemistry of the basin is highly influenced by rock water interactions. Except for SAR values, all other groundwater parameters fall in both permissible and not permissible categories. About, 93 and 98 percent of TDS values and the majority of SSP and KR values present in the groundwater samples during pre and post-monsoon seasons are not under the standard limit. IWQI indicates that 48 and 39 percent, as well as 20 and 30 percent of pre and post-monsoon season samples, comes under excellent and unsuitable for irrigation category respectively. Even though western and southern parts of the study area are suitable for irrigation but indices value clearly displays that it is critical. So, soil tests should be conducted effectively to minimize soil degradation and steps to be taken to increase crop production organically. Based on the water quality index, suitable crops may be selected for better yield as well as minimize crop loss due to poor quality water.

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Potable Water Treatment: Best Time to Measure Turbidity

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Abstract: The purpose of this study was to investigate the impact of time on the turbidity readings that and consequently guarantee the quality of the results in precision. Therefore, the methodology consists of creating three sets of river water turbidity levels (high, medium, and low). Jar-test was run for four times with the same concentrations of the added alum for each level. The optimum pH for the raw water followed by obtaining the optimum dose for the alum that were used to achieve the best turbidity removal in order to run the Jar-test to find the impact of time on turbidity readings. The high-level turbidity (200-250 NTU), was to measure the turbidity within the first 5 minutes of the sampling with an optimum dose = 38 mg/l and pH of 6.25. In terms of medium and low turbidity levels (100-130 NTU and 10-50 NTU), the best time to measure the turbidity is within the first 10 minutes of the sampling as there was no significant difference between the before and after the ten minutes with an optimum alum dose of 30 mg/l for medium level and alum dose of 15mg/l for the low level and both sets have an optimum pH equal to 7.5.

Keywords: Water quality, Turbidity, pH, Potable water, Alum dose

Due to the rapid growth in the population, industrial development and increasing economy, there is an increasing demand to the clean waters especially fresh waters. The principal source of drinking water supply is surface water. These sources represented by reservoirs, lakes and rivers are mainly contaminated by the wastewater and surface runoff. When the receiving waters expose to the effluent waters, there will be a change in the water quality. Urbanization and industrialization has an impact on the quality of the river water and consequently more loads will be added to the water treatment plant to meet the drinking water quality standards. The impact of these pollutants depends on the type and concentration of the pollutants and the length of exposure to the community. Surface waters contain suspended particulates that impart apparent color, increase turbidity. These particles are in water bodies usually originate from rainfall erosion on watersheds and the bed erosion of the stream by flowing water. The reduction in water clarity due to the presence of suspended matter that scattered or absorbed the light can be defined as Turbidity, and when the presence of suspended particles becomes visible in water, then the water is considered turbid water. The International Standards Organization (ISO) defined the turbidity as the decreasing of transparency of liquid due the presence of un dissolved maters . Therefore, turbidity can be considered as a representative of the most physical characteristics of water. Turbidity is an important indicator for the water quality as it reduces the efficiency of disinfection and subsequently it will provide the support to grow the harmful microorganisms in potable water leading to increasing the health risks. There is a strong relation between the water born disease and the distribution system problem. The increased concentrations of microorganisms were related to the increasing values of turbidity, pH, and temperature. Therefore, in order to make the water safe, the world health organization (WHO) have set the turbidity in drinking water should be kept below 5 NTU with higher chlorine doses or contact times. While the US Environmental Protection Agency (USEPA) sets the maximum level of turbidity in drinking water at 1 NTU and at no time higher than 5 NTU. Thus, turbidity is a significant parameter to describe water quality, and turbidity measurement plays an important role in water quality monitoring. The quality of river water can be varied seasonally and that have an impact of the value of turbidity. Many researchers have used water quality index (WQI) as an indicator for (surface and ground water) to evaluate the quality of water (excellent, good or poor) for drinking or irrigation purposes. The goal of water treatment is to make raw water safe and palatable to drink and therefore the objective of this study is to investigate the best time to record the readings for the turbidity from the turbid river waters.

MATERIAL AND METHODS

Preparation of turbid water: In order to prepare the suspension (clay and water) of required turbidity ranges, about 50g of clay was added to one liter of river water and mixed at 200 rpm for about 90 minutes and left for about one day in order to complete the hydration before preparing the desired turbidity ranges. The water that used in this study is from Al-Diwaniyah river, Iraq. The three ranges of water turbidity low, medium, and high were prepared. In order to have a low range level of turbidity, a sufficient amount of suspension was added to the river water in order to get the turbid water with the medium range, also an amount of suspension was added to the river water in order to have a synthetic turbid water with a turbidity range from (100-130) NTU. Finally, for the high level, a range of between 200-250

NTU was obtained via adding a certain quantity of suspension to the river water.

Preparation of alum: The alum solution was prepared by adding (5g) of the granular form of alum to about 500 ml of tap water. The solution then was mixed with 200rpm for 2 minutes. Then, the solution was left for about 24 hours to be ready for use.

Experimental procedure: The jar test procedure was adopted to estimate the best time to read the turbidity and how significant the time in changing the values of turbidity. The Jar test technique consisted of agitating the samples (before adding the alum) for 30 seconds, then adding the aqueous alum dose followed by rapid stirring at 125 rpm for 1 minute, followed by a slow mixing at 40 rpm for 45 minutes; and finally left for settling for 30 minutes. The settled sample was pipetted out a little (1cm) below the surface of water of each of these jars. The procedures for analysed parameters pH and turbidity, were followed the Standard Methods for the Examinations of Water and Wastewater (1998). Turbidity meter (Lovibond TB 300 IR) was used to measure the turbidity. pH meter was used to determine the value of pH of the samples.

Statistical analysis*:* Within the groups of experimental data, the significance of means was evaluated by using T-Test statistical analysis at 5% significance.

RESULTS AND DISUCSSION

Determination of Optimum pH

Low turbidity level (15-50) NTU: The Jar Test was run for four times and the average values and each sample was measured twice, and therefore each value in the (Table 1) represent the average of eight values. The optimum value for pH for the low-level range of raw water turbidity (15-50NTU) was 7.5

Medium turbidity level (100-130) NTU: The study revealed that at pH around 7.5 the removal can be achieved for the turbidity ranging from 100-130 NTU, and therefore pH=7.5 will be adopted to find the optimum dose to achieve the better removal (Table 1).

High turbidity level (200-250) NTU: The rapid decreasing of the turbidity with the pH around 6.25 (Table 1). There is a similarity in the trends of the low and medium levels which are differ than that one of the high turbidity level and that maybe due to the initial turbidity of the raw water that used for the optimizing the pH.

Determination the Optimum Alum Dose

Low turbidity level (15-50) NTU: The optimum value for alum dose for the low-level range of raw water turbidity (15-50 NTU) was around (15mg/l (Table 2).

Medium turbidity level (100-130) NTU: The removal can be achieved for the turbidity ranging from 100-130 NTU with an alum dose of 30mg/l (Table 2), and therefore 30mg/l will be adopted to find the best time to read the turbidity after the coagulation flocculation process with the Jar test.

High turbidity level (200-250) NTU: The best dose that can perform a significant turbidity removal for the range of 200-250 NTU was about 38mg/l as shown in Table 2. Thus, a 38mg/l as an alum dose will be used to find the best time to measure the turbidity after the coagulation flocculation process with the Jar test.

Determination of optimum time for turbid meter: After finding the optimum pH values and alum doses values for low, medium, and high turbidity levels. The Jar test was run for four times for these three levels, the times of readings the samples after ending the Jar test were selected (0, 5, 10, 20,30, and 40 minutes) to see the influence of time on the turbidity readings under the same environmental and operational conditions. In order to find whether there is a difference between the times of readings, a statistical analysis (T-Test) was used to perform that difference for a certain level of turbidity.

Low turbidity level (15-50) NTU: The difference between the times of each reading for the low turbidity (15-50) NTU was significant (Table 3). There is no significant difference between the readings at the time zero and time 5 minutes (0.176), while a significant difference has occurred between time at t=0 and t= 10 minutes (0.001). Therefore, it can be concluded the best time to measurement the turbidity at time less than 10 minutes from the end of jar test.

Medium turbidity level (100-130) NTU: The t-test values for the

Table 1. pH-turbidity relationship at different level of turbidity (NTU)

pH	Low turbidity	Medium turbidity	High turbidity
8.5	5.73	6.86	3.83
8	3.72	3.79	3.50
7.5	3.35	2.50	3.22
7	3.76	3.22	2.93
6	6.08	3.26	1.41
5	10.24	9.17	5.85

Table 2. pH-turbidity relationship at medium level of turbidity

Alum dose (mg l^{-1})	Low turbidity	Medium turbidity	High turbidity
0	9.83	38.03	23.24
10	2.41	8.03	9.47
15	1.92	4.16	2.77
20	2.32	4.18	2.66
30	2.35	2.73	2.75
40	2.05	2.94	3.55

Table 3. T- Test Values for the low turbidity level at 5% significance

Time (Min.)	Time (Min.)				
	0	5	10	20	30
0					
5	0.176				
10	0.001	0.075			
20	0.000	0.038	0.572		
30	0.001	0.044	0.609	0.988	
40	0.000	0.003	0.020	0.118	0.154

Table 4. T- Test values for the medium turbidity level at 5% significance

Time (Min.)	Time (Min.)				
	0	5	10	20	30
0					
5	0.137				
10	0.048	0.399			
20	0.467	0.662	0.283		
30	0.436	0.418	0.140	0.874	
40	0.508	0.040	0.016	0.220	0.154

Table 5. T- Test values for the high turbidity level at 5% significance

Time (Min.)	Time (Min.)				
	0	5	10	20	30
0					
5	0.049				
10	0.003	0.429			
20	0.000	0.191	0.507		
30	0.001	0.253	0.655	0.828	
40	0.001	0.335	0.862	0.569	0.747

difference between the times of each reading for the medium turbidity range (100-130) NTU significant (Table 4). Although no significant difference was obtained between the readings at 5 minutes and directly after the sampling. However, it was observed that there is a significant difference has been occurred between average turbidity at time = 0 and time = 10minutes (0.048). This may be due the fact that the range of turbidity after the jar test for the medium level was relatively low and that conclude to take the readings for the turbidity within less than 10 minutes from the sampling. High turbidity level (200-250) NTU: The statistical t-test values for the difference between the times of each readings for the high turbidity range (200-250) NTU 5% significant (Table 5). The turbidity at time = 0 was significantly different than the mean readings for the turbidity at time = 5 minutes (0.049) and this is because of the high range of the raw turbidity. This result leads to conclude that the reading for the turbidity should be within the first 5 minutes of the sampling.

CONCLUSION

The optimum pH for achieving a reasonable turbidity removal was about 7.5 for the low range turbidity (15- 50) NTU and also for the medium range of turbidity (100-130) NTU, while it was about 6.25 for the high range of turbidity (200-250) NTU. The optimum amount of alum dose to perform a good removal was15 mg/l for the low level, 30 mg/l for the medium level, and 38 mg/l for the high level of turbidity. Finally, it can be concluded that the best time to measure the turbidity for the low and medium level is within the first 10 minutes of the sampling (after the Jar test). While for the high level of turbidity (200-250) NTU, it was found that within the first five minutes the readings for the turbidity should be taken.

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Genetic Variability and Diversity Analysis for Yield Attributing and Biochemical Parameters of Sorghum (*Sorghum bicolor* L.) Genotypes

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***Abstract*:** The experiment was carried out during summer season 2019 at Centurion University of Technology and Management, Odisha, to estimate the genetic variability and diversity in 20 sorghum genotypes. A wide range of variation for 14 yield attributing traits including 4 quality parameters (chlorophyll, antioxidants, flavonoids and HCN) were observed among the genotypes. High to moderate phenotypic and genotypic coefficient of variation were recorded for yield, panicle weight, panicle length, 1000 seed weight, total chlorophyll, and total flavonoids. High heritability accompanied by relatively high genetic advance as percent of mean was observed for yield, panicle length, panicle weight, leaf length, plant height, 1000 seed weight, days to 50% flowering, total chlorophyll, total flavonoids, and total antioxidants. D^2 analysis grouped the 20 genotypes into four distinct clusters. Cluster I and cluster IV, respectively, contained highest (6) and lowest (4) number of genotypes. The maximum and minimum inter-cluster distance was noticed between cluster II and IV (150.99) and between cluster III and IV (66.26), respectively. Panicle weight (72.11%) followed by 1000 seed weight (9.98%) and total chlorophyll (2.63%) showed maximum contribution towards total divergence among the genotypes. Genotypes of cluster IV were the best performing in correspond to yield and its components while, cluster II was finest in respect of maturity and biochemical characters. Hence genotypes of cluster IV and II may further be utilized in breeding programmes for evolving sorghum varieties with high yield and quality.

***Keywords*:** D^2 analysis, Genetic diversity, Genotypes, Variability

Sorghum (*Sorghum bicolor* L.) ranks fifth worldwide and grown as cereal crops after wheat, rice, maize, and barley. Globally, sorghum is cultivated on an area of 49.6 million hectares with a production and productivity of 48 million tonnes and 9677 kg per hectare respectively (FAOSTAT 2018). In India, sorghum is grown for food and feed purpose, occupying 4.96 million hectares area with production and productivity of 4.95 million tonnes and 998 kg ha^{-1} (Directorate of Economics and Statistics 2018). The crop is highly popular amongst farmers because of its greater adaptability to wide range of environmental fluctuation and utilization in numerous forms like green fodder, stover, silage and hay to suit the diverse needs of farming systems, besides its grain. It is rich in antioxidants and flavonoids which play a major role in the field of medicine. Similarly, on the economic basis, when antioxidants are present in more concentration, they have a direct impact on the yield (Hithamani et al 2014). On contrary, anti-nutritional factor called Hydrocyanic acid (HCN) in the seeds and other plant parts is the major constrain in cultivation of sorghum for consumption in the form of grain and fodder. Hence, the prime objective of any breeders and researchers all over the world is to develop varieties/hybrids with high yield and low HCN in sorghum. The knowledge of genetic parameters like genetic-advance and heritability among characters under selection is useful for the development of efficient breeding strategies and for the prediction of genetic progress in breeding programme (Akatwijuka et al 2016). Higher genetic distance between parents determines the achievement of higher heterosis in progeny. Keeping this in view, the present investigation on 20 sorghum genotypes was undertaken to access the genetic variability and diversity for yield and its component traits including biochemical parameters.

MATERIAL AND METHODS

The experiment was conducted during the summer season 2019 at M. S. Swaminathan School of Agriculture, CUTM, Paralakhemundi, Odisha. Geographically, the experimental site is located at 87.42°E longitude and 23.39°N latitude at an altitude of 182.9 m. Twenty genotypes of sorghum (Table 1) collected from different parts of India, were grown in Randomized Complete Block Design with three replications to study the genetic diversity among the genotypes. Each genotype was grown in rows with spacing of 20cm between plant and 50cm between rows. Five plants data of each genotype in every replication for fourteen yield

components, maturity and biochemical characters were recorded for statistical analysis. However, observation on yield and maturity were noted on plot basis. The analysis is based on the assessment of ten quantitative characters like plant height (PH), leaf length (LL), leaf breadth (LB), panicle length (PL), panicle weight (PW), dry matter production (DMP), days to 50% flowering (D50F), days to maturity (DM), 1000 seed weight (TSW) and seed yield and four qualitative parameters *viz*. total chlorophyll (TCHL), total antioxidants (TA), total flavonoids (TF) and Hydrocyanic acid (HCN). Estimation of chlorophyll, antioxidants and flavonoids content were done from leaf while, HCN concentration estimated from seed (powder). Total chlorophyll (mg ml^{-1}) was assessed using acetone as the main ingredient according to Srichaikul et al (2011). Total antioxidants (%) measured by 1,1-diphenyl1-2-picrylhydrazl (DPPH) method as per the protocol of Brand-Williams et al (1995). Subsequently, total flavonoid (mg ml^{-1}) was estimated as per Aluminium Chloride Colorimetric method suggested by Chang et al (2002) and HCN content (µg ml^{-1}) assessed independently from the seeds by extraction method (Cai et al 2003).

The mean value of all the characters were used to determine the genetic parameters like genotypic coefficient of variation and phenotypic coefficient of variation (Burton 1952) and heritability and genetic advance as percentage of mean according to Johnson et al (1955). Estimates of divergence among the 20 genotypes were based on multivariate analysis using Mahalanobi's (1928) D^2 statistic and generalized distance (D^2) extended by Rao (1952). All the statistical analysis done by using software INDOSTAT version 2019.

RESULTS AND DISCUSSION

Analysis of variance showed significant differences among genotypes for all traits studied except for leaf breadth and HCN (Table 2). Such enormous variation recorded among the genotypes for the different yield, maturity and biochemical traits indicates the scope for selection of these characters for further breeding programmes under the present agro-climatic condition of Odisha.

Table 2. Analysis of variance of morphological and biochemical traits of sorghum

Characters	Mean sum of squares		
Source of variation	Replication	Genotype	Error
Degree of freedom	2	19	38
Plant height (cm)	9.79	1249.74**	4.54
Leaf length (cm)	1.63	385.31**	2.19
Leaf breadth (cm)	0.29	0.92	0.39
Panicle length (cm)	3.33	80.61**	1.67
Panicle weight (g)	0.32	5107.17**	3.91
1000 Seed weight (g)	0.12	238.78**	1.70
Days to 50% flowering	1.31	200.22**	1.89
Days to maturity	4.85	66.18**	2.37
Dry matter production (%)	500.13	24.00**	20.26
Total chlorophyll (mg ml^{-1})	7.99	14.47**	1.40
Total flavonoid (mg ml^{-1})	277.55	19.82**	12.7
Total antioxidant (%)	2.53	49.88**	4.24
HCN (µg ml^{-1})	0.000006	0.000002	0.000001
Yield (kg ha^{-1})	0.90	5454.29**	14.60

Mean performance of twenty genotypes (Table 3) revealed that Chobari and Maldandi recorded for highest yield, panicle length, panicle weight and 1000 seed weight while, genotype Enikepadu followed by Sambhada appeared with highest dry matter production. Highest plant height was recorded in Martur and Parchur whereas, maximum leaf length and leaf breadth were observed for Sambadha followed by Enikepadu. The genotype Lakhpat and Rajchari exhibited early flowering while Tella sorghum and Enikepadu appeared as earliest maturing genotypes. Subsequently, highest chlorophyll content was recorded for Varuna jowar followed by Enikepadu and highest total flavonoids in Maldandi followed by Tella sorghum whereas, highest antioxidant was chronicled for yellow sorghum then Varuna jowar and lowest HCN concentration was estimated for Tella

Table 1. List of genotypes included under the study with their place of origin

Origin	Genotype
AICRP, Guntur, A.P	Seethamazonalu, Pajarla, Danduvaripalli, Thoriari ,Tella-sorghum, Yellowsorghum, Varuna-jowar, Singura, Lakhpat, Safed-moti,
TNAU, Coimbatore, Tamilnadu	HC-136, Maldandi
IIMR, Indore, Madhya Pradesh	Chobari, Meethi sud
HRD, Cuttack, Orissa	Rajchari, Sambhada
Sorghum Research station, Surat, Gujarat	Parchur, Martur
IIMR, Rajendranagar, Telangana	Bairamalguda ,Enikepadu

sorghum followed by Meethi sudan, Rajchari and Thoriari. Based on the mean values of fourteen yield contributing and biochemical characters, Chobari, Maldandi and Tella sorghum were best performing genotypes. Chobari and Maldandi recorded the highest yield and further particularly these genotypes are sizable for selection and can be utilized in sorghum breeding programs. High amount of genetic variability for many of these traits has also been reported earlier by Shinde (2012) and Tesfaye (2017).

The extent of phenotypic coefficient of variation (PCV) was higher than the subsequent genotypic coefficient of variation (GCV) for all the characters under study signifying that these traits were under influence of environment. GCV and PCV were moderate to high for yield, leaf length, panicle weight, 1000 seed weight, total chlorophyll, flavonoids and HCN (Table 4). The high to moderate values of genotypic and phenotypic coefficient of variation, suggested that there was a possibility of improvement yield in sorghum through direct selection of these traits. High to moderate GCV and PCV was recorded for yield, plant height, panicle length panicle weight, 1000 seed weight, flavonoids and total chlorophyll. Similar trend was observed by Geleta et al (2006) and Tesfaye (2017).

High heritability (%) coupled with high genetic advance as percentage of mean were observed for plant height, leaf length, panicle length, panicle weight, 1000 seed weight, days to 50% flowering, total chlorophyll, total flavonoids and yield indicated the lesser influence of environment in the expression of these characters and may be credited to be controlled by few major genes or prevalence of additive gene action in their inheritance. Hence, selection of these traits would be useful for improvement of sorghum. Similar result previously observed by Deepalakshmi et al (2007), Seetharam and Ganesamurthy (2013) and Ranjith et al (2017). High heritability accompanied by moderate GA were only in total antioxidant whereas estimate of high heritability with low GA were resulted in traits like day to maturity and HCN content indicated the presence of non-additive gene

Table 3. Mean performance of twenty genotypes of sorghum for different yield attributing and biochemical characters

Genotypes	PH (cm)	LL (cm)	LB (cm)	PL (cm)	PW (g)	TSW (g)	D50F	DM	DMP (%)	TCHL (mg ml^{-1})	TF (mg ml^{-1})	TA (%)	HCN (µg ml^{-1})	Yield (kg ha^{-1})
Seethamazonalu	114.72	53.84	6.18	24.79	221.50	53.60	78.00	113	27.60	8.24	29.65	36.04	0.0020	1045.77
Pajarla	127.98	49.80	6.22	27.25	237.92	52.74	79.00	109	27.68	8.84	26.56	37.50	0.0017	1040.67
Danduvaripalli	123.83	45.28	5.76	24.04	274.44	54.36	80.66	117	26.80	9.09	30.57	33.90	0.0020	1071.78
HC-136	140.56	52.61	6.40	25.97	244.55	53.38	78.00	105	26.84	10.03	28.06	36.58	0.0020	1030.55
Lakhpat	146.18	51.14	6.30	23.21	255.20	52.95	75.33	115	26.57	9.87	26.62	36.39	0.0020	1034.09
Safed moti	144.88	45.42	5.86	26.24	256.18	54.00	76.33	108	26.06	10.62	30.85	37.34	0.0023	1127.55
Chobari	167.30	34.44	5.27	29.33	518.35	60.75	79.33	111	27.45	8.46	28.11	34.60	0.0030	1222.29
Maldandi	168.66	38.71	6.27	28.92	493.94	54.65	77.33	118	26.74	10.94	33.21	35.10	0.0020	1159.57
Thoriari	151.52	45.40	6.45	20.32	321.38	53.10	79.00	107	27.50	7.74	28.16	34.65	0.0013	1049.97
Tella sorghum	160.33	47.47	5.95	18.90	318.14	52.50	78.66	103	27.22	9.54	36.08	34.37	0.0013	1012.06
Meethisudan	160.21	42.17	5.93	18.46	304.74	51.03	78.00	104	27.39	12.51	32.61	36.77	0.0013	1072.99
Rajchari	163.80	49.40	6.39	19.99	460.93	51.00	75.66	105	27.1	8.91	33.00	32.00	0.0013	1082.31
Yellow sorghum	143.22	42.62	6.07	28.48	373.26	48.94	76.33	108	26.74	10.68	28.70	45.33	0.0020	1071.86
Varuna jowar	158.62	51.38	5.98	23.64	448.40	51.80	79.66	107	28.49	14.28	28.37	48.44	0.0020	1017.36
Singura	174.62	44.66	6.14	25.52	483.02	49.02	78.00	114	27.20	9.61	28.51	33.50	0.0023	1154.89
Parchur	185.76	64.66	7.14	15.58	175.24	31.03	95.66	104	31.31	13.34	27.29	32.66	0.0037	786.39
Martur	186.69	65.96	7.18	16.72	145.84	35.73	93.33	105	31.05	13.57	27.00	37.90	0.0037	847.02
Bairamalguda	170.53	63.86	6.76	15.16	177.04	32.60	96.00	106	31.76	13.59	28.68	33.34	0.0027	692.29
Enikepadu	175.94	74.86	7.24	13.44	164.80	33.36	98.66	104	35.25	14.12	27.38	38.38	0.0033	996.22
Sambhada	180.66	75.01	7.43	14.32	150.24	35.70	96.33	113	35.28	13.55	28.09	37.34	0.0037	589.68
MEAN	157.30	51.93	6.34	22.01	301.25	48.11	82.46	108.80	28.55	10.88	29.38	36.38	0.0023	1005.26
CD (p=0.05)	3.52	2.44	2.64^{NS}	2.14	3.27	2.15	2.27	2.54	4.21	1.96	1.03	3.40	0.0019^{NS}	6.33

PH- plant height, LL- leaf length, LB- leaf breadth, PL- panicle length, PW- panicle weight, TSW- 1000 seed weight, DM- days to maturity, D50F- Days to 50% flowering, DMP- Dry matter production, TCHL- Total Chlorophyll Content, TF- Total Flavonoids, TA- Total Antioxidants, HCN- Hydrocyanic acid

action and substantial influence of environmental factors on these characters.

The genotypes of sorghum were grouped into four clusters using Tocher's method (Rao1952) employed on the Mahalanobi's elucidation distance (D^2) values (Fig. 1) indicating the existence of wide genetic diversity in the present material. The distribution pattern indicated that maximum number of genotypes included in cluster I (6) followed by cluster II and III with 5 genotypes each, whereas the cluster IV contained 4 genotypes only. Genotypes belong to the same cluster have narrow genetic divergent among themselves and selection of parents within the same cluster will not be considered efficient for the development of superior varieties through hybridization programme (Mohanraj et al 2006). Inter cluster distances were greater than the intra cluster distance suggesting the incidence of wider diversity among genotypes of distance groups (Table 6). The maximum distance of genotypes within the same cluster were in cluster III (20.24) followed by cluster IV (19.51). Highest inter cluster distance was observed between cluster II and IV (150.99) followed by cluster I and IV (98.08) while it was minimum between cluster I and III (38.05). Maximum inter cluster distance observed between cluster II and cluster IV signifying extensive diversity of the genotypes between the groups and these genotypes could be used as parents in breeding program for getting high heterotic F_1s and wider spectrum of variability in transgressive segregants. This finding is in agreement with the similar findings of Chittapur et al (2013) and Pavithra et al (2015) in sorghum.

Table 5. Grouping of twenty sorghum genotypes based on D^2 analysis

Cluster No.	Number of genotypes	Name of genotypes
I	6	Pajarla, Lakhpat, Seethamazonalu, HC-136, Safed moti, Danduvaripalli
II	5	Parchur, Bairamalguda, Tella sorghum, Rajchari, Martur
III	5	Sambhada, Enikepadu, Thoriari, Meethi sudan, Yellow sorghum
IV	4	Singura, Maldandi, Chobari, Varuna jowar

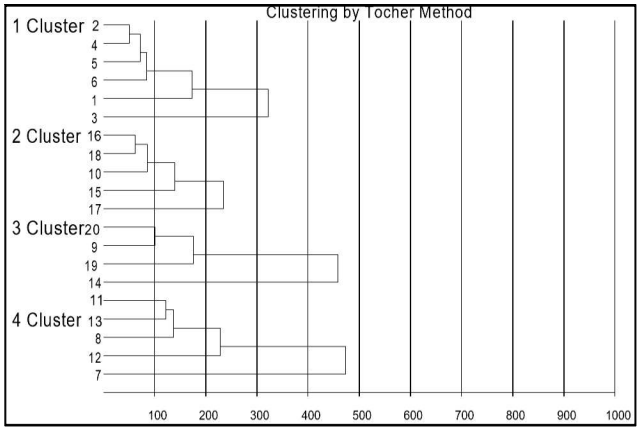


Fig. 1. Dendrogram showing the distance among the 20 Sorghum genotypes, (1 to 20 respectively: Seethamazonalu, Pajarla, Danduvaripalli, HC-136, Lakhpat, Safed moti, Chobari, Maldandi, Thoriari, Tella sorghum, Yellow sorghum, Varuna jowar, Singura, Meethi sudan, Rajchari, Parchur, Martur, Bairamulguda, Enikepadu and Sambhada)

Table 4. Estimates of variability parameters for fourteen characters in sorghum

Characters	Mean	Range	GCV	PCV	h_b^2 (%)	GA (%) of mean
Plant height (cm)	157.30	114.72-186.69	11.67	13.02	98.92	26.53
Leaf length (cm)	51.93	34.44-75.01	19.09	21.94	98.31	44.44
Leaf breadth (cm)	6.34	5.27-7.43	1.99	11.92	30.51	7.49
Panicle length (cm)	22.01	13.44-29.33	18.14	24.02	94.01	46.53
Panicle weight (g)	301.25	145.84-518.35	40.05	40.70	99.97	83.83
1000 seed weight (g)	48.11	31.03-60.75	15.96	18.67	97.89	37.65
Days to 50% flowering	82.46	75.33-98.66	8.33	9.99	97.21	20.02
Days to maturity	108.80	103-118	3.05	4.46	89.95	8.28
Dry matter production (%)	28.55	26.06-35.28	0.48	16.24	5.80	1.94
Total chlorophyll (mg ml^{-1})	10.88	7.74-14.28	19.17	22.05	87.45	34.34
Total flavonoid (mg ml^{-1})	29.38	26.56-36.08	13.21	15.24	85.57	24.28
Total antioxidant (%)	36.38	32-48.44	10.72	12.12	78.19	19.52
HCN (µg ml^{-1})	0.0023	0.0013-0.0037	15.35	23.35	80.28	9.09
Yield (kg ha^{-1})	1005.26	589.68-1222.29	16.78	16.98	97.63	34.15

GCV-Genotypic Coefficient of Variance, PCV-Phenotypic Coefficient of Variance, h_b^2- Broad sense heritability, GA-Genetic Advance

Out of the fourteen characters, the highest contribution towards genetics divergence was by panicle weight (72.11%) followed by 1000 seed-weight, total chlorophyll, plant height, leaf breadth, total flavonoids, total antioxidants, leaf length, days to 50% flowering and HCN meanwhile, panicle length, days to maturity and dry matter production did show any contribution towards the divergence (Fig. 2). This signified the existence of ample amount of diversity among the genotypes with respect to the above traits which can be provide the basis of selection of diverged parents for future hybridization programme. Kumar et al. (2018) observed that 1000-grain weight and plant height exhibited maximum contribution to diversity after number of grains per spike in barley which in in agreement of present result. The findings of Mahajan and Wadikar (2012), Shinde et al (2013) and Damor et al (2017) indicated the same trend in sorghum.

The average cluster mean value of fourteen characters revealed that none of the clusters contained genotype with all the desirable characters and so recombinant breeding between genotypes of different clusters would be preferable. Further, based on cluster mean (Table 7) cluster IV is superior in respect of panicle length (26.07 cm), panicle weight (480.93 g), total antioxidant (39.92%) and yield (969.75 kg ha^{-1}) in addition to that genotypes of this cluster were early flowering and maturing. Cluster II have highest mean value for plant height, leaf length, leaf width, dry matter production, chlorophyll and HCN content. Likewise, cluster III is important for 1000 seed weight and total flavonoids while none of the character exhibited highest mean value in cluster I. Hence, the characters contributing maximum to the divergence should give greater importance in deciding the cluster for further selection and choice of purpose based parents for hybridization programme. Highest contribution towards divergence was in regard with the highest panicle weight, total chlorophyll, total antioxidants, lowest HCN and highest yield. Similar findings were also reported by the Geleta et al (2006) and Tesfaye (2017), where the parents are selected from different clusters based on the characters panicle weight and total flavonoids.

Table 6. Average intra (bold) and inter-cluster distance for twenty genotypes of sorghum

Clusters	I	II	III	IV
I	15.05	60.35	38.05	98.08
II		14.30	90.01	150.99
III			20.24	66.26
IV				19.51

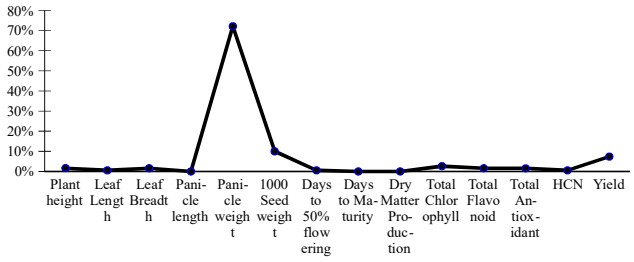


Fig. 2. Percent contribution of characters towards total divergence in sorghum genotypes

Table 7. Cluster mean performance of fourteen characters in twenty sorghum genotypes

Characters / clusters	I	II	III	IV
Plant height (cm)	133.92	179.92	156.34	163.52
Leaf length (cm)	49.68	68.87	40.29	47.02
Leaf breadth (cm)	6.12	7.15	6.08	6.07
Panicle length (cm)	22.44	15.05	24.13	26.07
Panicle weight (g)	248.30	162.63	329.38	480.93
1000Seed weight (g)	33.69	54.70	51.86	51.65
Days to 50% flowering	78.00	96.00	78.00	77.89
Days to Maturity	111.17	106.60	111.00	106.40
Dry Matter Production (%)	26.93	32.94	27.11	27.28
Total Chlorophyll (mg ml^{-1})	9.26	13.64	9.46	9.08
Total Flavonoid (mg ml^{-1})	28.26	27.78	31.30	30.79
Total Antioxidant (%)	34.76	35.54	35.16	39.92
HCN (µg ml^{-1})	0.0025	0.0012	0.0036	0.0019
Yield (kg ha^{-1})	734.22	876.26	902.27	969.75

CONCLUSION

In the present investigation, traits like plant height, leaf length, panicle length, panicle weight, 1000 seed weight, days to 50% flowering and total chlorophyll exhibited high to moderate GCV and PCV and high heritability coupled with high genetic advance as percent of mean reflects extreme positive effect on yield. This implies that most likely, the cause of heritability and genetic advance maybe due to additive gene effects and selection based on these traits would be fruitful. Cluster analysis revealed that genotypes belongs to wide divergence cluster may be selected as parent to utilize in future breeding programme likely to produce potential hybrids. Based on cluster mean, genotypes of cluster IV were the best performing in respect of yield and maturity indices whereas, cluster II was optimum correspond to vegetative and biochemical traits. Therefore, genotypes with above mentioned traits in cluster II and IV would offer a greater likelihood for the improvement of this crop and rational selection through hybridization. Furthermore, based on

individual mean performance genotype Chobari, Maldandi (high yield) and Tella sorghum (lowest HCN and highest flavonoids) have been identified as best performing genotypes under the present agroclimatic condition.

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Diversity of Cyanobacterial Population during Monsoon Season in Rice Fields of Hooghly, West Bengal, India

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Abstract: In the present study, 41 cyanobacterial species were collected and isolated from three different rice fields in Hooghly district of West Bengal at different stages (sowing, vegetative growth and mature stage) of rice cultivation during monsoon season. Of the collected species, 19 were non-heterocystous and 22 were heterocystous species. The cyanobactrial species diversity varies with variation in physico-chemical parameters of rice field soil as well as different stages of growth. Out of these isolated cyanobacterial species, *Calothrix marchica*, *Nostoc linckia* and *N. punctiforme* were of common occurrence in all stages in all sites. Among heterocystous genera, *Nostoc, Calothrix, Anabaena, Westiellopsis* and among non-heterocyatous genera, *Phormidium, Aphanothece* and *Oscillatoria* were most abundant. Correlation between occurrence of heterocystous cyanobacterial species and the soil parameters were explored by Canonical Correspondence Analysis (CCA). Soil parameters - pH, available P and nitrate played a significant role (as per CCA) in the occurrence of cyanobacterial species.

Keywords: Cyanobacteria, Diversity, Rice fields, Canonical correspondence analysis (CCA)

Rice fields, in tropical countries, provide a suitable environment for the growth and multiplication of cyanobacteria by providing suitable temperature, light, nutrients and stagnant water conditions (Ghadage and Karande 2019). Nitrogen fixing cyanobacteria are important microorganism in the rice fields because they contribute to soil fertility and improve productivity by fixing atmospheric nitrogen (Roger and Ladha 1992). Nitrogen is the second limiting factor (after water) for plant growth in many rice fields and deficiency of this element is compensated by chemical fertilizers. The excessive uses of chemical fertilizers have created several environmental problems like greenhouse effect, acidification of water and these problems can be solved by the use of bio-fertilizers (Choudhury and Kennedy 2004, Rai 2006). Study of cyanobacterial diversity gained importance especially after the recognition of their role in the maintaining sustainable natural environment. Apart from nitrogen fixation, cyanobacteria secrete some plant growth promoting substances such as vitamins, amino acids, hormones, sugars and other metabolites which have direct or indirect effect on plant growth and yields (Kumar and Rao 2012). These secreted extracellular substances increase the available phosphorous level in soil and decrease the effects of soil salinity (Saadatnia and Riahi 2009). Besides contributing nutrients, cyanobacteria produces agronomically significant changes in the physico-chemical properties of soil and soil-water interface of rice fields (Nayak et al 2004, Nayak and Prasanna 2007). District Hooghly is one of the most important agriculturally productive districts of the state of West Bengal. 70% of its population depends on agriculture. Study of cyanobacterial population in the rice-fields of this district thus bears great significance. The objectives of the present study in the district of Hooghly, was to investigate the cyanobacterial diversity in different rice fields during different stages of rice cultivation.

MATERIAL AND METHODS

Study area: The study area is located in outskirts of Tarakeswar town of Hooghly district, West Bengal, India and three rice fields were selected (Table 1). Cyanobacterial species and soil samples were collected from these rice fields.

Collection of cyanobacterial species and soil samples: Cyanobacterial species and soil samples were collected in different stages of rice cultivation - sowing stage, growth stage and mature stage of rice plant. Collected cyanobacterial species were cleaned and preserved in Department of Botany, Visva-Bharati.

Isolation of cyanobacterial species from soil samples: Soil samples from rice fields were put in a petridishes with little distilled water. After few day of incubation visible growth of cyanobacteria appeared in petridishes. Cyanobacterial

biomasses were drawn into pipette and transferred to solid BG-11 N- agar plate medium. Cyanobacterial culture were maintained at 7 pH, 25 ± 5ºC with 14/10 hours light-dark cycle photoperiod.

Morphological study: Morphological features of cyanobacterial species were observed by Leica DM 2500 microscope fitted with a digital camera. Parameters studied were - nature of filament, absence or presence of sheath, shape and size of vegetative cells, presence of heterocyst and akinete. Microphotographs of cyanobacteria and taxonomically significant features were taken for proper taxonomic identification and identified following Desikachary (1959), Anagnostidis and Komárek (1988), Komárek and Anagnostidis (2005) and Komárek (2013).

Diversity and dominance index: Shannon-Wiener index of diversity [H'($\log_e$)] and Simpson's dominance index (D_{SIMP}) were calculated using PAST statistical software version 2.07 to show cyanobacterial community structure.

Determination of physico-chemical parameters of soil: The physico-chemical parameters of rice field soil such as - pH, electrical conductivity, organic carbon, available nitrogen, available phosphorus and nitrate were measured. The pH of the soil samples were determined by Orion digital pH meter and electrical conductivity measured by Systronics Conductivity Bridge. Organic carbon content was estimated by Walkley and Black (1934) method, available phosphorus and available nitrogen of soil samples by using the Bray and Kurtz (1945) and Subbiah and Asija (1956) method respectively. Nitrate content of the soil samples were analyzed by using Orion multipara meter with dedicated electrodes.

Canonical correspondence analysis (CCA): Canonical Correspondence Analysis (CANOCO version 4.5; TerBraak 1986) was used to correlate physico-chemical parameters of rice field soil samples and cyanobacterial species in three different stages of rice cultivation, i.e. sowing stage, growth stage and mature stage. Biplot scores of the environmental parameters were noted. CCA ordination was tested for significance with Monte Carlo test (500 runs) using CANOCO software.

Venn diagrams: Venn diagrams were generated by using the tool http://www.interactivenn.net to represent the unique and common cyanobacterial species in different rice fields during different stages of rice cultivation.

RESULTS AND DISCUSSION

The cyanobacterial species collected and isolated from three different rice fields (Table 1) at different stages (sowing, growth and mature stages) of rice cultivation (Plate 1) showed wide range of species diversity. A total of 41 cyanobacterial species were recorded and identified (Table 2). They belong to 11 different families. Out of these 41 species, 15 belongs to family Nostocaceae, 6 belongs to Phormidiaceae followed by Oscillatoriaceae, Rivulariaceae, Synechococcaceae (4 each), Psedoanabaenaceae (3), Merismopediaceae, Microcystaceae, Hapalosiphonaceae, Fischerellaceae, Scytonemataceae (1 each). On the basis of distribution percentage of cyanobacterial species, occurrences of Nostocaceae family member were maximum (36.59%) followed by Phormidiaceae (14.64%), Oscillatoriaceae, Rivulariaceae, Synechococcaceae (9.75% each), Psedoanabaenaceae (7.32%), Merismopediaceae, Microcystaceae, Hapalosiphonaceae, Fischerellaceae and Scytonemataceae (2.44% each). Most of the cyanobacterial species collected and isolated from the study sites were heterocystous. Out of these cyanobacterial species, *Calothrix marchica*, *Nostoc linckia* and *N. punctiforme* were found in all stages in all sites. Among heterocystous cyanobacteria, genera of *Nostoc, Calothrix, Anabaena, Westiellopsis* and in non-heterocyatous cyanobacteria, gerena of *Phormidium, Aphanothece* and *Oscillatoria* are abundant (Plate 2). The present findings are in conformity with Nayak and Prasanna (2007) who reported that heterocystous forms were more abundant in rice field soils of India.

Of the three stages in three sites, mature stage of site III exhibited the maximum number of cyanobacterial species and sowing stage of site III showed the minimum number. In site I and II, growth stage showed the maximum number of cyanobacterial species. Sowing stage showed lowest number of cyanobacterial species than growth stage and mature stage in all the sites. So, it is clear from our observation that, cyanobacterial species diversity increases with increase in the growth and maturity of rice plant. Cyanobacteria play an important role in maintenance and build up soil fertility, consequently increase rice plant growth and yield as a natural bio-fertilizer (Song et al 2005). Number of heterocystous cyanobacteria was maximum in growth and mature stage than sowing stage in all three sites.

Collected and isolated 41 cyanobacterial species

Table 1. Location of collection sites in Tarakeswar, Hooghly

Collection sites	Location	Latitude and longitude
Site I	Bajitpur, Tarakeswar, Hooghly	N 22.880º E 88.027º
Site II	Mirzapur, Tarakeswar, Hooghly	N 22.884º E 88.039º
Site III	Sahapur, Tarakeswar, Hooghly	N 22.887º E 87.999º

Table 2. Diversity of cyanobacteria in the rice fields of Hooghly district of West Bengal

Name of the Cyanobacteria	Site I			Site II			Site III		
	SS.	GS.	MS.	SS.	GS.	MS.	SS.	GS.	MS.
Aphanocapsa biformis	+	-	-	-	-	-	+	-	-
A. pallida	+	-	-	-	+	+	-	-	+
A. microscopica	-	+	+	+	+	+	+	-	+
A. stagnina	-	+	-	+	-	-	-	+	-
A. naegelii	-	-	-	-	+	-	-	+	-
Gloeocapsa decorticans	+	-	-	-	-	-	-	+	-
Oscillatoria princeps	-	+	+	+	-	+	+	-	+
O. subbrevis	-	+	+	-	-	+	-	-	+
O. curviceps	-	+	-	-	-	-	-	+	+
Lyngbya martensiana	-	+	-	-	+	+	-	+	+
Leptolyngbya angusta	+	-	-	-	+	+	-	+	-
L. tenuis	-	+	+	-	+	-	+	-	+
Spirulina subsalsa	-	+	-	+	-	-	-	-	-
Phormidium corium	-	+	+	-	+	+	-	-	+
P. acula	+	-	+	-	+	+	-	-	-
P. ambiguum	+	-	-	-	+	+	-	+	+
P. rubidum	-	-	+	+	-	+	-	+	-
P. allorgei	-	-	+	-	+	-	+	-	+
Microcoleus paludosus	-	-	+	-	-	-	-	+	-
Calothrix marchica	+	+	+	+	+	+	+	+	+
C. marchica var. intermedia	-	+	+	+	+	-	-	+	+
C. elenkinii	-	-	-	-	+	+	-	+	+
C. brevissima	-	+	-	+	+	+	-	+	+
Wollea ambigua	-	+	-	-	+	+	-	-	+
W. vaginicola	-	+	+	-	+	+	-	+	+
Nostoc linckia	+	+	+	+	+	+	+	+	+
N. carneum	-	+	-	+	-	-	-	+	-
N. oryzae	-	+	+	+	+	+	+	-	+
N. punctiforme	+	+	+	+	+	+	+	+	+
N. paludosum	+	-	-	+	-	-	+	+	-
N. commune	-	+	+	+	+	-	-	-	+
Anabaena iyengari	-	+	-	-	+	+	-	+	+
A. torulosa	+	+	+	-	+	+	-	+	+
Macrospermum volzii	-	+	-	+	-	-	+	-	-
Cylindrospermum stagnale	+	-	+	-	+	+	+	-	+
C. majus	-	+	-	-	-	-	-	+	+
Trichormus variabilis	+	+	-	-	+	-	-	-	-
T. fertilissimus	-	-	-	+	-	+	-	-	-
Hapalosiphon welwitschii	+	-	+	+	-	+	+	+	+
Westiellopsis prolifica	-	+	+	+	+	+	-	+	+
Scytonema coactile	-	-	+	-	+	+	-	-	+
Total cyanobacterial species = 41	14	25	21	18	26	25	13	23	27

(Present "+"; Absent "-") (SS.: Sowing stage, GS.: Growth stage, MS.: Mature stage)

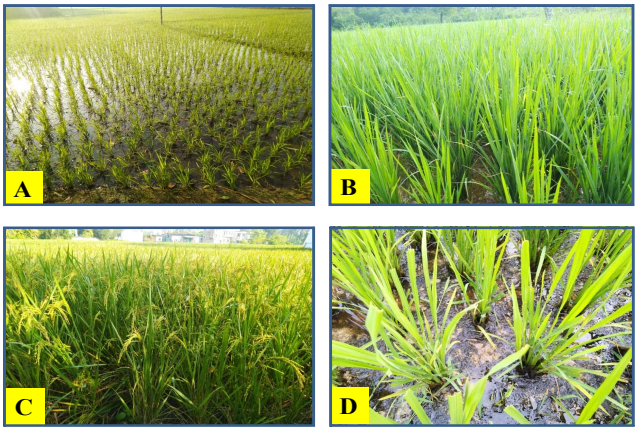


Plate 1. Different stages of rice cultivation, (A) Sowing stage, (B) Growth stage, (C) Mature stage, (D) Cyanobacterial growth in the rice field

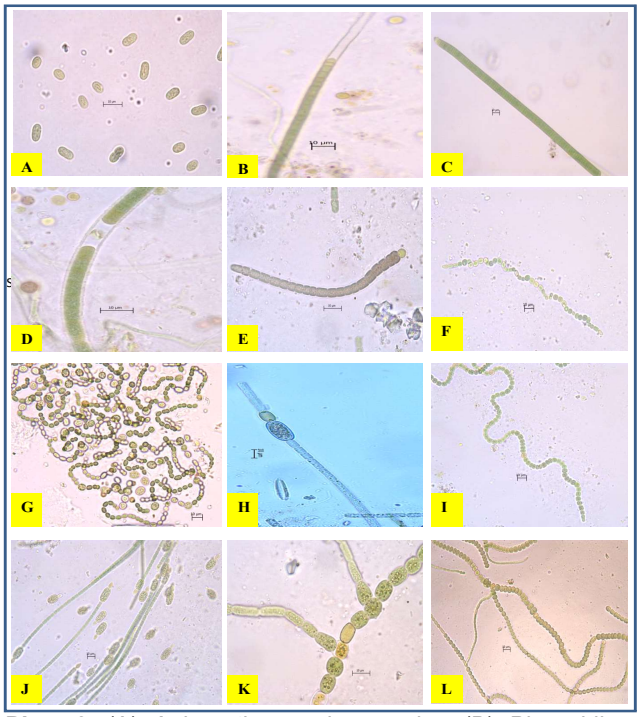


Plate 2. (A) *Aphanothece microscopica*, (B) *Phormidium corium*, (C) *Oscillatoria princeps*, (D) *Lyngbya martensiana*, (E) *Calothrix marchica*, (F) *Nostoc oryzae* (G) *Nostoc linckia*, (H) *Macrospermum volzii*, (I) *Anabaena torulosa*, (J) *Cylindrospermum stagnale*, (K) *Hapalosiphon welwitschii*, (L) *Westiellopsis prolifica*

belonging to 11 families were distributed in different sites. Shannon diversity index was maximum at mature stage of site II (1.907). Here, Simpson dominance index was also highest (0.809). Shannon diversity index and Simpson dominance index were lowest in growth stages of site I (1.562 and 0.713 respectively) (Table 3). Among the soil parameters, pH did not vary significantly between the study sites. The electrical conductivity was highest in growth stage (0.491mS) of site III and lowest (0.127 mS) in mature stage of site II. Highest value of organic C content was in mature stage (0.557%) and lowest (0.284%) in sowing stage of site III. The value of available N was maximum in growth stage of site II and lowest in sowing stage of site III. The available P and nitrate were highest in growth stage of site I and lowest in growth stage of site II (Table 4).

CCA showed relation between species occurrences and rice field soil parameters in three stages of rice cultivation - sowing stage, growth stage and mature stage. In view of the significance of nitrogen fixing cyanobacteria in rice cultivation, the occurrence of only heterocystous species of cyanobacteria are being considered for CCA. In the graph, "Δ" is marker for occurrence of species and "→" represents gradient of soil parameter variables. The results in CCA indicate that the relative weight, as denoted by extra fit values, for the soil parameter variables show a narrow range of variation with p value of 0.3300 (0.0937-0.2586) in sowing stage, p value of 0.3300 (0.1676-0.2328) in growth stage and p value of 0.3260 (0.0544-0.0707) in mature stage. As indicated by the eigenvalues, the first two axes are representing most of the variance in the data for all the three stages of present study.

In sowing stage, axis 1 has the strongest positive correlation with pH, available P and nitrate content of the soil and negative correlation with electrical conductivity and available N of the soil. Axis 2 has positive correlation with pH and negative correlation with electrical conductivity of the soil (Fig. 1). All the correlations were significant. From CCA, it has been observed that occurrence of *Nostoc commune* and *Westiellopsis prolifica* are negatively correlated with electrical conductivity. *Anabaena torulosa* showed correlation with increasing values of nitrate content and available P. *Cylindrospermum stagnale* indicated stronger correlation

Table 3. Diversity index of cyanobacterial species in three sites

Diversity index	Site I			Site II			Site III		
	SS.	GS.	MS.	SS.	GS.	MS.	SS.	GS.	MS.
Shannon–Wiener diversity index [H'($\log_e$)]	1.772	1.562	1.881	1.706	1.766	1.907	1.738	1.859	1.887
Simpson's dominance index (D_{SIPM})	0.765	0.713	0.802	0.746	0.781	0.809	0.745	0.795	0.803

with increasing pH than *Calothrix marchica*, *H. welwitschii, Nostoc linckia N. punctiforme* and *N. paludosum*.

In growth stage, axis 1 has positive correlation with available P, electrical conductivity and organic C and negative correlation with available N. Axis 2 has strong positive correlation with pH and nitrate and negative correlation with available N (Fig. 3). The occurrence of *Cylindrospermum majus* showed correlation with increasing available P. *Nostoc paludosum*, *Hapalosiphon welwitschii and Calothrix elenkinii* indicated correlation with increasing electrical conductivity and organic C, respectively. Occurrence of *Cylindrospermum stagnale* and *Scytonema coactile* towards the decreasing value of available N.

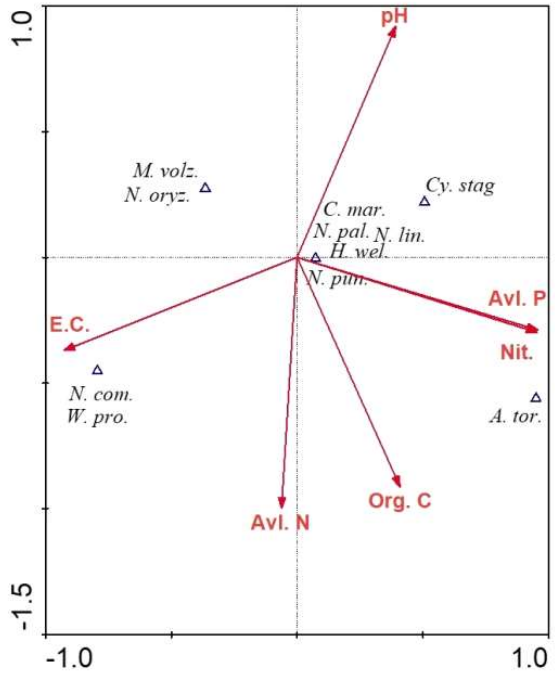


Fig. 1. CCA ordination biplot showing correlation between species occurrence and soil parameters of rice fields in sowing stage

Calothrix marchica, Westiellopsis prolifica, Nostoc punctiforme, Wollea Vaginicola, Anabaena iyengari and *Anabaena torulosa* correlated with low available P.

In mature stage, axis 1 has positive correlation with pH, nitrate and available P and negative correlation with organic C and electrical conductivity. Axis 2 has positive correlation with available N whereas, negative correlations with both organic C and electrical conductivity (Fig. 5). The occurrence of *Nostoc commune* has a correlation with increasing nitrate content and available P. *Cylindrospermum majus* negatively correlated with electrical conductivity. *Anabaena iyengari* and *Calothrix elenkinii* correlated with low available nitrogen. *Anabaena torulosa, Wollea vaginicola, Calothrix marchica, Westiellopsis prolifica, Nostoc punctiforme, Nostoc linckia, Cylindrospermum stagnale, Nostoc oryzae* and *Hapalosiphon welwitschii* correlated with low pH.

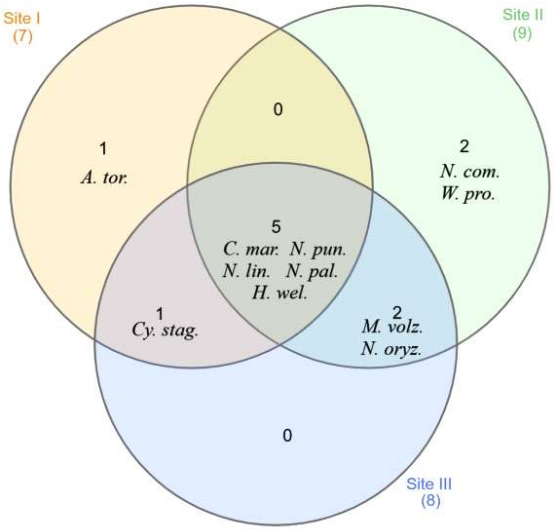


Fig. 2. Graphical presentation of the cyanobacterial species from the three study sites (Site I, II, III) in sowing stage based on commonality of occurrence

Table 4. Physico-chemical parameters of soil samples in different stages of rice cultivation of collected sites

Physico-chemical parameters	Site I			Site II			Site III		
	SS.	GS.	MS.	SS.	GS.	MS.	SS.	GS.	MS.
pH	6.08	6.13	6.86	5.62	5.62	6.28	6.04	5.68	6.14
E.C. (mS)	0.217	0.221	0.151	0.372	0.257	0.127	0.241	0.491	0.196
Organic C (%)	0.475	0.383	0.388	0.388	0.502	0.446	0.284	0.547	0.557
Available N (Kg ha^{-1})	125.44	175.61	175.61	125.44	225.79	200.74	75.264	150.52	175.61
Available P (Kg ha^{-1})	46.368	52.41	48.72	29.384	26.096	41.77	33.390	41.77	43.904
Nitrate (mg l^{-1})	3.71	3.87	2.31	1.38	0.987	1.18	1.91	1.54	1.40

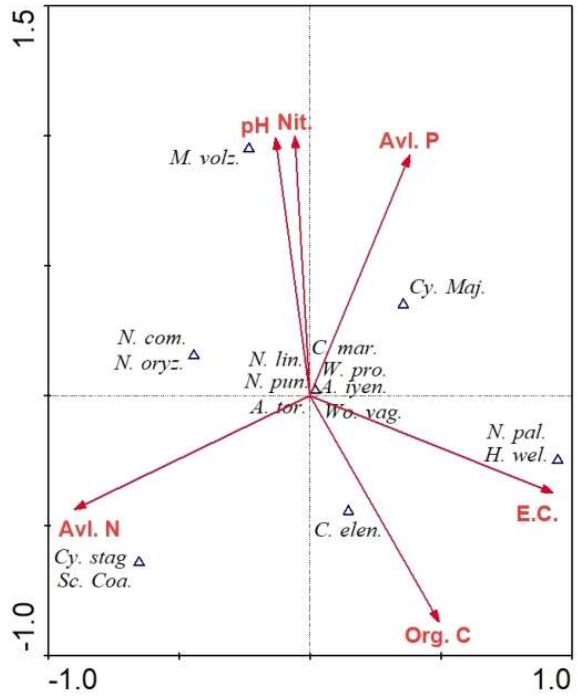


Fig. 3. CCA ordination biplot showing correlation between species occurrence and soil parameters of rice fields in growth stage

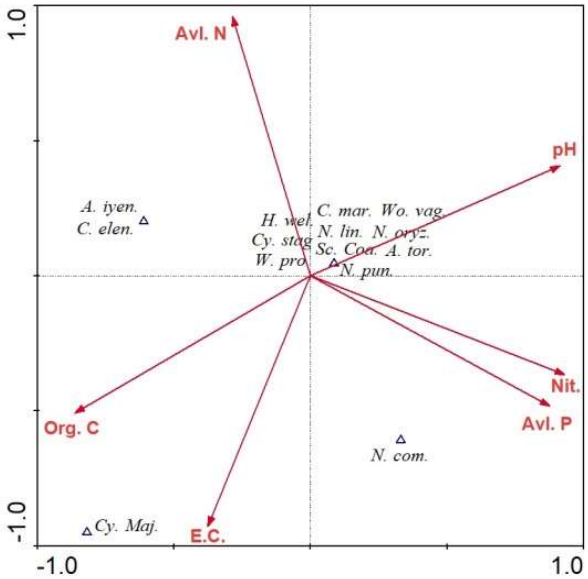


Fig. 5. CCA ordination biplot showing correlation between species occurrence and soil parameters of rice fields in mature stage

Common occurrence of heterocystous cyanobacteria in different study sites of each stage of rice plant growth has been demonstrated in Venn diagrams. Figure 2 shows that *Calothrix marchica, Nostoc linckia, Nostoc punctiforme, Nostoc*

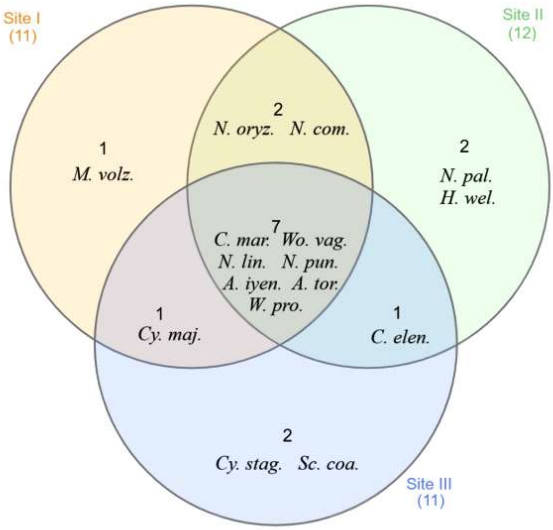


Fig. 4. Graphical presentation of the cyanobacterial species from the three study sites (Site I, II, III) in growth stage based on commonality of occurrence

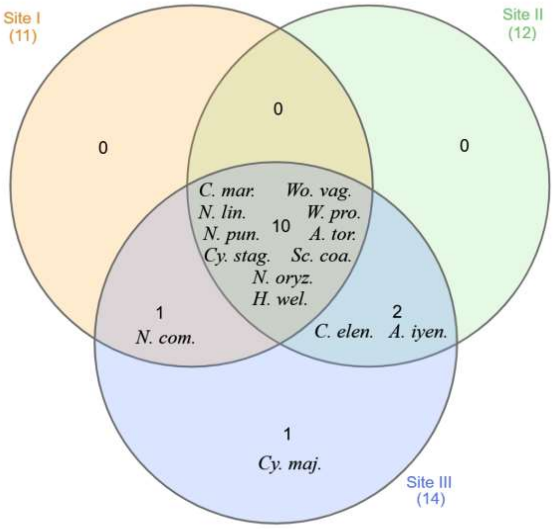


Fig. 6. Graphical presentation of the cyanobacterial species from the three study sites (Site I, II, III) in mature stage based on commonality of occurrence

Abbreviations

E.C., Electrical conductivity; **Org. C**, Organic Carbon; **Avl. P**, Available Phosphorus; **Avl. N**, Available Nitrogen; **Nit.**, Nitrate; ***C. mar.***, *Calothrix marchica*; ***C. elen.***, *Calothrix elenkinii*; ***Wo. vag.***, *Wollea Vaginicola*; ***N. lin.***, *Nostoc linckia*; ***N. oryz.***, *Nostoc oryzae*; ***N. pun.***, *Nostoc punctiforme*; ***N. pal.***, *Nostoc paludosum*; ***N. com.***, *Nostoc commune*; ***A. iyen.***, *Anabaena iyengari*; ***A. tor.***, *Anabaena torulosa*; ***M. volz.***, *Macrospermum volzii*; ***Cy. stag.***, *Cylindrospermum stagnale*; ***Cy. Maj.***, *Cylindrospermum majus*; ***H. wel.***, *Hapalosiphon welwitschii*; ***W. pro.***, *Westiellopsis prolifica*; ***Sc. Coa.***, *Scytonema coactile.*

paludosum and *Hapalosiphon welwitschii* are commonly occur in three sites of sowing stage. In growth stage (Fig. 4), cyanobacterial species - *Calothrix marchica, Wollea vaginicola, Nostoc linckia, Nostoc punctiforme, Anabaena iyengari, Anabaena torulosa, Westiellopsis prolifica* are commonly occur in three sites. Similarly, in mature stage (Fig. 6), cyanobacterial species - *Calothrix marchica, Wollea vaginicola, Nostoc linckia, Nostoc oryzae, Nostoc punctiforme, Anabaena torulosa, Cylindrospermum stagnale, Scytonema coactile, Westiellopsis prolifica* and *Hapalosiphon welwitschii* are commonly occur among three sites. The Figures 2, 4 and 6 clearly indicates that most of the species commonly occur in three sites of all the stages of rice plant growth. At the same time, it is observed that there are species which are site specific and reflects variation in species occurrence.

CONCLUSION

There is variation in species diversity at different stages of rice cultivation. Greater species diversity of the heterocystous cyanobacteria is observed at the mature stage of rice plants. Of the collected and isolated cyanobacterial species, *Calothrix marchica*, *Nostoc linckia* and *N. punctiforme* were found in all stages of rice plant growth. From the CCA, it has been concluded that, soil pH, nitrate content and available phosphorus showed maximum significance in the occurrence of cyanobacterial species.

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Effect of Crop Establishment Methods and Weed Management Practices on Yield and Economics of Rice (*Oryza sativa* L.)

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Abstract: A field study was undertaken to evaluate the crop establishment and weed management strategies for rice at Acharya Narendra Dev University of Agriculture and Technology, Kumarganj, Faizabad during *kharif* season, 2017-18. Twelve treatment combinations of two planting methods *viz.* transplanting, and direct seeded methods and six weed control practices *viz.* penoxsulam, penoxsulam *fb* 1 HW, bispyribac sodium, bispyribac sodium *fb* 1 HW, weed free and weedy check were selected for the study. Results revealed that plant growth attributes, yield attributes and grain yield was significantly superior in transplanted rice over direct seeded rice. In case of weed control practices growth characters, yield attributes, grain yield of rice were recorded the highest under weed free which was at par with bispyribac sodium *fb* 1 HW. The highest net return (Rs.60632) and benefit: cost ratio (1.90) was recorded under transplanted rice with bispyribac sodium *fb* 1 HW application

Keywords: Weeds, Direct seeded rice, Transplanted rice, Weed control practices, Yield

Rice (*Oryza sativa* L.) is one of the major cereal crops of the world and a substantial proportion of the human population across the globe, being dependent on rice for nutrition, are engaged in its cultivation, storage, trade and distribution. It contributes to one-fifth of the total population of world caloric intake and provides the highest supply of human dietary energy amongst all the cereal grains. The world's total rice area is 167 million ha and production is about 782 million tons with productivity of 4.67 Mt ha^{-1}. The productivity of rice in Southeast Asia is 4.41 tons ha^{-1} and China is the largest producer (FAOSTAT, 2018). India ranks first in acreage (43.1 m ha) and second in production (96.43 mt) only after China (Directorate of Economics Statistics 2017). India alone would require about 156 mt of rice by the year 2030 (ICAR 2010) at an annual increment of 3 mt in the current rice production (Dass et al 2017). Conventional method of rice growing is the raising of rice nursery in a nursery bed and transplanting one month old nursery seedlings in a puddled and flooded field (Ehsanullah et al 2007). This method not only effectively suppresses the rice weeds by preventing the light to reach the weeds through a layer of the standing water and also provides the rice plants with a better growing environment (Farooq et al 2011). However, immense labour and water is required to grow rice by conventional flooded method (Bouman et al 2007). Dry-seeding of rice is extensively practised in rainfed lowlands, uplands and flood-prone areas. It saves 15-20% irrigation water and reduces the production costs as compared to puddle transplanted rice. Weeds are a major constraint to dry-seeded rice production, causing 40-100% loss in grain yield (Bahar and Singh 2004). Manual weeding in upland rice is labour intensive. With the availability of proper weed management technology it is possible to raise the productivity of direct-seeded rice. Due to these reasons there is a need to shift from the conventionally flooded transplantation to direct seeding of rice in India. Yield potential of direct seeded rice is equivalent to the transplanted rice under good water management and weed control conditions. The alternative tillage and crop establishment are site specific and therefore, evaluations under wide agro-ecological conditions is important to have significant adoption (Kaur et al 2015).Weeds are more harmful pests of field crops as compared to other crop pests (insects, fungi, rodents, storage pests etc.) as far as their losses to crop produce are concerned. Weeds reduce crop yield, quality and production efficiency and may reduce productivity of rice by 30-35%. Weeds compete with the crop for limited resources and may also serve as alternate hosts for various insect and disease pests (Kaur et al 2015). Weeds cause heavy damage to direct-seeded rice (DSR) crop which can be to the tune of 5-100%. Manual weeding is becoming less common due to labor scarcity on farms and high labor wages. Thus, herbicides are considered to be an alternative/supplement to hand weeding (Singh et al 2007). Herbicides can provide superior weed control and their use is

more energy and labor efficient than manual or mechanical methods. In the present scenario of labor scarcity, herbicide use is more preferable and farmers can easily go for it. Ever increasing populations of herbicide resistant weeds, weed shift and consistent public pressure to reduce overall pesticide use, herbicide alternatives are now required without delay (Arunjith and Arthanari 2021). Recently, a number of low dose sulfonyl herbicides such as metsulfuron, bispyribac and azimsulfuron have been developed that have a broad spectrum of weed control in rice. However, there is need to evaluate these herbicides under various site specific conditions to check their weed control efficiency. The present investigation was undertaken to determine the most suitable weed management practices to control weeds in both transplanted and direct-seeded rice and to work out their economics. The study is also carried out to compare the performance and yield of rice under various weed management techniques.

MATERIAL AND METHODS

Experimental site and meteorological conditions: The experiment was conducted during *kharif* season of the year 2017-18 at Agronomy Research Farm of Narendra Deva University of Agriculture & Technology, Faizabad (U.P.). The experimental site is situated at 26° 47' N latitude, 82° 12' E longitude & an altitude of 113 meters above mean sea level. Geographically, this region falls under sub-tropical zone of gangetic alluvium of eastern Uttar Pradesh (India). The annual rainfall of the region is about 805 mm and 75 per cent of which are received from June to October. The winter months are cold and dry, quite often frost occurs during this periods. The weekly mean of maximum & minimum temperatures during the crop season ranged from 30.6°Cto 37.8°C &16.7°C to 28.7°C, respectively. The maximum rainfall of 151.8mm was recorded in the second week of July, 2017. The evaporation rate was maximum (8.4mm) in first week of June and minimum (3.8 mm) in the first week of July. The relative humidity was highest 90.8 per cent in the first week of July and lowest 62.9 per cent was recorded in the second week of June in 2017. The minimum (0.8 hrs.) and maximum (8.6 hrs.) sunshine hours were observed in the first week of July and last week of June 2017, respectively.

Experimental design and treatment details: The experiment was laid out in factorial randomized complete block design and replicated thrice with a net plot size of 5m×4m. Twelve treatment combination of two rice establishment methods viz. transplanting, and direct seeded methods and six weed control practices viz. penoxsulam 22.5g ha^{-1}, penoxsulam 22.5g ha^{-1} fb 1 HW, bispyribac sodium 20g ha^{-1}, bispyribac sodium 20g ha^{-1} fb 1 HW, weed free and weedy check were selected for the study. The herbicides as per the treatment schedule were applied as post- emergence by using 500 litres of water ha^{-1} with knapsack sprayer fitted with flat fan deflector nozzle.

Agronomic practices: A common procedure was followed in raising seedlings in the seedbed. The seedbed was prepared by puddling with repeated ploughing followed by laddering. Weeds were removed and irrigation was gently provided to the bed as and when necessary. Healthy and bold seeds of rice variety Sarjoo-52 were sown on 20th July 2017 in puddled soil. After the harvest of previous crop the experimental field was ploughed once with soil turning plough and cross harrowed two times. After each ploughing, planking was done to level the field and obtain the fine tilth and lay out was done. The crop was fertilized with a uniform dose of nitrogen, phosphorus and potassium @ 120 kg, 60 kg and 40 kg ha^{-1}, respectively. Urea, DAP and Murate of potash were used as the source of nitrogen, phosphorus and potassium. The specific quantity of fertilizer was calculated on the basis of gross plot size. $ZnSo_4$25 kg ha^{-1} was applied as micro-nutrient in rice. The half quantity of nitrogen and full quantity of phosphorus and potassium were broadcasted in the field during final field preparation and mixed-up thoroughly in the field. The rest half dose of nitrogen was top-dressed in two splits first at 30 and second at 45days age. Sowing of experimental crop was done according to treatment. In direct seeded rice (DSR) it was done with the help of broad casting method. In transplanting method, 21 days old seedlings were transplanted at the spacing of 20 x10 cm using two seedling $hill^{-1}$. The crop was raised under irrigated conditions as per recommended package of practice. First hand weeding was done on 20th August and second on 5th September 2017. Irrigation treatments based on Days after disappearance of ponded water (DADPW) were started just after transplanting with 7 cm depth of water in each irrigation as per treatment. Water depth was maintained by using Parshall flume. The crop was harvested manually by serrated edged sickles at physiological maturity when panicles had about 85% ripened spikelets and upper portion of spikelets look straw colored. At the time of harvesting the grains were subjected to hard enough, having less than 16 per cent moisture in the grains. Firstly the border area was harvested. The harvesting of net plot area was done and final harvested produce of each net plot was weighed after sun drying for recording biological yield. Threshing was done manually by wooden sticks. The grain yield of individual plot after winnowing was weighed. The quantity of straw per plot was calculated by subtracting the weight of grains from biological produce. Yield of both grain and straw was expressed in q ha^{1}.

Plant growth characters: Plant height of main shoot of tagged plants was measured from the ground level to the tip of top most leaf prior to ear emergence and from ground to the base of ear after ear emergence. The number of tillers m^{-2} harvest stage was counted by placing a quadrate of 50 x 50 cm (0.25 m^2) randomly at three places in each plot and the total number of tillers per square meter was computed. Dry matter accumulation at harvest stage was recorded. For this purpose, the plant shoots per m^2 were cut close to the ground level and put in the paper bags. After sun drying, the samples were dried into hot air oven at 70 ^{0}C till the constant weight attained. Leaf area was measured by automatic leaf area meter. Plants of 1 m^{-2} were taken and green leaves were separated out to record their surface area. All the leaves were grouped into three viz., small, medium and large. Five leaves from each group were taken and their surface area was measures. The average area of five leaves was multiplied with respective leaf number of a group and sum of all three gave the total leaf area.

The LAI was computed by the following formula:

$$LAI = \frac{L}{A}$$

LAI -Leaf area index, L-Leaf area (cm^2), A - Land area (cm^2)

Yield attributes: At 90 days stage, the number of effective tillers was counted by placing a quadrate of 50x50 cm at three places at random in each plot and total number of effective tillers per square meter were computed. Five panicles were sampled from the tagged plants in each plot and then length was measured in centimeter. The average length of panicle was calculated. The number of filled grains from five panicles of each plot were counted and averaged for number of grains $panicle^{-1}$. After threshing and weighing, a random sample of grains was drawn from grain yield of each plot. From this sample, 1000-grain were counted at random and their weight (g) was recorded. After taking the weight of total biomass, the produce of each net plot was threshed separated and clean grains were sundried to maintain 12-14% moisture. The grain yield was recorded in kg $plot^{-1}$ and finally the values were converted into q ha^{-1}. Straw yield from net plot area was computed by subtracting the grain yield from total produce harvested and later on converted into q ha^{-1}. Harvest index is the ratio of the economic yield and biological yield and calculated by formula as given by Donald (1962). It was expressed in percentage.

Economic studies: Cost of cultivation of different treatment was worked out by considering all the expenses incurred in the cultivation of experimental crop and added with common cost due to various operations and inputs used. Accordingly cost of cultivation was calculated for each treatment. Gross return was worked out by multiplying grain and straw yield separately under various treatment combinations with their existing market price. The monetary value of both grain and straw was added together in order to achieve gross return. Net return was calculated by deducting the cost of cultivation from the gross return of the individual treatment combination. Benefit-cost ratio was worked out by dividing the net return to the cost of cultivation of the individual treatment combination.

Statistical analysis: The data recorded in respect to different observations in the present experiment were analyzed statistically with the help of following procedure for factorial randomized block design (RBD).

RESULTS AND DISCUSSION

Growth and development: Transplanting method recorded higher plant height (112.63 cm), which was statistically at par with direct seeded rice (103.25 cm) at harvest stage. Among the weed control, weed free resulted in higher plant height almost at all the stages of crop growth. However at harvest stage, weed free treatment being at par with bispyribac sodium + 1 HW and bispyribac sodium, recorded significantly higher plant height over other treatments. It might be due to more space, sunlight and nutrients available to wider spaced plants of transplant than close spaced plants which facilitated the plants to attain more height. Shriame et al (2000) reported that the number of functional leaves and leaf area were higher under wider spacing, which increased the photosynthetic rate leading to taller plant. Younger seedlings have more vigor, root growth and lesser transplant shock because of lesser leaf area during initial growth stages which stimulate the cell division causing more stem elongation and ultimately have might increased plant height in transplanted rice rather than direct seeded rice (Rahman 2001). Number of tillers was significantly affected by various planting methods at different stages of crop growth. Significantly higher number of tillers was counted under transplanted method (360.36 m^2) as compared to direct seeding (295.47 m^2) at harvest stages. Maximum number of shoots (m^2) were recorded from weed free plot, which was *at par* with the application of bispyribac sodium + 1HW, and significantly more over bispyribac sodium, penoxsulam *fb* 1HW, penoxsulam and weedy check at 30, 60, 90 and at harvest. The highest leaf area index was recorded in transplanted rice, which was significantly higher over direct seeded rice at harvest stage. The higher number of $tillers^{-1}$ might be due to wider spacing, transplanting younger seedlings, earlier transplanting and better water management. Earlier transplanting reduces the transplanting shock at a more convenient point in the growth cycle when they could rebound faster and had little

effect on tiller age (Uphoff 2002). Reduced number of shoots under direct seeded method might have been due to lesser intra plant space and heavy occurrence of weed resulting in more weed competition. Transplanted rice recorded higher leaf area index (2.17) as compared to direct seeded rice (2.09). Among weed control practices, the highest LAI was in weed free, which and was *at par* with bispyribac sodium *fb* 1HW and bispyribac sodium and was significantly more over 1 HW, penoxsulam and weedy check at all the growth stages of crop except at 30 DAS/DAT. Dry matter accumulation also recorded similar trend. Higher number of tillers m^{-2} in transplanted rice increased the leaf area that covered the ground area, hence enhancing the leaf area index. High leaf area index is associated with increased in assimilation of food material through photosynthesis on account of vigorous root and shoot growth, which ultimately led to higher dry matter production at each of the stage of observation. Similar results have been reported by Thiyagarajan et al (2002) and Hussain et al (2012).

Yield and yield attributing characters: Number of panicle m^{-2}, panicle length and number of grains panicle^{-1} was recorded significantly higher under transplanting method followed by direct seeded rice (Table 2). Yield attributing characters are the function of growth and development that develop during vegetative phase of the plant. Due to better partitioning of photosynthesis from source to sink as a result of better growth owing to favorable growing conditions might have resulted in to better development and higher value of yield attributes. These findings are well supported by Thakur

Table 1. Effect of crop establishment methods and weed control practices on plant growth parameters of rice at harvest stage

Treatment	Plant height (cm)	No. of shoots (m^2)	Leaf area index	Dry matter production (g/m^2)
Crop establishment methods				
Direct seeded rice	103.25	295.47	2.09	933.40
Transplanted rice	112.63	360.36	2.17	1193.00
CD (p=0.05)	5.59	16.54	NS	59.04
Weed control practices				
Penoxsulam	101.30	321.30	2.08	1051.51
Penoxsulamfb by 1HW	105.25	331.38	2.12	1055.36
Bispyribac sodium	110.65	342.09	2.14	1093.03
Bispyribac sodium fb by 1HW	113.70	350.91	2.18	1148.02
Weed free	116.85	362.25	2.20	1172.64
Weedy check	99.90	259.56	2.06	858.67
CD (p=0.05)	9.69	28.66	0.19	102.27

Table 2. Effect of crop establishment methods and weed control practices on yield attributes, grain yield, straw yield and harvest index of rice

Treatment	Effective tillers/m^2	Panicle length (cm)	Grains/ panicle	Test weight (gm)	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Harvest index (%)
Crop establishment methods							
Direct seeded rice	281.40	23.63	96.60	23.27	37.43	55.91	40.06
Transplanted rice	343.20	24.01	106.24	23.36	49.30	70.00	41.26
CD (p=0.05)	16.86	N S	4.77	N S	2.19	3.41	N S
Weed control practices							
Penoxsulam	306.00	23.73	95.50	23.25	42.40	62.75	40.25
Penoxsulamfb by 1HW	315.60	23.93	99.25	23.31	43.15	62.39	40.80
Bispyribac Sodium	325.80	24.08	104.35	23.38	44.90	64.40	41.00
Bispyribac sodium fb by 1HW	334.20	24.23	107.30	23.45	47.30	67.50	41.13
Weed free	345.00	24.55	110.25	23.48	48.50	68.76	41.28
Weedy check	247.20	22.40	91.88	23.03	33.95	51.92	39.50
CD (p=0.05)	29.20	N S	8.27	N S	3.80	5.91	N S

et al (2009). Grain yield of rice was influenced significantly by crop planting methods (Table 2). The crop established under wider spacing transplanting (20 x 10 cm) method resulted in significantly higher grain yield (49.30 q ha^{-1}) than direct seeded rice (37.43 q ha^{-1}). Yield is functions of complex inter relationship of growth in vegetative phase and yield attributes, as well. Higher yield under transplanting method was due to better crop growth and development resulting in to higher value of yield attributes which had direct bearing on the grain yield. Higher number of panicle per unit area, panicle size and filled grains percentage in case of transplanting method as compared to other method of crop establishment might be responsible for superiority of this treatment over other in respect of grain yield. Similar results have been reported by Krishna et al (2008). Straw yield also recorded similar trend, being higher in transplanted rice. Higher number of tiller m^{-2} with moderate plant height and better performance of yield attributing ultimately led the increase the biomass in the transplanting method of rice establishment. The lowest yield was under direct seeded method due to less effective tiller m^{-2} and increased inter and intra-plant competition for available growth resources on account of heavy weed infestation. Harvest index was also influenced significantly due to various planting methods and was higher with transplanting method. Similar findings have also been reported by Hussain et al (2003) and Stoop (2005).

In DSR, the reduction in grain yield was mainly due to high density of weeds and more dry matter accumulation of total weeds at maturity in weedy check plots. The lowest grain yield obtained in weedy check was also associated with lowest number of shoots (m^{-2}), lowest number of effective tillers (m^{-2}), lower test weight (g) and lowest length of panicle due to higher crop-weed competition. Among the weed control treatments, bispyribac sodium + 1 HW at 30 DAS, recorded efficient control of all the weeds (grasses, non-grasses and sedges). This treatment gave the highest grain yield (47.30 q ha^{-1}) which was at par with weed free check having grain yield 48.50 q ha^{-1}, significantly higher than other treatments. Increase in grain yield in this treatment due to more number of tillers (m^{-2}), higher dry matter accumulation by crop (g m^{-2}) and less dry matter accumulation by total weeds (g m^{-2}) at all the stages of crop growth. The finding was supported by Moorthy and Saha (2003) from Cuttack, (Orissa) and Saha (2005). The population of *E. colona, E. crusgalli, Commelina benghalensis* and *Cyperus rotundus* reduced with the application of Bispyribac-sodium + 1HW and produced significantly higher grain yield as compared to Penoxsulam @ 22.5 g ha^{-1} at 30 DAS. The finding was supported by Bahar and Singh (2004).

Economics: Among the weed control treatments, maximum cost of cultivation was from transplanting along with Bispyribac sodium @ 20 g ha^{-1} (Rs. 37118 ha^{-1}) followed by transplanted Penoxasulam, while transplanting along with weedy check recorded minimum cost of cultivation over rest of the treatments. Highest gross return (Rs. 95145 ha^{-1}) and net return (Rs.60632 ha^{-1}) were also recorded from transplanting methods along with bispyribac-sodium @ 20g ha^{-1}. However, the highest benefit: cost ratio 1.90 per rupee invested) was recorded from bispyribac-sodium @ 20g ha^{-1} due to more grain and straw yield (47.30 and 67.50q ha^{-1}) in these treatments (Table 3). Similar result was also observed by Bahar and Singh (2004).

Table 3. Effect of crop establishment methods and weed control practices on economics of rice cultivation

Treatments	Gross return (Rs ha^{-1})	Net return (Rs ha^{-1})	B.C: Ratio (Rs ha^{-1})
Penoxsulam 22.5 g h^{-1} at 15 DAS/DAT + Transplanted rice	64360	33992	1.12
Penoxsulam 22.5 g h^{-1} at 2-3 leaf stage weed fb HW at 35 DAS/DAT + Transplanted rice	66005	35537	1.16
Bispyribac Na 20 g h^{-1} at 15DAS/DAT + Transplanted rice	70700	39082	1.24
Bispyribac Na 20 g h^{-1} at 2-3 leaf stage weed fb HW at 35 DAS/DAT + Transplanted rice	72550	40782	1.28
Weed free+ Transplanted rice	74800	39682	1.13
Weedy check + Transplanted rice	53250	24132	0.82
Penoxsulam 22.5 g h^{-1} at 15 DAS/DAT + DSR	74050	43432	1.48
Penoxsulam 22.5 g h^{-1} at 2-3 leaf stage weed fb HW at 35 DAS/DAT + DSR	85800	55132	1.79
Bispyribac Na 20 g h^{-1} at 15 DAS/DAT + DSR	88100	56412	1.78
Bispyribac Na 20 g h^{-1} at 2-3 leaf stage weed fb HW at 35 DAS/DAT + DSR	92500	60632	1.90
Weed free + DSR	95145	58027	1.56
Weedy check + DSR	69150	40032	1.37

CONCLUSION

The crop established by transplanting method produced higher grain yield, which was statistically superior to that of direct seeded rice. Use of bispyribac-sodium, a post emergence herbicide in transplanted rice followed by one hand weeding suppressed the weed growth was more profitable. Direct seeded rice can also be made and feasible by integrating different weed management approaches to acquire effective, sustainable, and long-term weed control in DSR.

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Impact of Palekar's Natural Farming on Farmers' Economy in Himachal Pradesh

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Abstract: An independent evaluation of Subhash Palekar Natural Farming (SPNF) was undertaken in Himachal Pradesh, covering 325 farmers from all four agro-climatic zones. We compared the yield potential, input cost and net returns in major crop combinations under SPNF during the *Rabi* (2018-19) and *Kharif* (2019-20) seasons, with Conventional Farming (CF). The cereals-pulses, cereals-vegetables, fruit-pulses-vegetables and vegetables-pulses were found as the four major crop combinations followed under SPNF on an average area of 0.26 ha, in the State. The fruit based SPNF farming combination was the most popular (40.6%) and profitable (REE=21.44%). A reduction of 14.34-45.55 per cent in cost of cultivation and an increase of 11.8-21.55 per cent in the net returns, over CF, validate the superiority of SPNF over the CF. The success of early SPNF adopters supports the viable potential of SPNF to sustain farming and enhance mountainous farmers' income, yet long term studies are required.

Keywords: ZBNF, SPNF, Economic impact, Conventional farming, Net returns

Agriculture has been the mainstay of the Indian economy for centuries. It accounted for 17.8 per cent of the country's gross value added (GVA) for the year 2019-20, with more than 50 per cent of the total workforce concentrated in agricultural and allied sector activities (Anonymous 2019a). There had been transformative changes in food production scenario of the country due to technological advances post Green Revolution. However, imbalanced use of agricultural inputs, declining factor productivity, depleting natural resources, ever-increasing input costs, environmental degradation and adverse impact of climate change are major challenges in sustaining agricultural production systems (NAAS 2019). Several studies have shown adverse effect of imbalanced and indiscriminate use of agrochemicals on soil health and environment (Iqbal et al 2001, Kotschi 2015, Supriya et al 2018, IPBES 2019) and raised the concerns of food security (Lal 2009a, b, 2013, Pingali 2012).

Farmers, now have not been able to get a gainful return due to declining factor productivity, increasing cost of inputs, weather related uncertainties and low price realization. Over the years, there has been a decline in income from agriculture and this has resulted in agrarian distress (Mishra 2008). Low income and declining profitability has forced the farmers away from the agriculture. The analysis of Census data for occupational distribution of workforce shows a sharp decline in the size of self-cultivators (decline of 8.9 million during 2001-11) and this decline is being replaced by bulging agricultural labour category (Motkuri and Veslawatha 2013).

There is a need for environment friendly sustainable agricultural practices and making agriculture a profitable venture, so as to reduce the agrarian distress and retain cultivators in the sector. Alternative natural farming practices with ecological and social benefits have emerged and been promoted in pockets (Park and DuPonte 2008, Brown 2018), but they have not reached a mass scale. These natural farming practices promise reduced input costs, chemical-free produce, improved soil fertility and higher income. In the recent past, one such natural farming practice also known as Zero Budget Natural Farming (ZBNF) or Subhash Palekar Natural farming (SPNF) (Palekar 2005, 2006) is being promoted as low-input, climate-resilient farming that encourages farmers to use indigenous cow based low-cost locally-sourced inputs, eliminating the use of agro-chemicals. Natural farming, either SPNF or other practices, are a part of the solution to ensure that not only the ecology of the area is not disturbed, but the ecosystem remains resilient to adverse effects of global shift in climate patterns. The FAO has urged all countries to move towards the adoption of Agroecology to meet the twin goals of global food security and conservation of the environment and SPNF principles are in sync with the principles of Agroecology. It has been widely accepted by the farmers (Neelam and Kadian 2016, Tripathi et al 2018, Khadse and Rosset 2019). There has been arguments both in favour and against the viability of the organic and natural

farming systems (Seufert et al 2012, Strohbach et al 2015, Kuruganti 2019, NAAS 2019, Rao 2019).

Highlighting the predominance of smallholder farmers (68.50% marginal and 17.70% small farmers) in India, The Economic Survey 2018-19 (Anonymous 2019b) emphasized the importance of ZBNF as one of the alternative farming practices for improving the farmers' income, in the backdrop of declining fertilizer response and farm income. Various state governments in India have also started programmes to promote SPNF/ZBNF system. The SPNF was started in Himachal Pradesh (HP), where the average land holding size is about 1.0 ha and about 89.00 per cent farmers are small and marginal, in the year 2016. The HP Government also started a scheme 'Prakritik Kheti Khushhal Kisan' (PK3) Yojna during 2018, with the objective to make agriculture economically viable and profitable and reduce agrarian distress and risk through cost reduction and sustainable climate-resilient agricultural practices. However, not much scientific data pertaining to various aspects of cost of cultivation and performance of various crops under SPNF system is available. Keeping in view the above background, the present study is an attempt to identify the farmers practicing SPNF on various crops/crop combinations and to estimate economics and impact of various crop combinations being grown under SPNF system.

MATERIAL AND METHODS

A comprehensive study to evaluate the impact of SPNF on yield of different crops/crop combinations and the relative economics in comparison to CF system was undertaken in Himachal Pradesh during 2018-19. Five districts *viz*. Kangra, Una (sub tropical), Mandi (Sub-tropical and sub-temperate), Shimla (wet temperate) and Kinnaur (dry temperate), covering all the agro-climatic zones of Himachal Pradesh were purpusively selected for the present study. The list of the farmers practicing SPNF as well as CF was obtained from the Project Director, ATMA of the respective district. A total of 325 SPNF farmers from these districts were selected with probability proportion to size. The district wise distribution of the sampled farmers is given in the Table 1.

Table 1. District wise distribution of the sampled farmers

District	Sample size (No.)
Kangra	128
Kinnaur	5
Mandi	32
Shimla	114
Una	46
Total	325

The primary data were collected from the selected SPNF farmers through survey method, using well structured and pre-tested schedule for the two seasons i.e. Rabi (2018-19) and Kharif (2019-20). The primary data included landholding under natural farming, season wise major crop combination, crop productivity, expenditure and income from the crop combination under SPNF and CF system. The descriptive analysis of the field survey data was done for the study. The Crop Equivalent Yield (CEY) and the Relative Economic Efficiency (REE) were also worked out.

RESULTS AND DISCUSSION

Following the burgeoning success of SPNF on farmers' field in different states, particularly in Andhra Pradesh, the Government of Himachal Pradesh launched 'Prakritik Kheti Khushhal Kissan (PK3)' Yojna to sustain farmers' livelihood by reducing the cost of farming and ultimately leads to a substantial increase of income of farmers by 2022. The Subhash Palekar Natural Farming has been taken as a technique for this purpose. The data collected on different crop combinations from SPNF farmers were analysed and compared with their routine practice through CF system.

Crop combinations under SPNF: The survey study revealed that farmers of the State are growing various crops under different combinations. These combinations were categorised as i) cereals- pulses, ii) cereals- vegetables, iii) fruits- pulses- vegetables and iv) vegetables- pulses (Table 2). The data indicate that the farmers were raising the crops in combinations with pulses or leguminous vegetables for the better nutrient management in each crop combination, as per the training manual of Palekar (2013). The major portion of the nitrogen requirement in ZBNF is met through fixation of the atmospheric nitrogen (Smith et al 2020). This multi-cropping system substantially enhances income per unit area and ensures a more evenly distribution of income and employment throughout the year from harvesting different crops in a cropping season. This system helps to maximise land use and minimise the risk of crop yield loss (Bharucha et al 2020).

Lower acreage under SPNF can be attributed to the fact that more than 88 per cent farmers in the State are small and marginal (Anonymous 2020). Besides, the farmers were advised to start this farming initially only on a small acerage to judge the initial success before larger scale adoption. Among different crop combinations, the maximum average acreage farmer^{-1} (0.31 ha) was under fruits- pulses- vegetables combination, followed by cereals- pulses (0.25 ha), cereals- vegetables (0.19 ha) and vegetables- pulses (0.19 ha). In terms of adoption, fruit- pulses- vegetables was the most popular cropping combination adopted by 40.6 per cent

farmers followed by cereals- pulses (38.2%) (Fig. 1). The leguminous vegetables were being grown by 10.4 per cent farmers in combination with cereals. Similarly 10.8 per cent farmers were growing vegetables in combination with pulses. Intercropping with leguminous crops is one of the components of Zero Budget Natural Farming (ZBNF) and it improves the crop productivity and soil fertility by way of fixing the atmospheric nitrogen (Poonam et al 2020).

Area and adoption of different crop combinations in SPNF system: The proportion of the farmers practising different crop combinations and the respective average landholding (Fig. 2) indicate an average area of 0.26 ha farmer^{-1} under SPNF system.

Comparative productivity of crops grown under SPNF and CF: As different types of crops were included in a multiple or mixed cropping system, it is difficult to compare the economic produce of one crop to another. Therefore, a comparison was made based on crop equivalent yields (CEY) of multiple cropping combinations. The CEY was calculated by converting the yields of the main crops along with intercrops into equivalent yield of any one crop based on price of the produce. The CEY value for SPNF crops combination was higher than recorded for CF (Fig. 3). The increase in CEY under cereals-pulses combination was 17.22 per cent, while in vegetable and fruit based cropping sequences, the increase was less than 10 per cent. A higher increase in cereals and pulses can be attributed to the comparative remunerative prices of pulses and symbiotic effect of pulses on cereal crop yield. The inclusion of specialized legumes in different crop combinations supports the agro-ecological principles such as greater crop diversity and nitrogen fixation, enabling a reduction in synthetic inputs (Therond et al 2017, Watson et al 2017). An increase in yield upto 32 per cent in different crops grown under ZBNF principle having legume as one of the intercrop has been reported from the Andhra Pradesh (Tripathi et al 2018). However, many researchers have also apprehended that mass conversion to ZBNF may limit country's potential to meet the future food sustainability goals (Kumar et al 2019, NAAS 2019, Smith et al 2020).

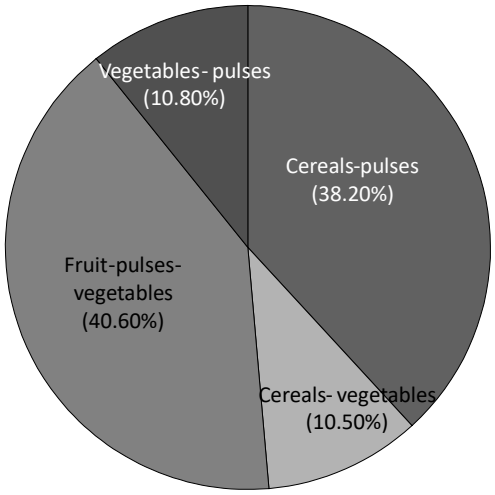


Fig. 1. Distribution of sampled farmers according to major crop combinations

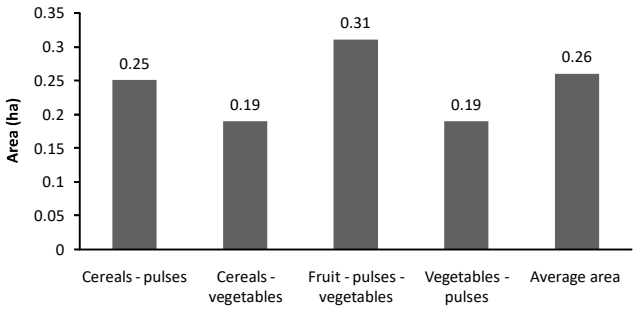


Fig. 2. Average area under different crop combinations in SPNF system

Table 2. Season-wise crop combinations in SPNF system

Crop combinations	*Kharif*	*Rabi*
Cereals- pulses	Maize + Soybean Maize + Black gram Maize + Cowpea Maize + Kidney bean	Wheat + Gram + Mustard Wheat + Gram Wheat + Peas + Mustard
Cereals- vegetables	Maize + French bean	Wheat + Pea
Fruit- pulses- vegetables	Apple + Peas + Kidney bean Apple + Kidney bean Apple + Peas + Coriander +Cabbage Apple + Garlic + Peas + French beans Apple + Peas + Coriander + Cauliflower	
Vegetables- pulses	Capsicum + French beans Tomato + French beans Ginger+ Soybean + Colocasia Okra+ French bean	Onion + Coriander+ Fenugreek + Gram Garlic + Peas Peas + Spinach + Coriander + Radish

Comparative economics of cropping combinations under SPNF and CF system: The comparative economics of various cropping combinations under SPNF and CF system has indicated a decline in the total cost of cultivation, across all crop combinations (Table 3). The total expenditure in fruit based cropping sequences showed a marked decline from Rs 2,40,638 to 1,31,025 ha^{-1}, which indicate that the SPNF system reduces farmers direct costs, boosting yields and promotes the use of locally sourced non-synthetic inputs, compared to capital intensive CF. The CF is currently facing different challenges like declining factor productivity, inadequate and imbalanced use of nutrients, low water and nutrient use efficiency, depleting natural resources, increasing cost of inputs etc. (NAAS 2019). The extent of decline in total expenditure in fruit and vegetable based cropping sequences clearly indicated that the chemical based farming technologies are highly capital intensive. The net returns and the total income in SPNF were higher than CF across all the cropping combinations. The Relative Economic Efficiency (REE), which is a comparative measure of economic gains, was 11.80 to 21.55 per cent higher in all the crop combinations under the SPNF in comparison to the CF system. A significant reduction in the cost of cultivation of all the crops under ZBNF has already been documented by ABZBNF (2018) and Kumar et al (2019).

Economic impact of SPNF on farming community: Chemical inputs are one of the major cost components in production of cash crops like fruits and vegetables under the CF system in the State. This ongoing farming practice has been leading to the increase in cost of cultivation and ultimately reducing the farmers' income. The adoption of SPNF technology has led to a significant decline in the cost of cultivation of these crops. The decline in average cost or total expenditure under SPNF vis-a-vis CF on the sampled farms varied from 45.55 to 14.34 per cent in different crop combinations with highest in the fruit based combination (Fig. 4). The remarkable reduction in cost of cultivation owe to the non-use of costly market driven inputs. According to a study conducted by Khadse et al (2019), 78.7, 85.7 and 90.9 per cent of the farmers claim an increase in yield, an improvement in income and a decrease in production cost, respectively. On the other hand, the net returns in SPNF varied from 11.80 to 21.55 per cent, in comparison to CF system in all the crop categories. The increased returns in SPNF can be attributed to the savings in expenditure due to non-use of chemical fertilizers, pesticides and additional income from intercrops. Mix cropping helped utilise the farm area more efficiently than sole crop cultivation to further increase the net profit, in addition to increase the variety of

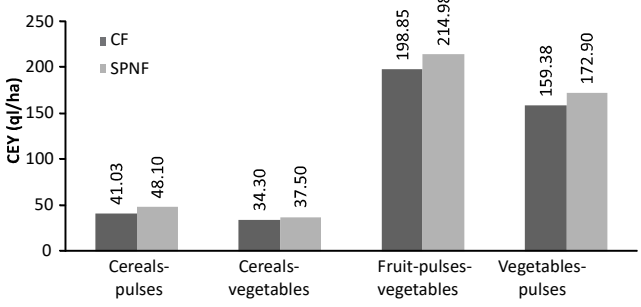


Fig. 3. Crop Equivalent Yield (CEY) of various crop combinations under SPNF and CF system

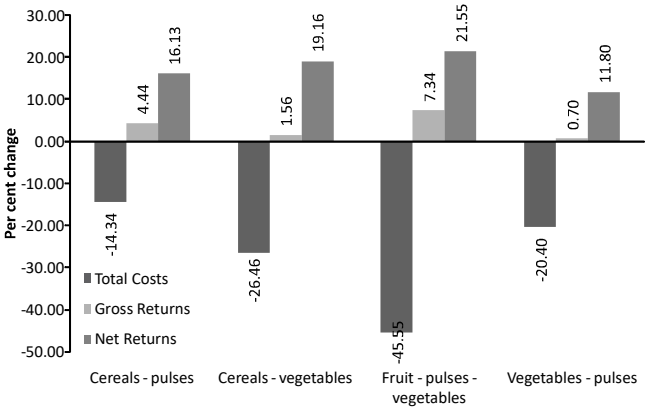


Fig. 4. Economic impact of SPNF over CF system

Table 3. Comparative economics of crop combinations under SPNF and CF

Particulars	Economics of farming systems (Rs ha^{-1})						REE (%)
	SPNF			CF			
	Total costs	Gross returns	Net returns	Total costs	Gross returns	Net returns	
Cereals and pulses	58,938	1,87,213	1,28,275	68,800	1,79,263	1,10,463	16.13
Cereals, pulses & vegetables	81,638	2,92,350	2,10,713	1,11,025	2,87,863	1,76,838	18.82
Fruit, pulses & vegetables	1,31,025	12,19588	10,88,563	2,40,638	11,36,200	8,95,563	21.55
Vegetables and pulses	99,613	3,65,288	2,65,675	1,25,138	3,62,763	2,37,625	11.80

available crop produce at different times in a cropping season. It was also observed that none of the farmer was adopting SPNF technique following all its four principles in the initial formative year of practice on their farms. However, it was also interesting to record that the trained farmers were well conversant with their SPNF practice deficiencies, for which they were committed to overcome in the proceeding cropping seasons.

In conclusion, the farmers of Himachal Pradesh are practicing SPNF on different crop combinations on an average area of 0.26 ha. The farmers displayed the highest interest to practice SPNF in fruit-pulses-vegetable combination (40.6%), resulting in the maximum returns (REE=21.44%). The farming system resulted in the positive impact on the farmers' income thereby reducing the cost of cultivation (14.34-45.55%) and increasing the net returns (11.8-21.55%) in comparison to the CF system. Our results, based on the preliminary years of SPNF implementation in the State, envisage that this farming system carries the potential to increase farmers' income through cost reduction vis-à-vis sustainability of long term production and income.

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Productivity and Quality of Sweet Potato Leaves (*Ipomoea batatas*) as Animal Feed in Integrated System in the Abadoned Limestone Mining Site

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Abstract: The negative impact of the limestone mining activities is the formation of bare land which results in ecosystem changes to the limestone mountain. Changes in the ecosystem will reduce the productivity, quality and continuity of forage availability so that it can reduce the performance and development of goats farming in the limestone mountain areas. Therefore, it is necessary to utilize the abandoned-limestone mining site through an integrated system of livestock with sweet potato plants (*Ipomoea batatas*) as feed and forage sources. This study aims to determine the interaction effect between local sweet potato types and the level of goat compost fertilization on the productivity and quality of sweet potato leaves as small ruminants' feed. The study was conducted through an experimental method in bare land of abandoned limestone mining site applying factorial complete randomized design complete (CRD) with 3 replicates. The first factor was three types of local sweet potatoes namely purple (V), white (W) and orange (O); the second factor was fertilization levels of goat litter compost namely k1 (0.5 kg m^{-2}), k2 (1.0 kg m^{-2}), k3 (1.5 kg m^{-2}) and k4 (2.0 kg m^{-2}) fertilizations. The parameters measured were the productivity and quality of sweet potato leaves. The results showed that the productivity of sweet potato leaves was influenced by the type of sweet potato and the level of goat compost fertilization; the quality of sweet potato leaves was only affected by sweet potato types. Orange (O) sweet potato with a minimum level of goat compost fertilization of 1.5 kg/m^2 (15 tonnes/ha) (k3) was the suitable formula to be developed in former limestone mining areas.

Keywords: Goat compost, Sweet potato leaves, Limestone mountain

Limestone mountains are landscapes that have strategic functions for the environment because they serve as source of building materials, water resources, biodiversity and forages. Sarwanto et al (2015) showed that the diversity of indigenous forages in the limestone mountains of Gombong, Central Java, Indonesia reached 36 species consisting of 12 grass species (33.3%), 8 legumes (22.2%), 14 shrubs (38.9%) and 2 ferns (5.6%) with fresh production of about 29.75 tonnes/ha/year. The diversity of indigenous forage is dominated among others by *Eragrostis amabillis*, *Cynodon dactylon*, *Centrosema pubescens* and *Urena lobata* species. The limestone mining activities carried out by the community leaves bare land which causes changes in the limestone mountain ecosystem. Sarwanto and Prayitno (2015) reported that limestone mining results in changes in the ecosystem as indicated by a decrease in the diversity and productivity of indigenous forage by 58.1 and 72.41%. The indigenous forage species of *Cynodon dactylon*, *Imperata cylindrica* and *Themeda arguens* are still found in abandoned-limestone mining site. Apart from mining activities, many people raise goats as an effort to support the family economy on the site. Decreasing diversity and productivity of indigenous forage due to limestone mining activities can reduce goat productivity and community welfare. The goats keeping in the limestone mountain area uses a traditional system where forage, goat's urine and faeces are mixed to produce large amounts of goat compost litter.

One way to make utilize the bare land from abandoned-limestone mining site is the integrated system i.e. re-vegetation of food crops fertilized with goat compost litter. Sarwanto and Tuswati (2018) conducted bare land re-vegetation of abandoned-limestone mining by developing forage in the form of dwarf elephant grass (*Pennisetum purpureum* cv *Mott*) fertilized with goat litter compost as much as 1.5 kg m^{-2} or 15 tons ha^{-1}. The addition of goat litter compost aims to increase the fertility of the abandoned-limestone mining soil because it contains total nitrogen: 0.049 - 0.141%; P2O5: 0.067 - 0.133%; and K2O: 0.086 - 0.100 %. The abandoned-limestone mining area can be utilized through an integrated system of goats farming with food crops. The suitable food crop to be developed is sweet potato (*Ipomoea batatas*) because sweet potato is suitable for aggro-climate of tropical climates (Kabede et al 2011, Lam 2016) including Indonesia. Sweet potatoes can grow on various kinds of soil, are favoured by the community and

have of high economic value. Kabede et al (2008) and Kabede et al (2011) stated that the sweet potato plant is a traditional plant in tropical countries that is resistant to drought. Sweet potato plants are source of protein and minerals that can be provided as goat feed. Sweet potato plants can be used as a substitute for concentrate, in which the provision is up to 50% of the total feed given to goats. The results of research conducted by Sun et al (2014) show that sweet potato leaves have high nutrient value because they are a source of protein, fibre, minerals such as Ca, P, K, Mg, Fe, Mn and Cu, and it contain antioxidants. The results of research by Irungu et al (2017) show that sweet potato plants have a good post-harvest regeneration rate, diseases resistant as well as drought resistant. Sweet potato leaves are also a superior forage that can increase livestock production. Zereu et al (2014) added that sweet potato plants have high-quality leaves, petioles and stems which can be used as forage especially for small ruminants (Yacout et al 2016).

The integrated system between plants and livestock according to Russelle et al. (2006) can guarantee environmental sustainability, utilize livestock compost to increase soil fertility, ensure the availability of forage and can increase farmers' profits. Hilimire (2011) states that the system of integrating crops with livestock is the right alternative to current agricultural systems because it can increase soil fertility, increase agricultural yields, produce food diversity and increase land efficiency. Therefore, the implementation of the integrated system of goats - sweet potato plants is expected to reduce the damage to the ecosystem due to limestone mining activities.

MATERIAL AND METHODS

The study was conducted in a bare land of the abandoned-limestone mining, Gombong limestone mountains, Kebumen Regency, Central Java Indonesia. The analysis was conducted at the Feed Laboratory, Faculty of Animal Science, Jenderal Soedirman University, Purwokerto, Central Java Indonesia. The experiment was in factorial I design in completely randomized design with 3 replicates. The research treatments were as follows:

Factor I (local type of sweet potatoes): P: Purple sweet potatoes, W: White Sweet potatoes, O: Orange sweet potatoes

Factor II (level of goat litter fertilization): k1: k2 k3 and k4 - 0.5, 1.0, 1.5 and 2.0 kg m^{-2}.

There were 36 experimental units with an area of 2.0 m^2 for each experimental unit and a distance between plots of 0.5 m. The seedlings are 20 cm long and 6 cm deep. Compost was given in the experimental field 7 days before planting. Harvesting of sweet potatoes was carried after 3.5 months. The measured response variables were: productivity of sweet potato leaves including production of fresh sweet potato leaves (tonnes ha^{-1}) and production of dry sweet potato leaves (tonnes ha^{-1}); quality of sweet potato leaves determined by the crude protein content (AOAC 1990), digestibility of dry matter and organic matter (Tilley and Terry 1963), levels of total volatile fatty acids (steam distillation) and levels of $N\text{-}NH_3$ carried out in vitro using inoculum of bovine rumen fluid. The data obtained were analysed according Steel and Torrie (1980).

RESULTS AND DISCUSSION

Fresh Production of Sweet Potato Leaves (tonnes ha^{-1}): Fresh production of sweet potato leaves consists mostly of leaves and petioles as well as a few plant stems. Fresh production of sweet potato leaves of different types of sweet potato with various levels of goat litter compost was in the range of 6.6 - 16.6 tonnes ha^{-1} (Table 1). Most of the sweet potato waste in Ethiopia was given to livestock (51.1%) in fresh form, 45.6% in wilted form, while the remaining 2.3% was a mixture of fresh and wilted (Bayero et al 2010). Providing sweet potato waste to goats up to 75% of the total forage results in high consumption, daily body weight gain and efficiency (Aregheore 2004). The lowest fresh production of sweet potato leaves was at Pk2 and Pk4 whereas the highest fresh production of leaves was in Ok3 (Table 1).

Fresh production of sweet potato leaves was highly influenced by the type of sweet potato but not by the level of goat litter fertilization. Fresh production of P and W sweet potato leaves was lower than sweet potato O which can be caused due to differences in the morphology of leaves shape and number of leaves. The number of O sweet potato leaves was 114-197 with a leaves width of about 107-121 mm; the number of P sweet potato leaves was 97-158 with leaf width of 56-80 mm and the number of W sweet potato leaves was 88-157 leaves with leaf width of about 59-82 mm. This causes the fresh production of O sweet potato leaves to be higher than other types of sweet potato. The level of goat litter compost fertilization did not affect the fresh production of sweet potato leaves. This indicates that the addition of nutrients from goat litter compost to calcareous soils does not increase plant development. Susanto et al (2014) observed that fertilizing sweet potatoes with cow manure 30 days before planting increased the average number of leaves and leaf width per plant so as to increase the fresh production of sweet potato leaves waste. Nitrogen is a macro nutrient needed by plants because it can stimulate the growth of shoots, stems and leaves. The medium for planting sweet

potatoes is a mountainous area of South Gombong limestone which has a moderate nitrogen nutrient content, i.e., 0.24-0.43% (Sarwanto et al 2015). Another factor suggested to affect growth is soil moisture, which was very high ranging from 82-98%. Soil moisture can affect air circulation in the soil and soil pH which has an impact on the growth and supply of plant nutrients. The use of goat litter compost in the Gombong limestone mountains did not significantly increase soil nutrients for the growth of sweet potato plants. The goat litter compost in the limestone mountains had a high nutrient content, namely total N (5.498%), P2O5 (1.112%) and K2O (0.582%). However, the disadvantage of goat litter compost is that the C/N ratio is very low (4.06), which is still far from the ideal C/N ratio standard of 10-20.

Dry matter production of sweet potatoes leaves (ton ha^{-1}): The production of dry matter, apart from being influenced by the fresh production of sweet potato leaves, is also influenced by the dry matter content. The dry matter content and dry matter production of sweet potato leaves from the study were 9.51-16.64% and 0.691-1.673 tonnes/ha, respectively (Table 2). The dry matter content of sweet potato is lower than observations of Owusu et al (2008) which ranged from 11.80 to 19.84%. Murugan et al (2012) observed 16.3-18.9% and Zereu et al (2014) recorded 19.6-22.7%. The dry matter production of sweet potato leaves from this study was lower than the research by Sirait and Simanihuruk (2010) which stated that the production of properly fertilized sweet potato leaves was 7.51 tonnes ha^{-1} year^{-1} or 2.5 ton/ha/harvest.

The types of sweet potato and the levels of goat litter fertilization had a highly significant effect on the dry matter production of sweet potato leaves, though there was no interaction between the two factors. The dry matter production of O sweet potato leaves with levels of K3 and K4 fertilization was higher than the dry matter production of other treatments. Fertilization levels of k3 and k4 in sweet potato varieties P and W also tended to increase the production of dry matter although was statistically not different from the levels of k1 and k2 fertilization. This level of k3 and k4 fertilization resulted maximum dry matter production among other treatments, whereas the type of sweet potato leaves producing the highest dry matter production was sweet potato leaves O and the lowest was sweet potato leaves P. The Ok3 and Ok4 treatments produced themaximum dry matter . The dry matter production of O sweet potato leaves was the highest compared to other treatments. This could be because O sweet potato leaves produced the highest fresh sweet potato leaves among P and W sweet potatoes (Table 1). Thus, this may increase dry matter production of sweet potato leaves. Susanto et al (2014) showed that fertilizing sweet potato with cow manure 30 days before planting increased the average total dry weight of the plant indicating that the production of dry matter of plant leaves also increased. The higher the level of goat litter fertilization, the higher was the dry matter production of sweet potato leaves as a result of the increasing number of leaves and width of fresh sweet potato leaves. However, the effectiveness of K3 and K4 fertilization levels tended to be lower than the observations of Olorunnisomo et al (2006) which uses NPK and urea fertilizers, which can increase the dry matter production of sweet potato forage by 38.73%. The macro nutrient content of goat litter compost in this study was lower than inorganic fertilizers so that it was not optimal enough to increase the dry matter production of sweet potato leaves.

Crude protein content of sweet potato leaves: The crude protein content of local sweet potato ranged from 15.08 to 18.37% and was lower than estimated by earlier workers as 19.38 (Kabede et al 2008), 16.78-25.39 (Owusu et al 2008), 26.9 (Murugan et al 2012) and 20.5-28.4 percent(Zereu et al 2014).

Table 1. Fresh production of sweet potato leaves (tonnes ha^{-1}) with various levels of goat litter fertilization in bare land of the abandoned-limestone mining site

Sweet potato leaves	Levels of goat litter fertilization (kg m^{-2})			
	0.5 (k1)	1.0 (k2)	1.5 (k3)	2.0 (k4)
Purple sweet potatoes (P)	6.7^{a}	6.6^{a}	7.3^{a}	6.6^{a}
White sweet potatoes (W)	7.0^{a}	7.0^{a}	7.4^{a}	6.8^{a}
Orange sweet potatoes (O)	13.5^{b}	14.6^{b}	16.6^{b}	15.6^{b}

Different superscripts on the same column shows highly significant different (P<0.01)

Table 2. Dry matter production of sweet potato leaves (tonnes/ha) with various levels of fertilizing goat litter in bare land of the abandoned-limestone mining

Sweet potato leaves	Levels of goat litter fertilization			
	0.5 kg m^{-2} (k1)	1.0 kg m^{-2} (k2)	1.5 kg m^{-2} (k3)	2.0 kg m^{-2} (k4)
Purple sweet potatoes (P)	0.73^{aa}	0.69^{ab}	0.94^{ac}	1.02^{ac}
White sweet potatoes (W)	0.88^{ba}	1.11^{bb}	1.15^{bc}	1.01^{bc}
Orange sweet potatoes (O)	1.32^{ca}	1.39^{cb}	1.67^{cc}	1.67^{cc}

Different superscripts on the same column shows highly significant different (P<0.01)

The crude protein content of sweet potato was highly significantly influenced by the type of sweet potato but not by the level of goat litter fertilization. The type of sweet potato (W) with various levels of goat litter fertilization produced the lowest crude protein content of leaves among other treatments, whereas the protein content of P and O sweet potato leaves at all levels of fertilization was the same. This is presumably because the crude protein content of W sweet potato leaves is lower than those of other types of sweet potato. Plant protein content can be affected by the amount of nitrogen in the planting medium and fertilization (Lam 2016). The higher the addition of nitrogen in the planting medium will increase the crude protein content of sweet potato leaves. However, this was not the case in this study. The higher the level of compost litter fertilization did not significantly increase the crude protein content of sweet potato leaves. This can type of sweet potato growing media, namely limestone mountains have a relatively moderate nitrogen content (0.24-0.43%) (Sarwanto et al 2015). The addition of organic fertilizer of goat compost is be due to insufficient to increase productivity and crude protein content of sweet potato. This is also supported by the result of no difference in the fresh production of sweet potato leaves (Table 1), which indicates that plant productivity does not significantly increase Olorunnisomo et al (2006) observed that fertilizing sweet potato with NPK and urea did not increase the crude protein content in the root of the sweet potato. This could be an indication that the sweet potato leaves also do not experience an increase in crude protein content.

In vitro dry matter digestibility (DMD) *:* The in vitro digestibility of the sweet potato leaves waste ranged from 53.79 to 93.61% (Table 4), which tended to be lower than the study by Zereu et a. (2014) being 90.6 - 91.5%, and Chanjula et al (2003)being 87.8 - 87.9%.

The dry matter digestibility (DMD) of sweet potato leaves was strongly influenced by the type of sweet potato but was not affected by the level of goat litter compost fertilization. The highest value of DMD was with waste of sweet potato leaves P with an average of 87.71-93.61% followed by sweet potato W with an average of 71.10-78.28% and sweet potato O with an average 53.79-69.14% average, respectively. Factors that affect the digestibility of dry matter include crude fibre content and crude plant protein. The highest digestibility of dry matter in P potato leaves can be due to the balanced crude fibre and crude protein content of sweet potato so that it is easy to be utilised by rumen microbes. The crude protein content in P sweet potato leaves was higher than that of W sweet potato leaves (Table 3), so that it could produce higher DMD than W potato leaves. Onymba et al (2015) showed that the average crude fibre content of Nigerian local sweet potato leaves reached 25.10% with a crude protein content of 20.35%. The crude fibre content of 40 types of local Chinese sweet potato leaves is 9.25-14.26 g/100gBK with crude protein content of 17.53-30.53 g/100gBK (Sun et al 2014). The high crude fibre content can be a limiting factor for the digestibility of dry matter. The level of goat compost fertilization does not affect the digestibility of dry matter of sweet potato leaves waste. This can be due to the fact that fertilization also does not affect the crude protein content of leaves waste (Table 3). Macronutrients are needed in the formation of plant organic matter. Sarwanto et al (2015) observed that that macro nutrient content of the South Gombong limestone mountains has an organic matter of 2.9-4.52%, a moderate nitrogen content of 0.24-0.43%, a low P2O5 and K2O content of 0.095-0.184% and 0.069-0.237% and the high Ca content reaching 2.76%. This causes the development and quality of forage plants to be low. Fertilization of sweet potatoes using goat compost in the limestone mountains is thought to be insufficient to improve the quality of the nutrients in the planting medium so that the quality of plant organic matter is also low.

In vitro organic matter digestibility (OMD): The organic matter content of the sweet potato leaves was P: 82-84%. W: 83-85% and O: 76-80%. The organic matter content is lower than observations by Yacout et al (2016) being 89.38-91.11% and Murugan et al (2012) being d 85.9-91.5%. The digestibility of the organic matter of sweet potato leaves was around 94.49-97.26%; this value is not much different from the observation of Dominguez and Ly (2016). The digestibility of organic matter from sweet potato leaves was not affected

Table 3. Crude protein content (%) of sweet potato leaves with various levels of fertilization of goat litter compost in bare land of the abandoned-limestone mining

Sweet potato leaves waste	Levels of goat litter fertilization			
	0.5 kg m^{2} (k1)	1.0 kg m^{-2} (k2)	1.5 kg m^{-2} (k3)	2.0 kg m^{-2} (k4)
Purple sweet potatoes (P)	17.31^{a}	17.68^{a}	17.95^{a}	16.90^{a}
White sweet potatoes (W)	16.32^{b}	15.08^{b}	16.35^{b}	16.42^{b}
Orange sweet potatoes (O)	17.78^{a}	17.80^{a}	17.82^{a}	18.37^{a}

Different superscripts on the same column shows highly significant different (P<0.01)

by the type of sweet potato and the level of goat compost (Table 4). However, the average digestibility of all types of sweet potato leaves tended to be high. This shows that all types of sweet potato have high organic matter digestibility. Organic matter is part of dry matter, namely carbohydrates, proteins, fats, and vitamins so that the value and factors that affect the digestibility of dry matter are the same as the digestibility of organic matter. The dry matter digestibility of Jara Jara leaves waste was lower than the other treatments followed by the same organic matter digestibility as the other treatments. This is also supported by the same leaves waste protein content in all types of sweet potato. Irungu et al (2017) mentioned that the type of sweet potato does not affect the digestibility of the organic matter of sweet potato leaves. There was no difference in OMD due to different levels of fertilization, which could be due to the macro nutrient elements of the planting medium which did not increase with an increase of goat compost fertilization. The planting medium in the form of limestone soil containing 2.758% calcium causes plants to be lack of micro nutrients such as iron (Fe), manganese (Mn), zinc (Zn) and copper (Cu) which can reduce plant productivity and quality (Sarwanto et al 2015). Fertilization using goat compost is thought to be insufficient to improve the quality of the planting medium so that it does not affect the organic matter content of plants.

Volatile fatty acids production: Volatile fatty acids are the main energy source for ruminants, which comes from the carbohydrates fermentation. The production of VFA in several types of sweet potato with various levels of goat litter compost was in the range of 106.0-162.0 mM (Table 4), which is higher than observations of Sudarman et al (2016) namely 116.39 mM in the treatment of giving 50% sweet potato leaves with in vitro elephant grass basal feed. Irungu et al (2017) observed VFA production in four types of sweet potato leaves which vary 124.43 to125.03 mM. VFA production of sweet potato leaves was not significantly influenced by the type of sweet potato leaves and the level of goat litter fertilization. These results indicate that the non-structural carbohydrate content of the three types of sweet potato leaves is the same. Sun et al (2014) showed that the carbohydrate content in 40 types of sweet potato leaves was quite high, (42.82-61.26 g/100g DM). The high carbohydrate content of the three types of sweet potato is thought to be due to t high VFA production. Easily dissolved carbohydrates such as starch will be hydrolysed by rumen microbial enzymes then fermented into VFA, namely acetate, propionate and butyrate as well as CH_4 and CO_2 gases. The level of goat litter compost fertilization did not affect the VFA production of sweet potato leaves. This is because the addition of compost to the limestone soil is not sufficient to

Table 4. Dry matter digestibility (%), organic matter digestibility (%), VFA production (mM), and N-NH3 production of sweet potato leaves waste with various levels of goat compost fertilizer fertilization in bare land of the abandoned- limestone mining areas

Sweet potato leaves waste	Levels of goat litter fertilization			
	0.5 kg m^2 (k1)	1.0 kg m^{-2} (k2)	1.5 kg m^{-2} (k3)	2.0 kg m^{-2} (k4)
DMD				
Purple sweet potatoes (P)	88.31[a]	93.61[a]	88.78[a]	87.71[a]
White sweet potatoes (W)	71.10[b]	78.28[b]	78.12[b]	78.17[b]
Orange sweet potatoes (O)	64.04[c]	62.32[c]	69.14[c]	53.79[c]
OMD				
Purple sweet potatoes (P)	96.46	96.23	96.52	96.39
White sweet potatoes (W)	94.49	96.62	96.67	96.56
Orange sweet potatoes (O)	96.82	96.61	96.63	97.26
VFA Production				
Purple sweet potatoes (P)	132.7	139.3	116.7	146.7
White sweet potatoes (W)	151.3	162.0	106.0	157.3
Orange sweet potatoes (O)	141.3	140.7	138.7	145.3
$N\text{-}NH_3$ Production				
Purple sweet potatoes (P)	9.2[a]	10.4[a]	9.3[a]	11.3[a]
White sweet potatoes (W)	10.6[b]	9.4[b]	13.2[b]	17.9[b]
Orange sweet potatoes (O)	16.4[c]	16.1[c]	13.1[c]	14.6[c]

Different superscripts on the same column shows highly significant different (P<0.01)

increase the organic matter content of the plant, thus it affects the digestibility and amount of feed fermentation in the rumen. Goat litter compost may have a low nutrient content so that it is unable to improve the nutrients of limestone soil as the growing medium for sweet potatoes.

N-NH_3 production: Ammonia (NH3) is the result of fermentation of feed protein in the rumen which is used as a nitrogen source for microbial protein synthesis. The production of N-NH3 in several types of sweet potato with various levels of goat litter compost was in the range of 9.2-17.9 mM (Table 4), which is higher than the observation by Sudarman et al (2016) of about 9.01 mM. The production of N-NH_3 for various types of sweet potato leaves was strongly influenced by the type of sweet potato but was not influenced by the level of goat litter compost fertilization. In general, O sweet potato leaves resulted in greater N-NH_3 production than other treatments, though at the level of k4 fertilization it n lower N-NH_3 production than W sweet potato leaves. Ammonia production was strongly influenced by the protein content of the feed plant. The high production of O sweet potato leaves ammonia is due to the high crude protein content of sweet potato leaves (Table 4). However, different results occurred in P sweet potato leaves. Although P sweet potato leaves had the same crude protein content as sweet potato O, it had the lowest ammonia production among other types of sweet potato. This can be influenced by the quality of the protein and the anti-nutritional content of the purple sweet potato leaves. From the study, it is suggested that P sweet potato leaves was has a high anti-trypsin substance and thus it reduces protein digestibility and protein fermentation into ammonia.

CONCLUCION

Orange sweet potato (O) with a fertilization level of 1.5 kg/m^2 and 2.0 kg/m^2 (Ok3 and Ok4) is the right treatment to be developed in the abandoned-limestone mining areas. The development of orange sweet potato with a minimum fertilization level of goat litter of 1.5 kg/m^2 will increase the supply of forage in the limestone mining area.

CONFLICT OF INTEREST

The Authors declare that there is no conflict of interest or nil.

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Impact of Different Planting Dates and Plant Spacing on Vegetative and Floral Characteristics of *Zinnia elegans* in Kashmir Valley

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***Abstract*:** A study was undertaken to evaluate the impact of different planting dates *viz.,* 2nd week of May, 4nd week of May, 2nd week of June and 4nd week of May, and different plant spacing *viz.,* 30 × 30 cm, 30 × 40 cm and 30 × 50 cm on Zinnia in Kashmir valley. Results revealed that early sown crop, 2nd week of May took higher number of days to attain various phenophases, whereas, wider plant spacing of 30 × 50 cm proved to be best for almost all vegetative and flowering characteristics, whereas, closer spacing 30 × 30 cm resulted in maximum plant height.

***Keywords*:** Growth, Planting date, Spacing, Yield, Zinnia

Zinnia is a plant of sunflower tribe belongs to family Asteraceae, they are native to scrub and dry grassland stretching from the South-west to South America, with Mexico as centre of diversity. The genus name honours German master botanist, Johann Gottfried Zinn. *Zinnia elegans* known as youth-and-age, is a popular garden flower, preferably grows well in full sunshine, fertile, well drained and humus rich soil. Zinnia plants are champion of summer season annuals, ranges in height from 15-100 cm, leaves are sandpapery in texture, contrary, generally stalk less (sessile), pale to middle green in colour and having different forms (linear and ovate). Members of the genus are notable for their solitary long-stemmed flowers with wide range of bright colour. Zinnia is used as cut flower in beds, containers, border and background (Yassen et al 2010). Zinnia can also be used as mix-crop in tomatoes against nematodes, White Zinnia is also used for remedy of kidney and in treatment of swelling or aches (Mantur 1988).

Planting date and planting density has significant influence on growth and flowering of zinnia. Planting dates depend upon environmental conditions and the geographical location of the area, because of great variation in plant growth and blooming dates due to natural environment conditions, planting schedule cannot be determined on national scale. Environmental conditions varies from one location to other, therefore there is need to work out the planting schedule for the particular zone to optimize the growth, flower quality and yield of different annuals (Sharma et al 2013). Date of planting plays an important role in flower regulation, vegetative growth and quality and also satisfies the consumer's demand (Zubair et al 2006). Kashmir valley is located at an altitude of 1600 meters above mean sea level, there is synchronization of wet season with transplanting and dry season with that flowering and seed set timing, thus widens the scope for flower quality and ultimately seed production.

MATERIAL AND METHODS

The present investigation was carried out at Floriculture Research Farm, Division of Floriculture and Landscape Architecture. Sher-e-Kashmir University of Agriculture Science and Technology, Shalimar, Srinagar, during year 2017-18 to 2018-19. The experimental farm is located between 34° 05′ N latitude and 74° 98′ E longitude at an altitude of 1587 meters above mean sea level. The climate is temperate-cum-Mediterranean and continental type characterized by hot summer and severe winters. The average annual precipitation is 944.6 mm, and more than 80% precipitation received from western disturbances. The experiment consisted of four different planting dates (P_1 = 2nd week of May, P_2= 4th week of May, P_3= 2nd week of June and P_4 = 4th week of June) as main plot treatment and three plant spacing (S_1= 30×30 cm, S_2= 30×40 cm and S_3= 30×50 cm) as sub plot treatment. Healthy seedlings of uniform size and vigour at 5-6 leaf stage were selected and transplanted during evening time in seed beds accommodating (20, 16 and 12 plants m^{-2}). Five plants were randomly selected from each plot for collecting data. Mean value of all the parameters were analysed by Duncan's multiple range test (DMRT) at 5% level of probability. The experiment comprised of 12

different treatment combinations laid out in Split Plot Design and replicated thrice.

RESULTS AND DISCUSSION

Vegetative characters: Planting dates and plant spacing has significant effect on vegetative characteristics of zinnia. Maximum plant height of 124.66 cm was recorded in plants planted in 2nd week of May in comparison to plants planted in 4th week of June with plant height of 117.23 cm. These results are in accordance with the finding of Mishra (1997) and Dilta et al (2007) who reported increase in plant height may be attributed to favourable growing conditions with more vegetative growth and grew comparatively much longer in early planting and decreased with delayed planting. Favourable conditions with respect to temperature and relative humidity during growing period allow more photosynthesis and encourage plant growth. Plants spaced at 30 × 30 cm resulted maximum plant height of 122.44 cm in comparison to plants spaced at 30 x 50 cm recorded plant height of 119.19 cm. Srivastava et al (2002) in marigold, Singh and Sangama (2000) in china aster. Karavadia and Dhaduk (2002) in annual chrysanthemum, Wahba et al (2002) in *Chrysanthemum coronarium* and Beniwal et al (2003) in Chrysanthemum cv. Flirt reported production of taller plants with close spacing, this might be due to the fact that accommodating more number of plant per unit area create greater competition between plants for space, water, nutrients, sunlight and air thus, plant grow more in vertical growth.

In Perusal to data recorded significant effect of planting dates and plant spacing on number of primary branches plant^{-1} and secondary branches plant^{-1}. Plants planted in 2nd week of May resulted highest number of primary branches plant^{-1} (7.81) and secondary branches plant^{-1} (23.38) compared to 6.10 and 20.52 recorded in plants planted in 4th week of June. These results are in close agreement with the findings of Patil et al (2005) in gaillardia, Bhardwaj and Kumar (2001) in chincherinchee, Sharma et al (2013) in paper flower, Kaushal et al (2014) who reported relatively congenial weather conditions required for growth of zinnia might be prevailing during this cropping period in comparison to other planting dates thus, resulted in more vegetative growth in terms of number of nodes confined with maximum, number of primary and secondary branches plant^{-1}. Wider plant spacing leads to less inter plant competition for space, light and nutrients thus resulted maximum number of primary branches plant^{-1} (7.67), secondary branches plant^{-1}(23.04)and number of leaves plant^{-1}(143.88) spaced at 30 × 50 cm apart compared to plants spaced at 30 × 30 cm recorded lowest of primary branches plant^{-1}(6.35), secondary branches plant^{-1}(21.19)and number of leaves plant^{-1}(136.69). Similar results were recorded by Chanda and Roy Choudary in African marigold cv. Siracole (1991) and Belgoankar et al (1996) in annual chrysanthemum who reported highest lateral production under widely spaced plants.

Flowering characters: Perusal of data presented showed significant effect of planting dates and spacing on days taken to flower bud appearance and anthesis. Plants planted in 4th week of June resulted flower bud appearance and anthesis in 37.92 and 50.55 days respectively, whereas maximum days taken to flower bud appearance and anthesis (41.47 and 52.94 days) was recorded in plants planted in 2nd week of May. These results are in close conformity with the findings of Gowda (1990) and Dilta et al *(*2007) who reported similar result in china aster. Temperature is consider as the major factor influencing the number of days taken to flower bud

Table 1. Effect of planting dates and spacing on plant height (cm), number of primary and secondary branches plant^{-1} of Zinnia (*Zinnia elegans* Jacq.)

Treatment	Plant height (cm)				Number of primary branches plant^{-1}				Number of secondary branches plant^{-1}			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
P_1	126.78	124.66	122.56	124.66	7.26	7.93	8.25	7.81	22.50	22.83	24.83	23.38
P_2	123.68	122.81	120.01	122.16	7.13	7.71	7.78	7.54	21.56	22.15	23.50	22.40
P_3	121.49	119.61	118.01	119.70	5.61	6.81	7.75	6.72	21.20	21.61	22.20	21.67
P_4	117.23	117.61	116.21	117.23	5.40	5.98	6.91	6.10	19.50	20.41	21.65	20.52
Mean	122.44	121.17	119.19	-	6.35	7.11	7.67	-	21.19	21.75	23.04	-
CD (p=0.05)												
P			1.16					0.86				1.19
S			0.97					0.37				1.03
P × S			N.S.					N.S.				N.S.

Planting dates- P_1- 2nd week of May, P_2- 4th week of May, P_3- 2nd week of June, P_4- 4th week of June
Plant spacing- S_1- 30 X 30 cm, S_2-30 x 40 cm, S_3- 30 x 50 cm

appearance and anthesis, early transplanted seedlings being exposed to lower temperature showed delay in days taken to flower bud appearance and anthesis, however warmer temperature promote it. Plants spaced at 30 × 30 cm resulted flower bud appearance and anthesis in mean minimum days taken to flower bud appearance and anthesis in 38.91 and 50.83 days compared to plants spaced at 30 × 50 cm apart resulted flower bud appearance and anthesis in 40.03 and 52.25 days. Wider spacing favours availability of nutrients, sunlight and soil moisture to individual plants, resulted in increased vegetative growth of the plant and thus, delayed flower initiation as well as 50% flowering, while closer spacing might increase competition among plants for nutrients, water and sunlight resulting in quick cessation of vegetative growth and forcing the plants to flower earlier (Sreekanth 2005).

Highest (8.90 cm) flower diameter was recorded in 2nd week of May transplanted plants whereas lowest (7.40 cm) flower diameter was recorded in plants planted in 4th week of June. According to Mohanty et al (2015) moderate temperature prevailing during the crop period when planted in 2nd week of May might resulted in development of flowers with highest diameter and weight. Highest flower diameter of 8.61cm was recorded in plants spaced at 30 × 50 cm apart which is statistically superior to 7.17 cm recorded in plants spaced at 30 × 30 cm apart. Optimum spacing of 30 × 50 cm resulted efficient utilization of soil surface area along with more sunlight and also higher root activity. These results are also in the conformity with Belorkar et al (1992) in African marigold who observed highest flower diameter of 6.52 cm in plants spaced of 45 × 30 cm apart.

Data recorded on number of flowers plant^{-1} as influenced

Table 2. Effect of planting dates and spacing on plant spread (cm), days taken to flower bud appearance and days taken to anthesis of Zinnia (*Zinnia elegans* Jacq.)

Treatment	Plant spread (cm)				Days taken to flower bud appearance				Days taken to anthesis			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
P_1	52.08	57.04	66.86	58.66	40.77	41.16	42.50	41.47	52.16	52.83	53.83	52.94
P_2	50.84	55.76	66.20	57.60	39.44	39.83	40.50	39.92	51.50	52.16	52.50	52.05
P_3	49.83	55.20	64.26	56.43	37.96	38.37	38.77	38.37	50.50	51.00	51.16	50.88
P_4	49.03	52.83	61.06	54.31	37.50	37.90	38.36	37.92	49.16	51.00	51.50	50.55
Mean	50.45	55.21	64.60	-	38.91	39.32	40.03	-	50.83	51.75	52.25	-
CD (p=0.05)												
P				1.27				0.78				0.64
S				1.80				0.75				0.65
P × S				N.S.				N.S.				N.S.

Planting dates- P_1- 2nd week of May, P_2- 4th week of May, P_3- 2nd week of June, P_4- 4th week of June
Plant spacing- S_1- 30 X 30 cm, S_2-30 x 40 cm, S_3- 30 x 50 cm

Table 3. Effect of planting dates and spacing on flower diameter (cm), number of flowers per plant and duration of flowering (days) of Zinnia (*Zinnia elegans* Jacq.)

Treatment	Flower diameter (cm)				Number of flowers plant^{-1}				Duration of flowering (days)			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
P_1	7.64	8.92	9.19	8.58	20.33	22.50	23.83	22.22	39.66	40.83	42.16	40.88
P_2	7.90	9.46	9.33	8.90	18.33	20.33	22.16	20.27	38.16	38.83	39.66	38.88
P_3	6.56	8.16	8.06	7.60	17.66	19.50	20.66	19.27	37.00	37.83	38.83	37.88
P_4	6.60	7.71	7.90	7.40	14.33	17.83	19.33	17.16	35.00	37.50	38.33	36.94
Mean	7.17	8.48	8.61	-	17.66	20.04	21.50	-	37.45	38.75	39.75	-
CD (p=0.05)												
P				0.41				1.49				0.69
S				0.36				0.76				0.89
P × S				N.S.				N.S.				N.S.

Planting dates- P_1- 2nd week of May, P_2- 4th week of May, P_3- 2nd week of June, P_4- 4th week of June
Plant spacing- S_1- 30 X 30 cm, S_2-30 x 40 cm, S_3- 30 x 50 cm

by different planting dates revealed 2nd week of May transplanted plants recorded maximum (22.22) number of flowers plant^{-1}, whereas, minimum (17.16) number of flowers plant^{-1} were recorded in 4th week of June transplanted plants. The results are similar to findings of Mishra (1997) and Samantaray et al (1999) in marigold reported favourable environmental conditions for vegetative and reproductive growth. According to Dilta et al (2007) flower production is a genetic character, but is enhanced by temperature and light particularly. Among different plant spacing, maximum (21.50) number of flowers plant^{-1} were recorded in plants spaced at 30 × 50 cm which was statistically superior to other plant spacing, whereas minimum (17.66) number of flowers plant^{-1} were recorded in plants spaced at 30 × 30 cm apart. These results are in accordance with the results obtained by Berimavandi et al (2011) in calendula who reported wider spacing decreases the competition between the plants thus resulted in increased flower production.

Data pertaining to duration of flowering during both the year of experimentation, as affected by planting dates and plant spacing revealed that 2nd week of May transplanting resulted enhanced flowering duration of 40.88 days, whereas shortest (36.94 days) duration of flowering was recorded in plants transplanted in 4th week of June. These results are in close agreement with the earlier finding of Ghosh and Pal (2008) who reported temperature at the time of planting play a significant role in flowering duration, these plants could get sufficient time for putting up more vegetative and reproductive growth. Plants spaced at 30 × 50 cm apart resulted flowering duration of 39.75 days compared to 37.45 days recorded in plants spaced at 30 × 30 cm apart. According to Rathore (2007) long period of bloom under wider spacing may be due to fact that wider spacing provide congenial growing conditions to individual plant thus increased the duration of bloom.

CONCLUSION

Zinnia plants transplanted in 2nd week of May contributed best towards vegetative, floral and yield attributes in terms of plant height, number of primary branches per plant, number of secondary branches per plant, number of leaves per plant, leaf area plant, plant spread, flower diameter, number of flowers per plant and duration of flowering whereas, zinnia plants spaced at 30 x 50 cm apart optimized with best vegetative growth, flowering quality and yield characteristics compared to other provided spacing.

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Perception Based Climate Change Impacts on Forest Vegetation, Farming System and People Health in Uttarakhand Himalaya

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Abstract: The manuscript presents people's perception overview of climate change impacts on forest, farming systems, and human health in Mukteshwar and Joshimath regions of Uttarakhand Himalaya, India. People's perception indicating that climate change has serious, environmental, economic, and social impacts in the study region and pressed impacts on reduced precipitation as well as unseasonal heavy rainfall, longer drought period, which affects regeneration and phenology of forest species, invasion of alien invasive plant species in both forest and agricultural fields, production of fruits, vegetables, and cereal crops. Cultivation of cereal crops has also been affected by different insect pests and pathogens. Reducing adaptation against the climate change impact, the hill people of the study area are starting a mixed cropping system to enhance agricultural production. Climate change coupled with improper management of local resources and the farming systems will induce migration. Proper adaptation and mechanisms to addressing the climate change impacts are needed.

Keywords: Climate change, People's perception, Livelihood, Human health, Socio-economic status

The Indian Himalayan Region (IHR) is home to million people, many of them practice hill agriculture in fragile and diverse ecosystems, including species-rich forests. The climate change has been serious environmental, economic, and social impacts in the Himalayan region. Global climate change is predicted to have significant impacts on land use, livelihood security, and overall stability of social-ecological systems in the Himalayan region (Schild 2008, Chaudhary and Bawa 2011, Hartmann and Buchanan 2013) and beginning about fundamental changes to human behaviour (Evans 2019). In addition to average temperature increase, societies also face increases in the frequency of extreme weather events, air pollution, and sea-level rise, posing an array of physical threats to human health and well-being, both directly and indirectly (Watts et al 2018). Rural communities that depend on the use of natural resources for their livelihood are likely to suffer from its adverse impact of climate change (ICIMOD 2011). The Himalayan region is also experiencing critical problems often relating to climate change such as poverty, environmental degradation, depletion of natural resources, shortage of water resources, and desertification (Schild 2008). Among the most vulnerable to climate change are rural communities with few resources to cope with extreme weather events causing landslides, floods, erosion, drought (Barnett et al 2005, Karmann et al 2007), loss of biodiversity, and threats to food security (Xu et al 2009). Mountain agriculture is highly dependent on weather and seasonal rain and any kind of changes in climate have a major effect on crop yield and food supply in the Himalayan region (Maikhuri et al 2009).

Therefore, the main objective of the present study was to understand the people's perception of climate change and its impact on their livelihood, human health, and their adaptations to cope up with climate change to strengthen the mitigation and adaptation strategies in the Himalayan region.

MATERIAL AND METHODS

The present study was carried out in the mountainous parts of Uttarakhand, mainly in the Mukteshwar region of Nainital district which lies between Latitude: 29°28'19.92"N Longitude: 79° 38' 52.44" [at an average altitude of 2,171 m (7,123 ft), and the Joshimath region of Chamoli district lies between Latitude: 30.5506° N Longitude: 79.5660° E [at an average altitude of 6150 feet (1875 m)] Both regions are rich in flora and fauna diversity. The questionnaire method was used to understand the people's perceptions of climate change. Information on the impact of climate change on agriculture, livestock, and forest land of the study area was collected on the basis of intensive surveys and consultations with the local people through a well-structured questionnaire. A total of 540 participants (270+270) from 18 different villages (9 from each Mukteshwar and Joshimath regions) were interviewed through the questionnaire. All participants were head of their households, comprising both males and

females. The mean age of the participants was 44.7 years and the mean duration of their stay in the locality was 30 years. The majority was in their middle age group (45-60 years) (Table 1). Information was collected on different aspects such as climate variability, water availability, agricultural and livestock productivity, problems related to pests and diseases to livestock and human health, and its overall impact on socio-economic status. The survey was conducted in the local language for better understanding so as to confirm the authenticity and validity of the questions. After the collection of the complete information, the data was analyzed and complied with secondary literature, and then the manuscript was finalized.

RESULTS AND DISCUSSION

All the respondents of the study area were well aware of climate change. On the basis of their response, climate change is an increase in temperature (80.37 and 88.37%) followed by low snow and rainfall, a long drought period, melting glaciers, unseasonal heavy rainfall, rise in sea level both in Mukteshwar and Joshimath regions of western Himalaya (Table 1). In past studies, the local knowledge is consistent with scientific observations. (Sharma et al 2009) have reported a temperature rise in the Eastern Himalaya region mainly in January, February and March (0.01–0.048C annually). The household participants were from rural areas that are vulnerable to climate change (Rabbsni and Thornalley 2015). The local communities in the Himalayan region seem to have widespread indigenous knowledge about climate change impacts and have been successfully coping with these changes (Chaudhary and Bawa 2011, Byg and Salick 2009). Several recent studies (Immerzeel 2008, Bolch et al 2011) indicate that although glacial retreat in the Hindu Kush Himalayan (HKN) region is occurring (Miller et al 2008) have summarized likely changes in the contributions of glaciers to river discharge and rise in sea level. In recent research finding the HKH experienced a significant decline in snowfall (Ren et al 2016, You et al 2015) and glacial area (Kulkarni 2014, Wester et al 2019) in the last 4-5 decades. Similar earlier studies with farmers reported that weather patterns had changed over the past 5 to10 years and becoming more extreme and erratic, and the summer rains now seem to be delayed and that they lasted for a shorter period but were more intense than the earlier period. Farmers also observed that prolonged periods of drought, less snowfall at the higher altitudes, and perceived warming in ambient temperatures.

Possible causes of climate change: Most respondents of the study area (both Mukteshar and Joshimath regions) were also well familiar with the possible causes of climate change and believe that climate change was due to deforestation (70.37 and 62.96%) followed by the burning of fossils fuel, pollutions, excessive use of vehicles, overgrazing, use of plastic and cement materials, use of chemical fertilizers, intentional and unintentional forest fires both, and use of radioactive materials (Table 2). According to IPCC, the main reason for climate changes are some anthropogenic activities such as deforestation, combustion, emission of greenhouse gases, which are frequently released into the atmosphere (Pachauri 2007). Changes in climatic conditions have been apparent through various indicators including longer and more frequent drought spells, increasing temperatures, the decline in snowfall, erratic rainfall (Below et al 2010). Removal of forest cover alters global and regional climate patterns and results in catastrophic rainfall spells followed by prolonged dry periods (Strasser et al 2014).

Impact of climate change on biodiversity: The maximum impact of climate on regeneration (80.67 and 76.37%) of

Table 1. Showing people's responses about climate change

Variables	People's response (%)	
	Mukteshwar region	Joshimath region
Increase in temperature	87.78	80.37
Low snow and Rainfall	78.66	71.89
Longer drought	67.04	70.74
Melting of glaciers	36.67	31.48
Unseasonal heavy rainfall	35.19	17.41
Rise in sea level	24.81	29.26

Table 2. Showing people's response on possible causes of climate change

Variables	People's response (%)	
	Mukteshwar region	Joshimath region
Deforestation (for construction, fuel wood and cultivation)	70.37	62.96
Burning of fossils- fuel	68.52	69.26
Pollutions (air, soil. etc.)	63.70	60.00
Excessive use of vehicles	56.30	61.85
Overgrazing	54.07	50.37
Use of plastic & cements materials	50.00	54.44
Use of chemical fertilizers	42.59	38.89
Unintentional forest fire	38.89	35.19
Intentional forest fire	35.19	38.89
Use of radioactive materials	28.52	32.22

plant species followed by changes in phenophase of plants (both forest and cultivated) and invasion of alien plant species in the agriculture and forest and invasion of pest and pathogen in the plant in Mukteshwar and Joshimath both regions, respectively (Table 3). Recent studies indicate that the forest ecosystems are affected by changes in rainfall and average temperature, as well as by changes in the frequency of extreme weather events, including droughts, cyclones, intense storms, and wildfires (Tim et al 2020). These effects of weather and climate can be broadly described as changes affecting species distribution (Yan et al 2020) as well as the composition and structure (Negrini et al 2020, Conzale et al 2014) of forests. Climate also affects flowering and fruiting phenology (Hossain et al 2020), life-history traits (Peterson et al 2007, Zhang et al 2020, Yi et al 2019), and habitat requirements (Yan et al 2020). However, only a few studies have directly quantified climate-induced biodiversity extinctions. Even if it is difficult to disentangle the impacts of climate change from other anthropogenic stressors for a range of species, consequently, predictions may provide insights into the multiple components of climate change and their relative distribution threats to global biodiversity (IUCN 2014, Trull et al 2018). Advanced spring phenology damages flowers and tender young leaves, has negative impacts on plant growth and fruit development reported by (Dalal et al 2018, Miller and Primack 2008, Fitter and Fitter 2002, Amano et al 2010, Yu et al 2010). Phenology will continue to be affected in the Himalayas if the climate gets warmer as projected by IPCC 2007.

Impact of climate change on human and animal health: The changing weather pattern was also influenced human as well as animal health in many dimensions of the people and altered the range and seasonality of outbreak of vector-borne infections. Respondents of the study area were facing increasing health problems such as asthma (70.37 and 77.78%) followed by a viral infection, diarrhea, typhoid, allergy, eye problems, and malaria respectively. Respondent agreed that most of the diseases like asthma, allergy, and eye problems are mainly because of the invasion of alien plant species in and around their fields and air and water pollutions. Besides human disease, animals were also suffering from many diseases like foot and mouth disease (62.96 and 66.67%) followed by bluetongue (Table 4). In addition, the distribution and seasonal transmission of vector-borne infections (such as malaria, dengue fever, and schistosomiasis) may be affected by climate change (Sutherst 1998, Sharma 1996, WHO 2000). Models predict the potential for malaria to spread as a consequence of global climate change (Martens et al 1999, Rogers and Randolph 2000, Verweij et al 2004, Aebi 2005). especially since climate affects the survival and reproduction rates of vector-borne diseases; the intensity and temporal pattern of vector activity; and the rates of development, survival, and reproduction of pathogens within vectors (Kameyama et al 2001).

Impact of climate change on agriculture: The majority of respondents of the study area agreed that during recent decades there had been many changes observed in the climate. People also highlighted that now there is a higher incidence of dry spells resulting in low crop productivity and water scarcity for irrigation as well as drinking. There was low agricultural productivity (88.52 and 95.93%) followed by the introduction of alien invasive plant species (reducing the shape and size of fruits and grain (irrigation problem) and incidence of pest and pathogen (Table 5). The color and size of fruits in some horticultural plants is also an indication of variation in weather conditions as in cloudy and moist weather, apples lose their bright red sheen and become smaller in size. Respondent agreed that the frequency of

Table 3. Showing people's response on impact of climate change on biodiversity

Variables	People's response (%)	
	Mukteshwar region	Joshimath region
Decreasing regeneration of plant species	80.37	76.67
Changing phenophase of plants	80.00	76.30
Drying up water resources	75.19	78.89
Invasion of alien plant species in agriculture land	66.67	70.37
Invasion alien plant species in forest land	60.74	55.67
Invasion pest and pathogens in plants	59.26	62.96

Table 4. People's response on impact of climate change on human and animal health

Variables	People's response (%)	
	Mukteshwar region	Joshimath region
Asthama	70.37	77.78
Viral infection	69.37	66.67
Foot and mouth diseases in animal	62.96	66.67
Diarrhea	44.68	39.56
Typhoid	44.44	40.74
Allergy	36.04	33.33
Eye problem	35.08	34.33
Bluetongue in animals	37.04	43.44
Malaria	28.37	32.74

disease and insect/pest attacks have increased many folds; particularly in agro-horticultural crops example pest attacks particularly that of White grub due to low snowfall and temperature. The most significant evidence was, decreased in water resources The production of rice, corn, and wheat has declined due to increasing water stress arising partly from increasing temperature, the increasing frequency of El Niño, and a reduction in the number of rainy days (Boukas et al 2000, Jin et al 2001, Fischer 2002, Yang et al 2004). Past studies on people's perception indicate that the people who are engaged in the agriculture system do experience the impact of climate changes more since the climate has a profound effect on the production and yield of crops. The higher temperature and changing precipitation levels caused by climate change will decline crop yields in many countries over the coming decades (Stige et al 2006, Parry et al 2004, Di Flaco et al 2012). Mountain agriculture is highly dependent on weather and seasonal rain and any kind of changes in climate have a major effect on crop yield and food supply in the Himalaya region (Maikhuri and Rao 2001, Rao et al 2012). Respondents also reported that earlier there was plenty of perennial sources of water in the villages and during recent past, most of the water channels/sources have been fully dried up due to low rainfall as well as recurrent forest fires over the last 30 years and that has resulted in water scarcity for drinking and irrigation purposes.

An outbreak of insect, pest, and pathogen on vegetables, fruits, and cereal crops: Inhabitants of the study area observed that the outbreak of insect, pest, and pathogens have been seen last 20 to 25 years in vegetables, fruits, and food crops. The main regions are irregular rainfall (delayed or shift in rainfall, low rainfall or no rainfall), drastic changes in frequency and volume of precipitation patterns, low snowfall, longer drought, and rising temperature resulted in the invasion of insect, pest, and pathogens in vegetables, fruits and food crops. Agriculture and horticulture and age-old traditional food crops have become prone to disease (Eriksson 2006). Warming, especially the rise of the lowest temperature in winter increases the survival rate of pests over the winter and leading to outbreaks of pests during the year (Upreti et al 2017) observed that an average of 79% of the local residents in the high mountain areas of West, Central, East Nepal believe that insect pests have increased in recent years. The survey showed that local farmers believe that pests and diseases are increasing. Many surveys on the Himalayas also found that local people observed pests and diseases increased (Manandhar et al 2011, Paudel et al 2014, Sujakhu et al 2016, Negi and Maikhuri 2013).

Vegetables: Inhabitants of the study area experienced that the potato (94.81 and 95.56%) was mostly affected due to invasion of kinds of pathogens followed by green vegetables (rye, radish, spinach, fenugreek, mustered), pea, cabbage, tomato, bean, cauliflower, brinjal and bottle gourd respectively (Table 6). In a recent study, vegetable productivity in the hilly areas of Uttarakhand is declining because of degradation of resources, light soil with shallow depth, low soil fertility, higher incidences of pests and diseases, and more overdue to climate variation and changes. The previous study indicated that research on shifting of cropping seasons, growth and yield patterns, pest and disease scenario under changing climatic conditions in respect to vegetable crops, and use of traditional knowledge (Rakshit and Bhowmick 2012).

Fruits: The fruits of the Rosaceae family were mostly affected by pathogens and among these, the apple (83.70 and 90.74%) was mostly affected followed by apricot, pear, citrus, plum, and peach observed that the increasing incidence of pests and diseases due to climate change comprises a shift in disease ecology and played a vital role in apple production (Table 7). The present changes in climatic conditions such as a change in temperature, precipitation,

Table 5. People's response on impact of climate change on agriculture

Variables	People's response (%)	
	Mukteshwar region	Joshimath region
Low crop productivity	95.93	88.52
Introducing alien invasive plant species	77.41	69.26
Reducing shape and size of fruits and grains	72.85	59.27
Irrigation problems	66.78	59.46
Incidence of pest and pathogens	62.96	69.11

Table 6. People's response- impact of pathogen on vegetables

Variables	People's response (%)	
	Mukteshwar region	Joshimath region
Potato	95.56	94.81
Green vegetables	78.15	74.44
Pea	73.70	70.00
Cabbage	69.63	73.33
Tomato	65.93	69.63
Bean	62.96	70.37
Cauliflower	61.48	57.78
Brinjal	46.30	53.70
Bottle gourd	39.26	57.78

ground frost and hailstorm, and subsequent adversities in terms of proliferation of insect pest and diseases, loss of soil fertility, water availability, and natural calamities pose serious threats to the cultivation of apple (Basannagari and Kala 2013).

Cereal crops and pulses: Cereal crops and pules are mostly affected by the invasion of fungal pathogens. Kidney bean (63.78 and 70%) was mostly affected due to invasion of pathogens followed by finger millet, paddy, wheat, maize, soybean, and pulses (Table 8). Scientific research has shown that climate change may alter the developmental stages of plant pathogens that can affect crops and these results in increased crop losses due to diseases (Coakley et al 1999). Other scientific studies reported that many biological and ecological mechanisms by which climate change can affect the distribution, population size, and impacts of pests and diseases on food production(Canto et al 2009, Gale et al 2009, Thomson et al 2010, Pangga et al 2011, Juroszek and Tiedemann 2013, Bett 2017).

Changes in cropping pattern and adaptation adapt the mixed farming: Cropping pattern for the last 20 years changed due to changing climatic conditions such as extreme weather events, longer drought, erratic or plenty rainfall pattern. Before 20 years, equilibrium and stability, as well as sustainability, have been seen in the environmental conditions and agricultural and horticultural production was so good. The productivity of traditional agricultural systems has declined e and farmers move to other types of cultivation and adapt to new agricultural practices. In some areas of hills, farmers have already started taking adaptation measures which include replacing grain crops with vegetables (Gum et al 2009). Changing the cropping pattern, introducing new crops or replacing existing crops, or changing crop sequence can be a way to climate change adaptation (Lasco et al 2011). A recent study showed that people of higher altitude areas Uttarakhand started mixed cropping which ensures favorable conditions for each other and thus improves productivity. This provides protection against total crop failure and is an effective instrument of food security (Rautela 2015).

Socioeconomic consequences regarding climate change: Respondents of the study area are agreed that changing climatic conditions have been felt on their livelihood and others. Because, agriculture, horticulture, livestock are the main occupation of the farmer in the region. On the basis of their response, that climate change impact has increased their livelihood insecurity (94.44 and 90.74%) followed by water scarcity both drinking and irrigation (and losses of business (because the farmers sell their agro-horticultural and livestock-based products in nearby markets and earn some income for sustaining their livelihood. Ultimately, increased over expanse on education (63.70 and 83.33%) followed by health care (and other (like village-based collective socio-religious activities, marriage, etc. (Table 9). An earlier finding concluded that climate change can impact food security (Parry 2004) as well as socio-economic systems (Winnett 1998). In recent decades, the agro diversity of mountains has declined at an alarming rate due to various reasons including climate variability (Negi and Maikhuri 2013) which impacted the food security of the mountains region. A recent study reveals that coupled with social, economic, and political stresses, climate change

Table 7. People's response- impact of pathogen on fruits

Variables	People's response (%)	
	Mukteshwar region	Joshimath region
Apple	83.70	90.74
Apricot	62.22	73.33
Pear	58.89	70.00
Citrus	57.04	57.78
Plum	50.00	61.11
Peach	46.67	68.15

Table 8. People's response- impact pathogen on cereal crops and pules

Variables	People's response (%)	
	Mukteshwar region	Joshimath region
Kidney bean	63.78	70.00
Finger millet	59.64	62.59
Paddy	58.30	64.70
Wheat	48.89	53.70
Maize	47.78	51.60
Soybean	46.30	38.89
Pulses	37.04	40.74

Table 9. Showing people's response on impact of climate change on socio-economic status

Variables	People's response (%)	
	Mukteshwar region	Joshimath region
Livelihood insecurity	94.44	90.74
Water scarcity	88.90	91.70
Business losses	84.81	77.41
Education	83.33	73.70
Health	64.60	72.63
Other	46.54	51.23

could have serious cascading effects with potentially catastrophic consequences, including adverse impacts on ecosystem services supply, as well as on the agricultural productivity, human health, and livelihoods of the millions of people living in the region particularly where they are dependent upon natural resources (Rautela 2015).

Suggestion regarding mitigation of the impact of climate change: People suggested that climate change awareness is a key issue (88.15 and 81.22% response) followed by education training should be organized in the study area so that the people would be aware of the possible influences of climate change. Moreover, the people of experienced that the plantation of broad-leaved species (85.19 and 79.78%) should be increased followed by a ban on plastic materials, restrictions on forest fire, ban on chemical fertilizers, restriction on overgrazing, proper management of garbage, and less use of vehicles (Table 10).

Table 10. Showing people's suggestion regarding the mitigation of climate change impact

Variables	People's response (%)	
	Mukteshwar region	Joshimath region
Climate change awareness training	88.15	81.22
Plantation	85.19	79.78
Ban on plastic materials	65.78	70.00
Restriction of forest fire	62.59	65.36
Environmental subject at primary level	59.67	69.26
Ban on chemical fertilizers	58.89	68.72
Restriction on overgrazing	58.15	60.37
Proper management of garbage	55.70	62.22
Less use of vehicles	48.89	56.30

CONCLUSION

The people were well aware of climate change, possible causes, and its impact on forests, farming systems as well as human health. The majority living in the study area are farmers and their main source of livelihood is agriculture and livestock. They are totally dependent on forest and forest-based resources for sustaining their livelihood. Due to changing climatic conditions, these resources are depleting and they felt the food insecurity and serious socioeconomic consequences will become in the future. Moreover, the regeneration and phenology of plant species, invasion of alien plant species, reduction in production as well as shape and size of fruits, vegetable, and cereal crops are affecting due to changing climate conditions. Different insect-pest and pathogens also affecting the fruits, vegetables, and cereals crops and pules. Regarding these, the people of the area have started to adopt mixed cropping and introduce new vegetable crops. Therefore, there is a necessary need to further identify and document the climate change impact on livelihood and develop appropriate and effective adaptation strategies from the point of view of future perspectives. Awareness is also needed to support climate adaptation in agriculture through the development of climate-resilient crops and appropriate agricultural practices.

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Phenotypic and Molecular Diagnostic of *Fusarium* spp. Isolates Associated with Potato Roots

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Abstract: This study conducted to diagnose *Fusarium* spp. isolates associated with potato roots phenotypically and genetically. The results of laboratory examination by optical microscopy of fungi accompanying the roots of potato plants showed the presence of 18 *Fusarium* isolates isolated from the roots of potato plants that showed symptoms of wilting and yellowing, which were collected from potato farms in Baghdad and Salah al-Din Governorate. The results of molecular diagnostics using the specialized genetic region primer kit (ITS) (PCR technique) also showed that the three diagnosed isolates belong to *F. oxysporum*, which is one of the main pathogens on the potato that causes *Fusarium* wilt disease. The nucleotide sequences were deposited in the NCBI Gene Bank under the accession number (Mw292595_ Mw292596_ Mw292597), and the pathogenicity test showed the effectiveness of most of the studied isolates in establishing the pathogenic ability on potato buds in vitro as it gave the isolates that were diagnosed with molecular F7, F9, F10, the severity of infection was 83.3, 100 and 100% respectively.

Keywords: *Fusarium oxysporum*, *Fusarium* wilt, Fungal pathogens identification, Molecular diagnostics, NCBI gene bank

The potato crop *Solanum tuberosum* L. is one of the most important food crops cultivated in the world, and it is one of the annual bivalve plants and belongs to the Solanum genus of the Solanaceae family, which includes more than 2000 species and 90 genera. Potato crop ranks fourth in the world in terms of nutritional and economic importance, and Iraq comes fourth in the Arab countries after Egypt, Algeria and Morocco (Armin 2011). The potato crop is exposed to many diseases, including viral and fungal diseases, and one of the most important fungal diseases is Fusarium wilt disease caused by *Fusarium oxysporum*, which causes wilt and *F. solani*, which causes root rot in the field, as well as the dry rot disease that affects the tubers after harvest, causing great damage, especially to the seeds, which affects the emergence and growth of plants in addition to its destruction of the vegetative system. In addition, the fungus Fusarium infects potato plants in its various stages of development, including *Fusarium sumbucinum*, *F. oxysporum* and *F. caeruleum* (Shrivastava 1970, Charles 1994). Therefore, this study aimed to isolate and diagnose fungi associated with potato roots by phenotypic and molecular methods, and to test their pathogenicity.

MATERIAL AND METHODS

Isolation and diagnosis: The roots were washed with running water for 30 minutes to get rid of the dirt, then the roots of the affected plants were cut into small pieces of (0.5-1) cm long and surface sterilized with a solution of sodium hypochlorite (1% free chlorine) for three minutes, then washed with sterile distilled water and dried on sterile filter paper. Potato dextrose agar (PDA) plus the antibiotic (Amoxicillin) were planted on the nutrient media with 4 pieces per dish at a rate of 3 replicates per sample and incubated at a temperature (25°C ± 1) for three days, then purified by taking a piece from the edge The fungal colony was placed in the center of another petri dish containing the nutrient media (PDA) and *Fusarium spp.* was identified to the level of genus phenotypically depending on the colony's shape and color, the shape of the fungi, and the microconidia and macroconidia according to the approved taxonomic keys (Leslie and Summerell 2006).

Pathogenesis test of isolates of *Fusarium* spp.: De Bokx (1972) Core Grafting method was followed in preparing potato shoots with some modification, as it stimulated the potato tubers of the Burin variety to produce and form the buds, where seed potatoes were taken from a refrigerated store after they broke the dormancy phase and placed in an incubator at a temperature (18-20°C). Without lighting for 14 days. When the buds reached a length of 1-2 cm, they were removed from their bases. Then they were sterilized with sodium hypochlorite (1% free chlorine) for three minutes and then washed with sterile distilled water. 18 Fusarium isolates

were used in this test. Three buds were assigned to each isolate of the Fusarium genus, distributed over three plates (bud per plate). The nutrient media was used with sterile water (20 g acres per liter of distilled water) after adding the anti-bacterial Amoxicillin. The buds were placed horizontally in the dishes so that the nutrient media covered half of the thickness of the bud. The dishes were incubated at a temperature of (25 ± 1) ˚C for a period of time 24 hours before the fungus pollination. The fungal inoculum was prepared by adding 5 ml of sterile distilled water to the dish containing the pathogen, moving the dish spiritually, then withdrawing 1 ml of the fungus spore's suspension and adding it to the sides of each bud and the dishes were incubated at a temperature of (25 ± 1) ˚C for 10-12 days. To calculate the severity of infestation of buds, use the following pathological evidence:

0 = No infection (healthy bud)

1 = Early infection - half of the buds are infected 2= More than half of the bud is infected

Molecular diagnosis of *Fusarium* spp. Isolates with Polymerase Chain Reaction (PCR): After the initial diagnosis of *Fusarium spp*. by light microscopy. The diagnosis was confirmed by using a molecular diagnostic technique by the method of polymerase chain reaction (PCR) to diagnose *Fusarium* spp. for genre level. The single spore method was used to activate *Fusarium* isolates (F7, F9 and F10), and then transferred to the food medium (PSB) Potato Sucrose Broth and incubated at a temperature of (25 ± 1)ºC for six days, and after the completion of the growth of the fungus in the form of a disc on the surface of the media then the filaments and fungal spores were collected and washed with sterile distilled water and then dried on sterile Whatman No.1 filter paper under sterile conditions, then placed in sterile plastic test tubes and kept in the freezer until DNA extraction.

DNA extraction of *Fusarium* spp. Isolates: The process of extracting DNA from *Fusarium spp.* Isolates was carried out in the laboratories of Wahj Al DNA Company Baghdad using a kit Macrogen Inc., using the primers (ITS1 and ITS4) according to the following steps:

1. 500 mg of fungal strings were crushed using a sterile ceramic mortar using liquid nitrogen and GP1 Buffer was added to it and considered as part of the sample weight. The process was repeated for each of the three isolates of Fusarium spp. (F7, F9 and F10) separately, taking into account the sterilization of the mortar after each isolation, 100-200 mg of the three colonies of fungus isolates were taken and transferred to a sterile Eppendorf Tube test tube.
2. Adding 400 microliters of Universal Digestion Buffer and 20 microliters of Proteinase K to the samples for the purpose of breaking down the cell wall. The ingredients were mixed using the Vortex vibrator. The tubes were placed in a water bath at 60°C for 60 minutes, taking into account the shaking of the tube every 5 minutes.
3. 100 µl of Universal Buffer PF was added to the tubes, then mixed with a Vortex vibrator. The tubes were then incubated at -20ºC for 5 minutes to break down the cell wall.
4. The mixture was filtered by a Filter Column and then the sample was placed in a Centrifuge for 5 minutes at a speed of 12000 rpm. Transfer the scent to a 1.5 mL Eppendorf Tube and discard the sediment.
5. 200 µl of Universal Buffer BP were added to the tube and mix with the Vortex device.
6. 200 µl of ethyl alcohol Ethanol at a concentration of 96-100% were mixed with Vortex and then the precipitate to an EZ-10 tube and discard at a speed of 12000 rpm for two minutes.
7. Elution Buffer was added in the amount of 50 microliters and left for 3 minutes to disengage the bond between DNA and silica gel, then a centrifugation process was carried out at 12000 rpm and for 3 minutes in order to precipitate DNA.
8. DNA was transferred from an EZ-10 tube to a sterile Eppendorf tube.

DNA replication of Fusarium spp. isolates (F7, F9, and F10): The 5 µl of extracted DNA was added with 2 µl starting ITS1 and 2 µl starting ITS4 (Table 1) with 11 µl of deionized water Ionic distilled water and placed in 0.2 ml tubes containing 5 µl of Master Mix then the materials were mixed with a device. The Expense was shaken, discarded in a centrifuge for 15 seconds with a shaking period of 5 seconds, and the tubes were transferred to a PCR Thermal Cycler under optimal conditions for the cycles (Table 2) (White et al 1990). The duplicated DNA fragments were sent to Macrogen Inc. for determining the nucleotide sequence. Nucleotide analysis was performed using the computer software MEGAX (Kumar et al 2018) and SDT v1.2 (Muhire et al 2014). The nucleotide sequences were deposited in the NCBI Gene bank under the Accession Number (MW292595_MW292596_MW292597).

Gel electrophoresis phase: Agarose gel at a concentration of 1% was used to detect DNA bands. The agarose gel was prepared by dissolving 1 g of agarose in 90 ml of sterile distilled water and 10 ml of a solution (TBE Buffer X10). The mixture with a microwave was heated for 3 minutes then the mixture was cooled down and 5 µl of ethidium bromide was added to the mixture, mixing the mixture by light shaking, and

poured into the gel preparation vessel in the electrophoresis device with a UV sterilized comb to make a drill in the gel at temperature's lab, then the comb was removed and added 5 µL of pieces of DNA (Ladder) to the first hole (containing standard DNA pieces) then the same amount of extracted DNA was added to the rest of the pits. The device was covered with its cover and conducted the electrophoresis process at 70 volts for a period of 60 minutes. To detect the extracted and amplified DNA bundles that represent the PCR products, the used DNA fragments were purified and the samples were sent to Macrogen Inc. for the purpose of determining the sequence of nitrogenous bases.

RESULTS AND DISCUSSION

Isolation and diagnosis: The results of laboratory examination by optical microscopy of fungi associated with potato roots showed the presence of 18 isolates traceable to the genus *Fusarium* isolated from the roots of potato plants that showed symptoms of wilting and yellowing. These isolates showed a clear variation in their growth on the culture medium (Fig. 2), with clear differences in the colors of the fungal colonies, which ranged between (white, orange, red, purple), and the isolates were characterized by a growth rate (medium _ fast growing) on the culture media (PDA) and the fungus colonies. *F. oxysporum* has varied colors on the culture medium from white to transparent to pink and purple and contains macroconidia, which appeared crescent-shaped and divided by 3_5 septa and consist of a single generative cell monophialde on a branched conidial host that combines to form *Sporodochia*, the apical cell was arched and the cell Basal, foot-shaped, as well as microconidia, small spores. spherical, and not divided by septa, formed in the form of false heads on the conidial carrier, which appeared in a single, short form and ended with a number of phialide cells while Chlamydospores were formed singly or in pairs with a smooth or rough wall (Snyder and Hansen, 1941, Guadet et al 1989, Kazem and Janabi 2013) and this indicates the presence of genetic heterogeneities between the strains of different types of the same fungus (Hirano and Arie 2006).

Pathogenesis test of isolates of *Fusarium* spp. Isolates by using the potato buds' method grown on the culture media *in vitro*: The significant differences and clear variances in the pathogenic susceptibility of *Fusarium spp.* was observed (Table 2). Isolates in the growth of potato shoots grown on the culture media (PDA), these results showed the effectiveness of most of the studied isolates in establishing the pathogenicity of potato plant buds (Fig. 4). The severity of the infection ranged for the isolates to 100%, and the F1 isolate did not show the ability to cause infection, while the F11 isolate recorded the lowest pathological ability of 33.3% compared with the lowest significant difference of (32.84), while isolates showed F9 and F10, the highest pathogenic ability 100%, respectively. These results also agree with Al-Zobaie et al (2000) who demonstrated the effectiveness of this technology in proving the pathogenicity of the species of *Fusarium spp.* which studied and differentiate between isolates of pathogenic species, as between the tested genera is one of the most important causes that infect potato buds, as the fungus is characterized by its speed and high severity of infection in attacking the buds and consuming the nutrient in its tissues, which transforms into a mummy form.

Molecular diagnosis of *Fusarium* spp. isolates. (F7, F9, and F10) with Polymerase Chain Reaction (PCR): The results of the polymerase chain reaction for DNA amplification using the primers pair (ITS4- ITS1-) and the results of electrophoresis on the agarose gel showed packages with a molecular weight of 510 base pairs for the three isolates (F7, F9 and F10) involved in the reaction, and this result confirms that the isolated fungus is *Fusarium oxysporum* (Fig. 5). Bayona et al (2011) diagnosed two isolates of *Fusarium oxysporum* isolated from the roots of potato plants. The results of the nucleotide sequence analysis showed that the DNA was duplicated from the mycelium of Fusarium spp. The isolate from roots of potato plants infected with Fusarium wilt by ITS-specific primer set belongs to the genome of *F. oxysporum*. The partial nucleotide sequences achieved the highest 99% match with the ITS gene region of equivalent nucleotide sequences from the United States of America, Mexico, Italy, China and Nigeria retrieved from the genebank (Fig. 6). The contiguous

Table 1. Sequence of ITS4 / ITS1 primer nitrogen bases used in diagnosing *Fusarium* spp. isolates

Primers	Sequence of primer nitrogen bases
ITS1	3′- TCCGTAGGTGAACCTGCGG -5′
ITS4	-TCCTCCGCTTATTGATATGC- 5′ 3′

Table 2. DNA replication of *Fusarium* spp. Isolates

Sequence	Steps	Temperature (C^{O})	Time	Number of cycles
1	Initial Denaturation	94C^{O}	3 mints.	1
2	Denaturation	94C^{O}	45 seconds	35
3	Annealing	52C^{O}	1 minute	
4	Extension	72C^{O}	1 minute	
5	Final extension	72C^{O}	٧mints.	1



Fig. 1. Represents infected potato plant roots in Fusarium wilt *Fusarium* spp. isolates

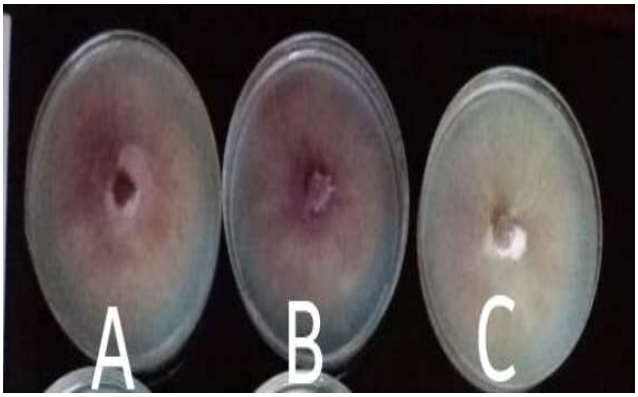


Fig. 2. Represents *Fusarium* spp. isolates **A**: F7 **B**: F9 **C**: F10

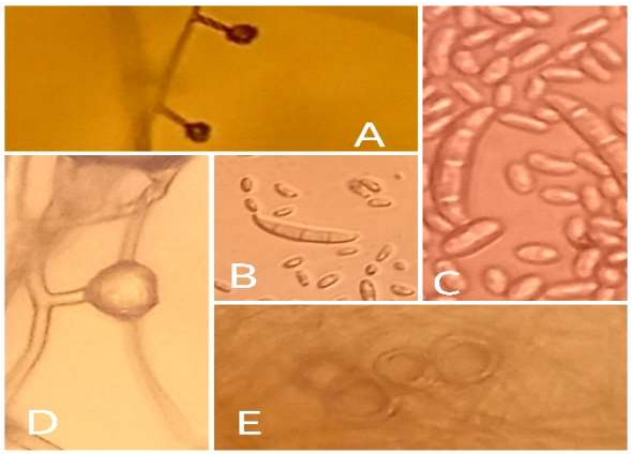


Fig. 3. Represents microsocial shapes of Fusarium spp. after 2 weeks. **A** and **D**: false heads, **B** and **C**macroconidia and microconidia, **E**: Chlamydospores

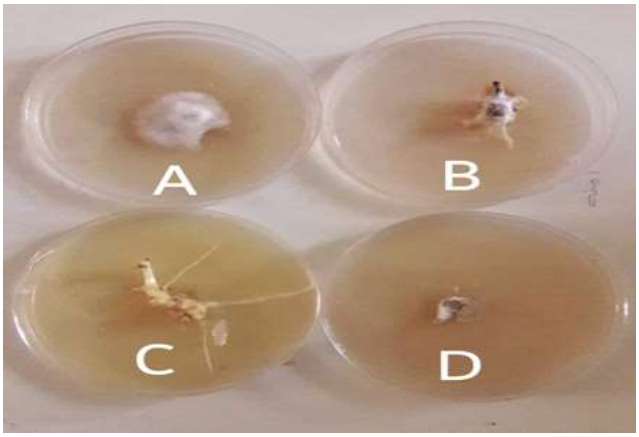


Fig. 4. Represents Pathogenesis test of isolates of Fusarium spp. according to the buds' technique grown on the nutrient in vitro. **A** and **D**:More than half of the bud is infected (F9-F10) **B**: Early infection - half of the buds are infected (F7) **C**: No infection (Control)



Fig. 5. PCR product the band size 510 bp. The product was electrophoresis on 2% agarose at 5 volt/cm^2. 1X TBE buffer for 1:30 hours. N: DNA ladder (100)

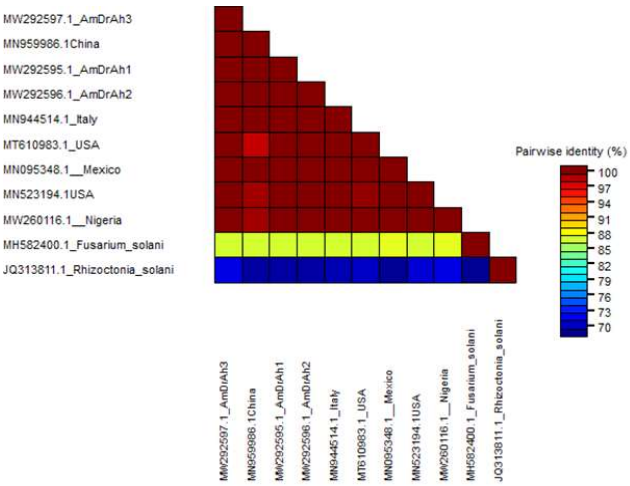


Fig. 6. Matching ratios of the nucleotide sequences of *F. oxysporum*

tree genotype was collected from the nucleotide partial sequence of the ITS genome that included 18S ribosomal RNA gene, internal transcribed spacer 1, 5.8S ribosomal RNA gene and internal transcribed spacer 2 Iraqi *F. oxysporum* isolates with other returning isolates. The fungus has the same in one group, separating it from the *F. solani* species under comparison (Fig. 7). The molecular analysis of the sequence was consistent with the morphological diagnosis of the fungus. The three isolates F7, F9 and F10 due to *F. oxysporum* and not to another fungus.

Table 3. Pathogenicity test for *Fusarium* spp. isolates by using potato buds' method grown in the culture media

Isolates	Infection severity
F1	0.0
F2	83.0
F3	83.0
F4	50.0
F5	50.0
F6	66.7
F7	83.3
F8	50.0
F9	100.0
F10	100.0
F11	33.3
F12	66.7
F13	50.0
F14	50.0
F15	50.0
F16	66.7
F17	83.0
F18	66.7
Control	0.0
CD (p=0.05)	32.84

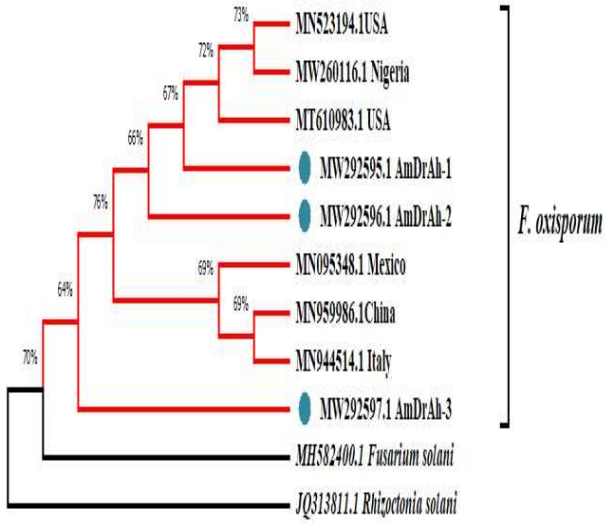


Fig. 7. Genetic relationship to *F. oxysporum*

Comparisons of nucleotide congruence ratios of ITS-region partial sequences of *F. oxysporum* isolates isolated from roots of potato plants showing symptoms of Fusarium wilt with equivalent counterparts retrieved from the genebank. The nucleotide sequence of *F. solani* and *Rhizoctonia solani* was introduced for comparison. Nucleotide analyzes were performed using SDT v1.2 software.

Genetic origins tree Neighbor-joining type was constructed from the nucleotide partial sequence of the ITS region of *F. oxysporum* isolates which isolated from the roots of potato plants showing symptoms of Fusarium wilt (indicated by the symbol) with their equivalent counterparts retrieved from the genebank. The numeric values to each branch represent the values of bootstrap. The nucleotide sequence of *F. solani* and *R. solani* were included to make a comparison by using MEGAX software.

CONCLUSION

In this research work, the results of laboratory examination by optical microscopy of fungi accompanying the roots of potato plants showed the presence of 18 *Fusarium* isolates which isolated from the roots of potato plants that showed symptoms of wilting and yellowing, which were collected from potato farms in Baghdad and Salah al-Din Governorate. showed the ability of all *Fusarium* isolates to infect potato plants when their pathogenicity was tested on potato's buds where the pathogenicity test showed the effectiveness of most of the studied isolates in establishing the pathogenic ability on potato's buds in vitro as it gave the isolates that were diagnosed with molecular F7, F9, F10, the severity of infection was 83.3, 100 and 100% respectively and these results were confirmed in the molecular analysis of *Fusarium* isolates, which proved that *Fusarium* spp. is one of the main pathogens that causes vascular wilt disease on potatoes in Iraq.

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Spreading of *Alternaria* spp. in Mycoflora of Winter Wheat Seeds in North-East of Ukraine

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***Abstract*:** The article deals with the abiotic and biotic factors which influence the dynamic system of wheat seed mycoflora. The study of seed-born fungi in the north-east of Ukraine showed the dominance of a genus of fungi, *Alternaria*. The diagnosis of species according to the peculiarities of colony growth on potato-carrot environment and the structure of conidial sporulation, 5 kinds of fungi were discovered (*A. tenuissima* (Nees et T. Nees: Fr.)*, A. alternata* (Fr.) Keissl*. A. infectoria, A. arborescens* and *A. avenicola* E.G. Simmons, Kosiak & Kwasna). *A. arborescens* (37.4%) was the most common species among those identified. PCR analysis of experimental survey confirmed the dominance of this species in the north-east of Ukraine. The investigation of the spreading of the genus of *Alternaria* proved their placing in five regions from the north to the south with the largest amount of fungi in the northern territories. It can be concluded that the presence of *Alternaria* species varied depending on the place of sampling and the year of study.

***Keywords*:** *Alternaria* species**,** Seed mycoflora, Winter wheat, The north-east of Ukraine

The mycoflora of seeds consists of different species of fungi, the presence of which is determined by various factors. The main world representatives of the complex of wheat seed fungi were *Alternaria, Aspergillus, Ceratobasidium, Cercospora, Cochliobolus, Curvularia, Drechslera, Fusarium, Gaeumannomyces, Microdochium, Penicillium, Pyricularia, Pythium, Rhizoctonia, Rhizopus, Sclerophthora, Trichoderma* and *Tricoconella* (Miller 1995). The fungi of the *Alternaria* genus are widespread among the seed mycoflora of cereals: in Argentina (Andersen et al 2015), Italy (Ramires et al 2018), Germany (Müller and Korn 2013), Slovakia (Mašková et al 2012), Russia (Gannibal 2018), Kazakhstan (Turzhanova et al 2020). During the last ten years, several studies of *Alternaria* spp. in wheat seeds have been done by Ukrainian scientists. During 2009-2012 only *A. alternata* (20.3%) was isolated in the endophytic mycoflora of wheat seeds in the central part of the country (Kovalishina et al 2012). The analysis of isolates of *Alternaria* spp. in different regions of Ukraine during 2012-2013 showed the dominance of *A. tenuissima* (70%) and a significant percentage of *A. infectoria* (25.6%) (Holosna 2015). In the region of Polissya during 2011-2013 only one species *(A. alternata)* was isolated (35.6%). It dominated in the mycoflora of wheat seeds (Tymoshchuk et al 2014). Due to its wide distribution, the genus of *Alternaria* plays a significant role as in wildlife so in the human life. Most *Alternaria* species are saprophytes, which along with other microorganisms, destroy plant debris. *Alternaria* fungi were the main endophytes of seeds and stems of *Triticum aestivum* L., *T. dicoccoides* and *Aegilops sharonensis* (Ofek-Lalzar et al 2016). They produce about 300 secondary metabolites that have dangerous (phytotoxins, mycotoxins). *Alternaria* fungi can cause allergic reactions in humans (Kttafah et al 2020). Some species produce substances with herbicidal (Dalinova et al 2020), insecticidal (Singh et al 2012), antimicrobial (Berestetskiy et al 2018) and antiviral (Bashyal et al 2014) properties. In China, *A. alternata* was isolated from rust pustules of *Puccinia striiformis* f. sp. tritici and proved to be a hyperparasite of this biotrophic wheat pathogen (Zheng et al 2017). *Alternaria* fungi are dangerous phytopathogens that cause diseases of economically important plants, including cereals, fruits, oilseeds, cucumbers, tomatoes, citrus, cauliflowers, peppers, tobacco, and strawberries etc. (Lee et al 2015, Meena et al 2016). Thus, *Alternaria* spp. has a significant distribution in the mycoflora of seeds in Ukraine and other countries. The variability of their species composition has been confirmed by various researchers. There is no monitoring of *Alternaria* fungi in Ukraine. Therefore, the aim of the study was to establish their distribution among other fungi of wheat seeds mycoflora and determine their species composition.

MATERIAL AND METHODS

Analysis of seed-born fungi: Thirty samples of winter

wheat seeds of Ukrainian and foreign selection were collected from five regions of north-eastern Ukraine during 2018–2019: Shostka (51.76921234521743, 33.48084672807519), Hlukhiv (51.67418850582228, 33.9098918820434), Sumy (50.88382108560319, 34.771726091851214; 50.93410032452191, 34.78592051269139), Okhtyrka (50.21895647608306, 35.02756103561299), and Kharkiv (49.994852637197205, 36.452404689801284) regions. The analysis of seed mycoflora was performed by biological methods on potato-glucose agar (PGA) (Kyryk and Pikovsky 2012). Two hundred seeds were taken from each sample. First, they were rinsed for an hour under running water and then sterilized in 1% potassium permanganate solution for 1-2 minutes and washed with sterile water. Subsequently, they were dried in two layers of filter paper and 20-25 seeds were placed into Petri dishes. Incubation was performed in a thermostat at a temperature of 22-24°C. The seeds were examined for the presence of seed borne mycoflora from the third to the eighth day of incubation. Fungi were identified using a microscope (morphology of mycelium, asexual and sexual sporulation).

Identification of *Alternaria* spp.: *Alternaria* fungi were sowed in a special environment (potato-carrot agar, PCA). Petri cups were incubated in special lighting conditions for a photoperiod of 12/12 hours under fluorescent lamps. Fungi were identified by sporulation habit and morphology of conidia and conidiophores (Simmons 2007, Gannibal 2011).

PCR diagnostics of *A. arborescens*: DNA isolation from samples of the genus of *Alternaria* was performed using the NeoPrep100 DNA Magnet_plant set (NEO_GEN, Ukraine). This set is based on Lysing soln. It is intended for celllysis, solubilization of cell debris, as well as for denaturation of cell nucleases. DNA sorbs on NeoSorb (R) (sorbent) in the presence of Lysing soln. Then it easily washed off the proteins and the salt of Buffer soln. DNA can be used for its intended purpose without further purification or processing. Lysis was performed in a 3 mol solution of guanidine thiocyanate (produced by Amresco, USA) at 65°C per 1 hour. PCR was performed using a set of reagents for DNA amplification "PCR MIX 2x HOT" (produced by NEO_GEN, Ukraine), which contains a ready-made mixture for DNA amplification (Taq DNA polymerase, which was inhibited for "hot start"; deoxynucleoside triphosphates, $MgCl_2$, paint for application to the gel as part of an optimized buffer system for standard PCR). The total volume of the reaction mixture was 20 µl (10 µl of 2x mixture for PCR; 0.1 µl of specific primers; 4.9 µl of deionized water for PCR, 5 µl DNA). Sequence of specific primers: direct – 5'GCTCACTCGATTGC ATGCACCTCA3'G, reverse – 5'TGTTGCTCATT TCGGATGCTG3'. The amplification program included the following stages: 95°C for 12 minutes – 1 cycle, 95°C for 15 seconds – 40 cycles, 65°C for 15 seconds – 40 cycles, 72°C for 15 seconds – 40 cycles, 72°C for 1 minute – 1 cycle. PCR products were separated by electrophoresis in 2.5% agarose gel at a voltage of 8 V/cm (30 minutes) with ethidium bromide.

RESULTS AND DISCUSSION

Identification of *Alternaria* species by cultural and morphological characteristics: Initially, the colonies of *Alternaria* fungi, which grew in wheat seeds during the analysis of seed mycoflora on potato-glucose agar environment were observed. The colonies differ in colors, structures and intensities of air mycelium formation. Different formations of sporulation of fungi from Petri dishes were noted with a microscope. A detailed study of conidia showed their different structures. Therefore, a special environment (Potato Carrot Agar, PCA) was used to identify the following species: *A. tenuissima, A. alternata, A. infectoria, A. arborescens*, and *A. avenicola*. The main features of the identification of small-spore species were the three-dimensional sporulation patterns and the structure of conidia (Fig. 1).

A. tenuissima on PCA formed colonies with a dark center. Similar colonies of this species were grown in isolation from soybeans, but they still had separate dark areas (Stevan et al 2011). Conidia were arranged in long chains (5-17). Spores are brown with a short secondary



Fig. 1. The three-dimensional sporulation pattern of *Alternaria* spp. on PCA (*A. tenuissima*, *A. alternata*, *A. arborescens,* and *A. avenicola)*

conidiophore, often had 3-4 longitudinal and 2 transverse septas. Lateral secondary conidiophores were formed on the parts of the conidia. *A. alternata* had almost black colonies on the PCA. The color, structure, and the growth of colonies of this species depend on many factors (Mishra and Khan 2014). Depending on the environment, their color can be varied from pale white to black (Dipak et al 2013). Conidia are more elongated in comparison with *A. tenuissima*. There were 4-6 conidia in one short chain. Spores formed small bushes and had an apical secondary conidiophore with 1 conidiogenic locus.*A. infectoria* formed light brown colonies with light aerial mycelium in the center on the PCA. A typical feature of this species complex was the late formation of conidia (7-10 days). Spores had light brown color, atypical shape. The presence of long secondary conidiophores in conidia was noted. The three-dimensional sporulation pattern differs from simply broken chains to the characteristic large bushes. *A. arborescens* had several types of colonies. In most cases the fungi of the PCA formed gray-green colonies with gray aerial mycelium in the center. Then small chains (5-6 brown spores) attached to the long conidiophores, which did not branch much. In some cases there was the formation of dark green colonies, in which the chains of spores were more often branched. Conidia had characteristic of secondary apical conidiophores. Apical branching characteristic of *A. arborescens* was observed even on PGA in 24-hour darkness. Although previous studies have shown the increase in lateral and suppression of apical branching when this species was grown in complete darkness (Orina et al 2010). *A. avenicola* of KMA had brown colonies with gray aerial mycelium. Conidia are light brown and of various shapes and spore production is quite abundant. A characteristic feature was the presence of spores with lateral secondary conidiophores, which formed short chains or individual conidia. In most cases they were formed on opposite parts of the same conidia.

Thus, most of the identified species belong to small-spore *Alternaria* species, which have a conidia length of less than 60 µm. The species *A. alternata, A. arborescens* and *A. tenuissima* were phylogenetically very close and combined into one section of *Alternaria* (Gannibal 2015). The species of the *A. infectoria* complex are included in the *Infectoria* section (Lawrence et al 2016). *A. avenicola* belongs to the section of *Panax* (Woudenberg et al 2013). Therefore, fungi of the *Alternaria* section are dominated in the mycoflora of winter wheat seeds in the north-eastern forest-steppe of Ukraine during 2018–2019. Recent analyzes of the species composition of *Alternaria* fungi have also shown the dominance of this section. In Italy, 105 isolates out of 134 belonged to the *Alternaria* section, and most were *A. alternata* and *A. tenuissima* (Ramires et al 2018). The cluster of *A. alternata* and *A. tennuissima* was dominant in wheat seeds with black point in Kazakhstan (Turzhanova et al 2020).

Determination of *A. arborescens* by PCR: Since the isolation spectrum of *Alternaria* spp. has changed in recent years (emergence of new species and their dominance in the north-eastern forest-steppe of Ukraine) additional PCR diagnostics were performed. Twenty isolates, which we previously identified as *A. arborescens* by the characteristics of conidial sporulation. Isolates of two species were included into the study (*A. avenicola* (Hlukhiv district) and *A. alternata* (Okhtyrka district)) to compare the results. The affiliation of all studied isolates to the species of *A. arborescens* (except for two) was confirmed (Fig. 2).

The belonging of the isolates of Kharkiv region (X1, X2, X5) to *A. arborescens* was confirmed. X4 and isolates aa1 and av1 (*A. alternata* and *A. avenicola*, respectively) were not representatives of this species. B2, CM7, P1 and KSh2 (the first three variants of Sumy and the fourth one of Shostka regions) were identified as isolates of *A. arborescens*. Isolates of *A. avenicola* and *A. alternata* did not show affiliation to the studied species. The determination of the species of *A. arborescens* according to the structure of conidial sporulation and morphology of colonies on KMA was confirmed by PCR.

Spreading of *Alternaria* spp. in the internal mycoflora of winter wheat seeds: The mycoflora of winter wheat seeds was studied on potato-glucose agar (PGA). The genus of *Alternaria* was dominated among the other species in the complex of fungi inside the seeds for two years of research. Among five identified *Alternaria* species, only one was predominated (*A. arborescens* -Table 1). Other species have not been identified in other regions during the years of research. Only once *A. avenicola* had a significant percentage of isolation in Hlukhiv region in 2019, but it was widespread in all samplings. In contrast to the previous studies (Rozhkova et al 2016) with the dominance of *A. tenuissima* in the north-eastern Forest-Steppe, present

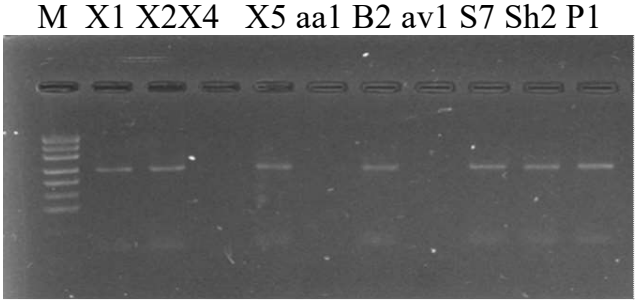


Fig. 2. PCR results on the electrophoregram

investigation proved the distribution of it in three regions. Its highest percentage of isolation was noted in Okhtyrka region. *A. infectoria* was distributed in four regions with a low percentage (maximum was 9%). *A. alternata* had the lowest distribution and amount of isolation.

The place of cultivation of winter wheat significantly affected the allocation of *Alternaria* species in different years by 5% less level of probability ($p<0.0497$). Similar results were obtained by Gannibal (2018). Infection of wheat and barley grain in different years on average in different districts of Krasnodar and Stavropol Territories varied significantly for the *Alternaria* section 7.0-71.5% and *Infectoriae* – 8.6-74.0%. In most cases, the contamination of grain simultaneously in different regions and in different years in the same region differed statistically significantly ($p<0.001$). The study of the mycocomplex of winter wheat seeds from different areas of Ukraine in 2016–2017 showed a decrease in the presence of *A. alternata* from North to South. This species was contained in all analyzed samples from Polissya, from the Forest-Steppe – in 56% of samples, from the Steppe – in 40% (Ostrovsky et al 2018). Isolation of different *Alternaria* species was found when growing wheat in different places. In 2018, three different species were isolated from wheat seeds in Shostka, Hlukhiv, and Sumy regions. Two species were identified in the Okhtyrka region, and four species – in the Kharkiv region. In 2019, the number of species in three places increased (Shostka, Hlukhiv, and Okhtyrka regions). The same species remained in Sumy, their quantity decreased to two in Kharkiv region. Thus, *A. arborescens* was dominated in all regions where seed samples were taken. Its highest percentage of isolation was 63.9% in Hlukhiv region (2018). Its prevalence averaged is 37.4% over two years of research. *A. avenicola* is significantly inferior to the previous species in its amount of 10.5%. *A. tenuissima* and *A. infectoria* had a low percentage

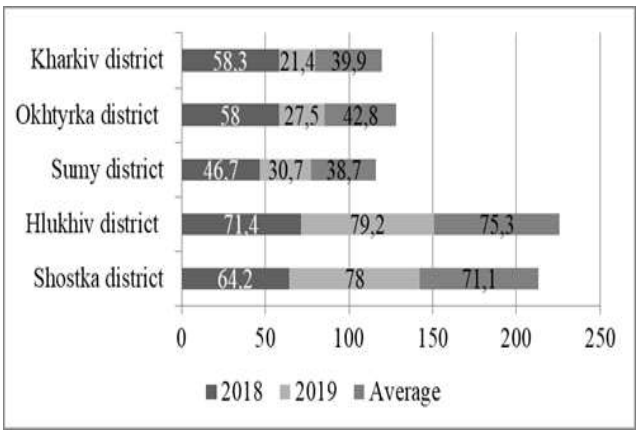


Fig. 3. Presence of *Alternaria* spp. in the internal mycoflora of winter wheat seeds ($p=0.865$ (2018); $p=0.025$ (2019)

of prevalence among the other species (3.4 and 2.1%, respectively), and *A. alternata* had very minor one. The calculation of the total amount of *Alternaria* sp. proved their dominant presence in the northern regions, such as Hlukhiv and Shostka (Fig. 3).

The total number of *Alternaria* spp. isolated from seeds significantly depended on the place of cultivation of wheat only in 2019. The highest percentage of fungal isolation was noted in 2019. The lowest indicators of the presence of *Alternaria* fungi were determined in the same year in the southernmost region of Kharkiv. On average, the percentage of isolation of the genus of *Alternaria* sp. makes about 53.6% during 2018-2019 in the north-eastern Forest-Steppe of Ukraine. This indicates their dominance among other fungi of the winter wheat seed mycoflora. Studies of other Ukrainian scientists have also proved the dominant position of the genus of *Alternaria* sp. in Sumy and Kharkiv regions (Mykhalska et al 2019).

Table 1. Species of the genus *Alternaria*, which are parts of the internal mycoflora of winter wheat seeds (north-east of Ukraine)

Place of seed sampling	Species of the genus *Alternaria*, % isolation among all fungal colonies				
	A. arborescens	*A. avenicola*	*A. tenuissima*	*A. alternata*	*A. infectoria*
	2018/2019	2018/2019	2018/2019	2018/2019	2018/2019
Shostka region	54.9/57.1	0.5/16.8	8.5/1.5	-*	-/2.6
Hlukhiv region	63.9/12.5	-/64.5	5/2	-	2.5/0.3
Sumyregion	35.3/29.5	5.1/0.9	-	-	6.3/0.3
Okhtyrka region	41.1/24.3	-/1.7	16.9/-	-/1.5	-
Kharkiv region	35/20.3	14/1.1	-	0.3/-	9/-
On the average	46/28.7 (37.4)	3.9/17 (10.5)	6.1/0.7 (3.4)	0.06/0.3 (0.2)	3.6/0.6 (2.1)
LSD (0.05)	4.2/2.5	3.2/1.9	2.3/ -	-	1.6/0.5

Note: *- Fungi didn't germinate from seeds

CONCLUSION

The average isolation of *Alternaria* fungi from winter wheat seeds was 53.6%. Therefore, they predominated in the mycoflora among others during 2018-2019 in the north-eastern Forest-Steppe of Ukraine. Five species of *Alternaria* fungi were identified in potato-carrot environment: *A. tenuissima, A. alternata, A. infectoria, A. arborescens*, and *A. avenicola*. PCR identification of *A. arborescens* confirmed the correctness of the preliminary species determination. *A. arborescens* (37.4%) was the most common species among those identified. The small-spore species from the *Alternaria* section had a dominant position in the mycoflora of winter wheat seeds. The region of cultivation significantly affected the amount of isolation and representativeness of *Alternaria* species. These fungi showed their dominant presence in the northern regions such as Hlukhiv and Shostka. The highest percentage of fungal isolation was in 2019 (79.2%).

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Response of Tomato Varieties to the Early Blight Disease Caused by *Alternaria solani*

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***Abstract*:** Tomato early blight disease is one of the important, common, and ubiquitous spreading disease that caused by *Alternaria solani*. This study involved examination of commonly cultivated tomato varieties in Basra (Yasmin, Mubakir and Sultana) to determine the extent of their response to infection by *A. solani*. Several parameters were considered to determine the response level of each tomato variety to the pathogenic fungus, which included the infection percentage, fruit damage percentage, the length, the wet and dry weight of shoot and root. The varieties (did not differ significantly among each other in the infection percentage (14.35- 24.39%). Furthermore, growth indicators represented non-significant differences between infected and healthy plants, while the dry weight rates of the root system of the infected plants was significantly less than control. Yasmin, Mubakir and Sultana varieties can be considered as a resistant or moderate resistant variety.

***Keywords*:** *Lycopersicon esculentum* Mill., *Alternaria solani*, Biochemical Response, Quantitative resistance, Early blight

Tomato is exposed to more than 200 plant diseases, most of which are fungal diseases (Agrios 2005, Srivastava et al 2010). Early blight disease is an important fungal disease caused by *Alternaria solani* that affect most parts of shoot system, which result in reduction in crop quality and quantity (Agrios 2005). The development of the infection mostly leads to defoliation, drying of branches, and premature dropping of fruits which in turn leads to large losses (35-78%) (Grigolli et al 2011). The early blight on tomatoes is one of the most dangerous diseases that invade tomatoes in warm and humid areas (Gleason and Edmunds 2006). The optimum conditions for infection are relative humidity that may exceed 80% and moderate temperatures of up to 27°C (Foolad et al 2000). The pathogens often adapt to attack the host with the presence of genetic resistance and overcome it. This study aimed to investigate the response of three tomato varieties, which are commonly grown in Basrah province to the early blight disease to determine the impact of variety factor on disease development and evaluate the resistance level of these varieties.

MATERIAL AND METHODS

Sample collection: Samples were collected from the leaves, stems and fruits of the tomato plants that had symptoms of early blight disease from Abi Al-Khaseeb, Al-Zubair, Safwan, and Karmat Ali. The pathogen (*A. solani*) was isolated from tomato leaves with early blight symptoms. A small piece were taken from the edge of the spots on the infected tissue. The leaves were surface sterilized with a 10% sodium hypochlorite for 3 minutes then washed with sterile distilled water after which they were dried on filter paper then transferred to Petri plates contained potato dextrose agar (PDA) medium (five pieces/plate), the inoculated dishes were incubated for two weeks at 25°C±1 (Aneja 2001). The isolation from soil samples was performed using dilution method, the soil samples were air dried and mixed then a serial of dilutions (10^{-1} - 10^{-6}) were prepared and the last dilution was used to inoculate PDA plate (1ml/plate). The plates were incubated at 25°C±1 for two weeks. The isolates were purified by single spore technique according to Johnston and Booth (1983). The purified samples were preserved using the glycerol preservation method: a glycerol: water solution (volume: volume) was prepared, after that *A. solani* spores suspension was mixed with same volume of glycerol (1:1) to prepare 25% of spores conservation glycerol solution (Hussein and AL-Galebi 2015). The conserved samples were stored at -20°C until usage.

Fungal Identification

Morphological identification: The fungal isolates were diagnosed morphologically according to Ellis (1971) and Kumar (2017) with the assistance of the reference strain of *A.solani* from Dr.Abed Abd Algaleel Ata, Maize Crop Diseases Research, Plant Pathology Researches Institute, Agricultural Research Centre (ARC), Giza, Egypt. The purified isolates were subjected to microscopic examination to determine the morphological characteristics in addition to

the colony and vegetative growth features.

Molecular Identification

DNA extraction: One week old colony of *A.solani* was prepared, the mycelium mass was collected and dried to fine powder with liquid nitrogen, then 25 mg of powder was transferred to 1.5 ml Eppendorf tube. The DNA extraction was performed using Wizard® Genomic DNA Purification Kit A1120 (Promega, USA) according to the manufacturer protocol. The DNA was quality and quantity was confirmed at 260/280 nm wavelength by Nano drop device (Termo-ScientificTM, Nanodrop 2000, USA). The PCR reaction was performed to amplify ITS1-ITS4 region using forward primer: 5´ TCCGTAGGTGAACCTGCGG 3' and reverse primer: 5´ TCCTCCGCTTATTGATATGC 3'. The PCR mixture involved 25 µl of Taq DNA Master Mix RED (Amplicon, Denmark) (Bellemain et al 2010), 2.5 µl of each primer, 100 ng of DNA template and the volume was completed to 50 µl with DD-Water. The PCR reaction conditions included denaturation at 95°C for 3 min. as initiation step followed by 35 cycles of: 30 sec. at 94°C for denaturation, 30 sec. at 58°C for annealing and 30 sec. at 72°C for extension, after which the reaction was ended with 10 min of final extension at 72°C. The PCR product was confirmed by gel electrophoreses on 2% agarose gel, the run was performed at 85 mv for 1 h and the DNA bands were stained with ethidium bromide. The samples were sent to Macrogen Co. (Korea) for sequencing. The sequence analysis was performed using Chromas ver. 2.6.6 software (Tecnelysium Pty Ltd, www.technelysium.com.au), while sequence comparison was applied using Basic Local Alignment Search Tool (BLAST) of National Centre for Biotechnology Information (NCBI) to confirm molecular identification of our isolates. After that the isolates were deposited in NCBI gen bank.

Pathogenicity of *A. solani*: The pathogenicity of *A. solani* ALAS-3 and the reference strain *A. solani* ALA was examined according to Foolad et al (2000). Healthy tomato leaves collected from each experimental plant (Yasmin, Mubakir and Sultana) separately. The leaves were superficially sterilized with 10% sodium hypochlorite for 2 min then washed with sterile distilled water and dried with sterile filter paper. After which the leaves were scraped with a sterile needle and inoculated with the *A.solani* spore suspension (harvested spores from infected leaves in sterilized distilled water with tress amounts of twin 80) and incubated in moist chamber at 24°C with successive periods of light and dark at interval of 12 hours of each for a week to ensure symptoms appearance (Shahbazi et al 2011). The pathogen was re-isolated from the infected leaves to confirm identity and pathogenicity.

Seeds viability: The viability of Yasmin, Mubakir, and Sultana seeds was examined by planting 10 tomato seeds of each variety in sterile Petri plate containing filter papers moistened with sterile distilled water in triplicates mode, the results were collected after 7 days (Skeels and Windmeijer 2018) and the percentage of germination was calculated according to the equation below:

$$\text{Seeds viability \%} = \frac{\text{No. of germinated seeds}}{\text{Total No. of tested seeds}} \times 100$$

The results were analysed statistically according to completely randomized design (CRD) using IBM SPSS statistical package ver. 24.

Greenhouse experiment: This experiment was carried out in a typical greenhouse with dimensions of 50 meters in length and nine meters in width. The process of ploughing and harrowing of greenhouse soil was carried out as recommended, then the greenhouse area was divided into two equal plots, each of them was divided into three raised beds (20 m in length, 2 m in width, and 30 cm in depth), a free one-meter edge was left around the plots to facilitate the service operations. The seedlings were planted at interval of 30 cm and served perfectly according to the recommended agricultural processes.

Evaluation of tomato varieties response to the *A.solani* infection: This experiment included the evaluation of the ability of three tomato varieties (Yasmin, Mubakir and Sultana) (Table 1) to grow and produce under *A.solani* infection stress, so it had designed in factorial CRD 3×2×3 that involved three levels of variety factor and two levels of infection factor (infected, and not infected), each factorial treatment was replicated in triple. The infection percentage, fruit damage percentage, the length of shoot and root systems, the wet weight of shoot and root systems, and the dry weight of shoot and root systems were considered as the main parameters for the estimation of tomato varieties response to the *A. solani* infection.

Artificial infection: The artificial infection was applied to the tomato plants in greenhouse using spore suspension as a source of inoculum. The spores of *A.solani* were prepared by growing the pathogenic isolate ALAS-3 on tomato leaves as mentioned before, the spores were harvested by washing the infected leaves with sterile distilled water supported with tress quantities of twin 80, the washing water was collected in sterile glass bottles for use in artificial inoculation of plants. The inoculation was applied by scraping plant leaves with sterile needle followed by spraying the spore suspension on wounded leaves. The inoculated parts were covered with clean sterile polyethylene bags to provide optimum conditions for infection development.

Estimation of the effect of *A.solani* infection on tomato plant growth and fruit production: After 130 days of the

seedlings planting (the end of the agricultural season), the length of shoot system, length of root system, the wet and dry weight of shoot system, and the wet and dry weight of root system were considered as a main criteria to estimate the effect of *A.solani* infection on tomato plant performance (Abdullah 2010, Zwain and Altabo 2019).

RESULTS AND DISCUSSION

Diagnosis of the pathogen: The morphological diagnosis (Fig. 1) showed two types of long peak spores, the long non-branched peak for isolates ALAS-3 and long branched one for ALAS-1 and ALAS-2. Based on the diagnostic traits reported in Ellis (1971) and Kumar (2017), the isolate ALAS-3 was identified as *A.solani*, while ALAS-1 and ALAS-2 had been identified as *Alternaria arborescens*. The morphological results were confirmed molecularly (Table2) and the sequences of identified isolates were deposited in NCBI under registration No. MW494956.1 and MW494957.1 for ALSA-1, and ALSA-2 respectively, while ALASA-3 was registered as MW494952.1.

Pathogenicity of the *A. solani*: The pathogenicity results (Fig. 2) for the two *A.solani* isolates (ALAS-3 and reference isolate ALA) confirmed that both isolates were able to infect plants and develop symptoms perfectly.

Seed viability: The seed viability of Yasmin and Sultana was 100% followed by Mubakir (96.67%) with non-significant differences.

Evaluation of Tomato Varieties Response to the *A.solani* Infection

Infection percentage: The infection percentage of *A.solani* (Table 3) revealed that Mubakir was the lowest (14.35%), which differed significantly from Yasmin (24.39%) but it didn't showed significant difference with Sultana (19.2%), which in turn had no significant difference with Yasmin. The differences among varieties seems to be genetic pattern dependent.

Fruits damage percentage: The estimation of the fruit damage percentage of the infected fruits and for two consecutive reap (Table 3) revealed no significant differences among examined varieties Yasmin, Mubakir and Sultana (70.30, 78.28 and 68.27%), respectively, in the sixth reap while they differed significantly in the seventh reap, at which Yasmin (57.94%) was significantly exceeded the other two varieties Mubakir and Sultana (85.76 and 84.35%), respectively that did not show any significant difference between them, which is could be a genetic characteristics dependent (Salim et al 2016).

Length of the shoots: The shoot lengths of all examined varieties showed no significant differences among them as well as no significant difference was observed between infected plants and control (Table 4). The infected Mubakir plants recorded a significant decrease in shoot system length compared with the control (115.33 and 154.00 cm), respectively. The shoot length seems to be not affected by *A.solani* infection in the high and moderate resistance varieties, while low resistance and sensitive varieties mostly influenced and presented a significant reduction in the shoot system length (Awan et al 2018).

Length of the root system: The root system length showed no significant differences in the averages of root length in Yasmin, Mubakir, and Sultana varieties (Table 4). The infected plants did not revealed significant difference comparing with the average of control. The variety Sultana showed a significant difference between the infected plants and control (38.67 and 49.33cm). The root system length mostly not affect by *A.solani* infection (Awan et al 2018).

Wet weight of the shoot system: The shoot system wet weight was significantly affected by *A.solani* infection (Table 5) as the average of shoot wet weight of infected plants showed a significant reduction (727.78 g plant^{-1}) comparing with the control (1122.22 g plant^{-1}). The varieties did not revealed significant differences among them in the variety shoot wet weight rates. The shoot wet weight of Yasmin and Mubakir (783.33 and 683.33 g plant^{-1}) respectively showed a

Table 1. Varieties used in the field experiment

Variety	Provider	Origin
Yasmin	Syngenta	India
Mubakir F1	Holland Aden	China
Sultana F1	Emmaseeds	China

Table 2. Molecular identification of isolated *Alternaia arborescens* strains ALAS-1, ALAS-2 respectively and *A. solani* ALAS-3 strain

Isolate name	Registration No.	Scientific name
ALAS-1	MW494956.1	*Alternaria arborescens*
ALAS-2	MW494957.1	*Alternaria arborescens*
ALAS-3	MW494952.1	*Alternaria solani*

Table 3. Infection and damage percentages caused by *A. solani*

Variety	Infection (%)	Damage (%)	
		Sixth reap	Seventh reap
Yasmin	24.39	70.3	57.94
Mubakir	14.35	78.28	85.76
Sultana	19.02	68.27	84.35
LSD (P= 0.05)	8.1	12.01	10.23

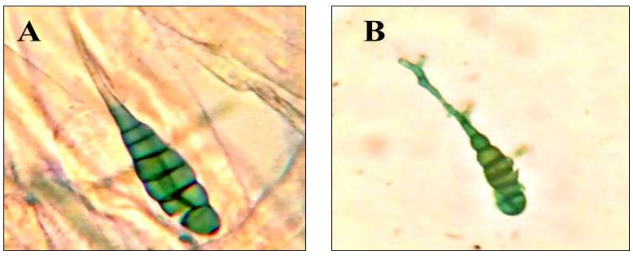


Fig. 1. The spores of the isolated fungi: *Alternaria solani* (A); *Alternaria arborescens* (B)

Table 4. Effect of *A. solani* infection on shoot and root systems length

Variety	Control (cm)	Treatment (cm)	Variety rate
Shoot system length			
Yasmin	116.33	120	118.17
Mubakir	154	115.33	134.67
Sultana	113.67	110.67	112.17
Treatment rate	128	115.33	
LSD (p=0.05) Variety=28.86, Treatment: 62.41, Interaction=21.53			
Root system length			
Yasmin	40.67	39.33	40.00
Mubakir	41.00	42.67	41.83
Sultana	49.33	38.67	44.00
Treatment rate	43.67	40.22	
LSD (p=0.05) Variety=7.91, Treatment=17.11, Interaction=5.90			

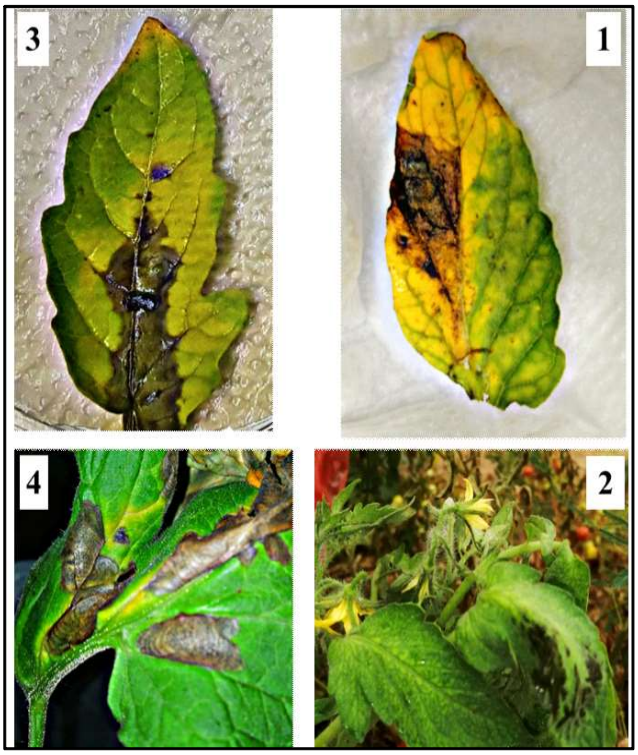


Fig. 2. The pathogenicity results for ALAS-3 (1, 2) and reference strain ALA (3, 4) in laboratory and field experiments respectively

Table 5. Effect of *A. solani* infection on wet and dry weight of the shoot and root systems of tomato plant

Variety	Control (cm)	Treatment (cm)	Variety
Shoot system wet weight			
Yasmin	1250.00	783.33	1016
Mubakir	1166.67	683.33	925.00
Sultana	950.00	716.67	833.33
Treatment rate	1122.22	727.78	
LSD (P= 0.05): Variety = 355.19, Treatment = 768.18, Interference = 265.2			
Shoot system dry weight			
Yasmin	336.00	188.67	262.33
Mubakir	258.00	192.00	225.00
Sultana	227.33	133.33	180.33
Treatment rate	273.78	171.33	
LSD (P= 0.05): Variety = 74.52, Treatment = 161.7, Interference = 55.62			
Root system wet weight			
Yasmin	84.77	73.62	79.2
Mubakir	107.5	55.9	81.7
Sultana	51.5	43.87	47.68
Treatment rate	81.25	57.8	
LSD (P= 0.05): Variety = 30, Treatment = 64.88, Interference = 22.39			
Root system dry weight			
Yasmin	21.33	19.33	20.33
Mubakir	30.67	14.67	22.67
Sultana	12.67	11.67	12.17
Treatment rate	21.56	15.22	
LSD (P= 0.05): Variety = 8.03, Treatment = 17.37, Interference = 6.00			

significant reduction comparing with their related control treatments (1250.00 and 1166.67 g plant^{-1}) respectively, while Sultana didn't differ significantly than control. The wet weight reduction of the shoot system could be result in fungal infection stress because of the consequent proteins utilization by the pathogen and low resistance ability of host plant that affect the protein content of the host which reflects on plant growth and viability (Faheed et al 2005).

Wet weight of the root system: The wet weight of root system revealed that Yasmin and Mubakir (79.20 and 81.70 g plant^{-1}) respectively were significantly surpass Sultana (47.68 g plant^{-1}) with no significant differences between them (Table 5). The total mean of the infected plant didn't differ than total control mean too. The infected Mubakir treatment recorded a significant reduction in root wet weight comparing with control (55.90 and 107.50) respectively, which could be related with the shoot system infection which caused whole plant to be stressed that decreases the downstream materials that provided to the root system.

Dry weight of shoots system: The dry weight of shoot system of Sultana (180.33 g plant^{-1}) was significantly lowest than Yasmin and Mubakir (262.33 and 225.00 g plant^{-1}), respectively, while no significant differences were observed between the treatment rates or among the factorial treatments (Table 5).

The dry weight of the root system: The dry weight of root system (Table 5) indicated significant differences among varieties, Mubakir and Yasmine (22.67 and 20.33 g plant^{-1}) respectively were significantly superior to Sultana (12.17 g plant^{-1}) The infected Mubakir variety showed a significant reduction in root system dry weight comparing with the control treatment, which is may be due to the abnormal plant growth because of infection stress on whole plant, especially through disease development (Fritz 2005).

CONCLUSION

The varieties (Yasmin, Mubakir and Sultana) can be considered as a resistant or moderate resistant variety under the cultivation conditions of Basrah province as they were able to grow and produce acceptably under the infection stress, which is could be based on their structural and/or biochemical defences that controlled genetically.

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Review of Legal and Policy Framework for Groundwater Governance in India

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Abstract: The existing legal and policy framework concerning groundwater (GW) and its governance is composed of a large number of different acts, rules, and principles adopted and enacted over the years at the national, state, and local level. The evolution of sucha framework in India can be studied under three broad categories: pre-colonial, colonial, and post-colonial. This paper examines the historical development of water resources management and the corresponding evolution of legal framework at the national level even though water is a 'State Subject' under the constitution of India. An attempt has been made to assess how far the existing legal framework for water management can address the critical issues and concerns relating to GW in India owing to its increasing scarcity, mismanagement, and environment-related problems.

Keywords: Water law, Right to water, Public trust, Model legislation, Constitutional framework

Water has been the driving force of almost every civilization from time immemorial. Great importance was attached by people to a suitable and adequate supply of water for different purposes like agriculture activities, cooking, drinking, washing, etc. Although interrelated, surface water and GW have often been studied and managed as separate resources. Surface water seeps through the soil and becomes GW. Conversely, GW can also feed surface water sources. Interactions between GW and surface water are complex. Contamination of GW can result in poor drinking water quality, loss of water supply, degraded surface water systems, high clean-up costs, and high costs for alternative water supplies, and/or potential health problems. The consequences of contaminated GW or degraded surface water are often serious. The GW governance in the country, which is *"the promotion of responsible action to ensure the protection and sustainable use of GW resources and long-term management of aquifer systems"* (FAO, 2016), is in its adolescent stage and there is scope for it to develop further under a conducive institutional and legal framework. A sense of urgency is absent due to a lack of understanding and awareness about GW issues and is a major obstacle to the development of leadership and commitment for effective GW governance. First-hand knowledge of the local situation and other relevant interdependencies is a must for effective planning but the technocrats without expertise in management, and/or bureaucrats without domain knowledge and with uncertain tenures will not be able to avert the alarming consequences of dire and diverse water challenges of the 21st century. Legal frameworks for GW governance are inadequate, but their poor implementation is a more pervasive and critical problem (Franks and Cleaver 2007). To assess the role of legal systems in addressing the deficiencies and gaps in GW governance under different prevailing situations, there is a need to examine the evolution of water law and its current status in the country.

Water Law in Ancient India

In ancient India, there were no formal laws on water and its management but these exist in different religious texts, customs, and written codes. However, the Indus Valley civilization which flourished around 2500 B.C. along the banks of river Indus and other parts of western and northern India, is known for well-planned cities having high standard structures of drainage, water supply, sewage, and storage. The Mohenjo-Daro and Harrapan ruins have revealed the fact that people of even that early period had given due importance to adequate water supply for various purposes like domestic, irrigation, and public baths (Siddiqui 1992). The legal norms in respect of water use began to emerge with the inception of Vedic social order where Dharma became the test stone for almost every action. Then, the Code of Manu or Dharam Shastra is one of the most important documents relating to water law which considers water as indivisible. Manu Samriti provides that the King should protect public water and discourage diversion or obstruction of waters. The laws provided a system of punishment for those who polluted, stole, or diverted the water. Manu laid down that anyone who destroys embankments of a tank should either be drowned or put to death by beheading

(Muller 1965). Kautilya, the chief advisor to Chandragupta Maurya (321-297 B.C) on politics and statecraft, provides in 'Arthashastra' that at the time of formation of new villages, the King is expected to construct reservoirs with continuous water supply or with water drawn from some other sources (Date 2008). 'Arthashastra' also indicates that users had to pay a water tax for its use (Cullet and Koonan 2011) which was 1/5th of the produce for manually transported water, 1/4th of the produce for water carried by bullocks, and 1/3rd of the produce for water lifted by mechanism into channels. The water for irrigation from natural reservoirs was taxed at the rate of 1/4th of the produce (Rangarajan 1992).

The early Vedic text exhibited the philosophy of spiritualism about water, whereas the post-Vedic literature created its significance in ritualism. During this period, Jainism and Buddhism grew up to encourage the preservation and protection of the environment and nature. Mahavir Jain and Gautam Buddha encouraged rightful conduct and right belief and promoted respect for other living creatures (Majumdar and Raychaudhuri 1978). Ashoka 'The Great' preached non-violence and emphasized planting trees and building reservoirs (Cullet 2009). Islamic Law treated water as a life-giving, sustaining, and purifying resource and recognised it as a resource common to all (Dien 1997).

The earliest reference to GW irrigation in Ancient India is found in Rigveda which mentions well-style irrigation, where the *Kupa* and *avata* wells once dug are stated to be always full of water, from which water was pulled with *varatra* (rope strap) and *chakra* (wheel), *Kosa* (pails) of water. This water was led into *surmisusira* (broad channels) and from there into *khanitrima* (diverting channels) into fields (Wickstrom 2010). The Muslim rulers showed keen interest in constructing irrigation works particularly canals and declared free access and use of water as a right to everyone (Singh 1992).

Water Law in Colonial Period

The evolution of water law in India during the colonial period is well documented. Colonization brought three chief impacts namely “a shift in perception of water from a resource gathering and food production economy into a commodity-oriented economy; a change in long-standing social relations and customs as local social relations became less important and social cohesion declined, and the development of the market and the importance given to wealth” (Saxena 2012) When the East India Company took over the administration of provinces, its immediate focus was on increasing land revenue (Gadgil and Guha 1992). British rule in India transformed water management in the country as local knowledge and institutions for managing it already existed. The British used irrigation to enhance the productivity of the land by providing it in regions with less rainfall or located away from rivers (Vani 1992).

In the pre-colonial system, the local zamindars arranged for the maintenance of the embankments, and peasants offered free labour for mending the major breaches in them (Bandyopadhyay 2009). Bengal Embankment Act, 1855 was passed by the colonial government which gave wider powers to the concerned statutory authorities and the management of embankments and water courses (Bengal Embankment Act 1855). Section 18 of this Act provided that a person desirous of using waters from such facilities was required to apply to the Collector, who may allow only when there was an advantage of doing so and certain acts of interfering with the system of embankments were punishable offenses under section 76 of the Act.

The first major development that laid down in wide and specific terms the State's role in the regulation of water resources came through the enactment of two main colonial enactments, i.e. Bengal Canals Act, 1864, and the Northern India Canal and Drainage Act, 1873. Successive statutes on water resources were based on the rules laid down under these statutes. The major criticism of this Act was the vesting of all control in the state to utilize and control all water resources such as rivers, streams flowing in natural channels, and lakes for public purposes (Cullet 2015). Historically, the irrigation laws were the most developed part of the water law in terms of statutory development. This was because the British government focused on large irrigation works to foster productivity and consequently, the revenue (Iyer 2012) “The history of the development of water resources in British India was an irrigation history and that history has established a state monopoly over water resources” (Ramanathan 1992).

Indian Easement Act, 1882 legalized customary rights in or over immovable property which any person, the public, or the government may possess, irrespective of other immovable property (Indian Easements Act 1882). This included rights for water issuing from a well, spring spout, or flowing water in government or public places. The laws that were enacted after the passing of the Easement Act slowly shifted the focus on individual water rights from natural to proprietary or usufruct rights. The necessary connection between property rights in land and proprietary right in water finds expression in The Transfer of Property Act, 1882 which provides that easement cannot be transferred apart from dominant heritage (Cullet and Gowlland 2010, Koonan 2016). The dominant heritage which creates water rights is limited to rights in GW and certain riparian rights in naturally flowing water. However, when the water has been provided by the government through canals for irrigation purposes, no such rights accrue to the landowner (Singh 1991).

One of the earliest laws on the conservation of the rivers in India is the Madras River Conservancy Act, 1884 which has been renamed as The Tamil Nadu River Conservancy Act, 1884 vide Tamil Nadu Adaptation of Laws (Second Amendment) Order, 14th January 1969 provided powers to a Conservator of rivers to survey and prohibit certain activities like the cultivation of such land which tended to obstruct or divert the course of the river. The purpose of the Act seemed to regulate the use of land within the river banks rather than the river itself.

To adopt and implement effective measures to preserve the fishery resources, the Indian Fisheries Act, 1897 was passed to define the right to the fishery in private waters as "*being the exclusive property of an individual or in which the person has for the time being an exclusive right of the fishery as an owner, lessee or in any other capacity*" (Cullet and Koonan 2011). Section 4 of this Act prohibited certain acts which caused pollution in water resources such as explosions or use of dynamites in inland, coastal waters, and the marine league as well as the poisoning of water with toxic materials.

The Government of India Act, 1935 separated the legislative powers between State Legislative Assemblies and the Parliament. Sections 130 to 134 of 1935 Act gave control to the provinces relating to water supply, water storage, hydropower irrigation, canals, drainage, and embankments, and to the Governor-General regarding disputes between princely states or provinces, who could appoint a commission to investigate and examine a conflict if deemed appropriate.

Further, in addition to the easement and customary rights, certain acts relating to water were made punishable offenses under the Indian Penal Code, 1860. Relevant sections 268, 277, 290,425, 430, 431,432, and 441 of IPC provided for fouling of water as a public nuisance, mischief by injury to irrigation works, or by wrongfully diverting water, and mischief by injury to the river or other water channels respectively. These provisions may be in general for the protection, conservation, and preservation of water resources (The Indian Penal Code 1860).

During the Colonial period, the GW was generally, conceived as a part of the land in legal parlance. The Indian Easement Act, 1882 also followed the common law principle of absolute proprietorship regarding GW. This Act recognized the right of every owner of the land to collect and use all water within his territory beneath the land. Therefore, its extraction by landowners where it existed is considered to be an unrestricted right. This rule originated in Britain in the 19th century and has been duly recognized by the Indian legal system (Koonan 2016) but it has been inadequate for addressing current issues of GW depletion and pollution. The system of land-based GW rights was created at a time when GW was not a chief source of freshwater and the technology was not that much developed to enable the withdrawal of GW unsustainably. As such historically, GW was not a serious concern in the spectre of water management (Cullet 2015, Ramanathan 1992, Koonan 2016).

Water in the Constitutional Framework

Many provisions in the Constitution of India (Constitution of India 1996) relating to water specify the legislative jurisdiction of the Union and State Governments, including local bodies. The Seventh Schedule of the Constitution expressly defines 'water' as a state subject, thus providing a significant part of legislative control for water-related issues to the states (leaving only inter-state river waters for the union government). Part III and IV of the Schedule contain the general principles and policies for natural resources management, including water resources, and there by guarantee the fundamental right to the citizens for free access and use of water. Under the Constitution, some fundamental duties to this effect have been imposed on the citizens too.

Article 15(2) of the Constitution, recognizing the need for equal access to water, provides explicitly that "no citizen shall on grounds only of religion, race, caste, sex, place of birth or any of them be subject to any disability, liability, restriction or condition concerning the use of wells, tanks, bathing ghats, etc." Sub-clause 2b of Article 15 relating to "the use of wells, bathing ghats, roads and places of public resort maintained wholly or partly under the funds provided by the state or dedicated to the use of the general public." This expression qualifies the provision of equal access to each of the places mentioned in sub-clause (b) but excludes a privately owned well or tank.

The right to life provided under the Constitution (Article 21) makes it obligatory for the State to assure an equitable distribution of the resources and ensure their environmental and ecological improvement and preservation. While the judiciary has confirmed the Constitutional right but due to the absence of a legal framework, the courts have not elaborated the fundamental components of this right. The right to access to water and the right to pollution-free water have also been considered as part of the right to life under Article 21 of the Constitution of India. This is due to profuse and advanced explanation or interpretation of the fundamental right to life under Article 21 by the Apex court and several high courts in a series of cases.

The Directive Principles of State Policy recognize the principle of "equal access to material resources of the community." Article 39(b) provides that "*the state shall, in particular, direct its policy towards securing that the*

ownership and control of the material resources of the community are so distributed as best to subserve the common good." Article 47 of the Constitution assigns the State a responsibility "to raise the standard of nutrition and living and improve public health." Article 51-A (g) imposes a fundamental duty on every citizen of India "to protect and improve the natural environment including forests, lakes, rivers, wildlife and to have compassion for living creatures." The legislative powers have been separated between the State Legislative Assemblies and the Parliament, and the Constitution provides a vital role to the states in water management by incorporating water in the State List, recognizing the diverse conditions existing in different areas.

Article 245 of the Constitution provides that the "Parliament makes laws for the whole or any part of the country and a legislature of the state for the whole or any part of the State's territory." The Parliament has exclusive powers to make laws on subjects given under Union List (List I) of the Seventh Schedule. Entry 56 in List I is related to "regulation and development of interstate rivers and river valleys to the extent to which such regulation and development under the control of Union are stated by the Parliament by law to be of public interest." In exercise of this power, the Parliament passed the River Boards Act, 1956 which provides "*a framework to set river boards by the Union Government to advise the state governments relating to the regulation or development of an inter-state river or river valley*" (The River Boards Act 1956).

The Constitution provides for the Constitution of tribunals to resolve the disputes between the states under Article 262 concerning river water distribution. Accordingly, the Parliament has enacted the Inter-State Water Disputes Act, 1956, which provides for the adjudication of inter-state river disputes among states by setting up the tribunals to adjudicate the conflict (Inter-State Water Disputes Act 1956). The subject matter of water is included in the Union list as well as State List and is not listed in the Concurrent List, but under Entry 201 in the Concurrent List, namely "economic and social planning.", the approval of the Union Government is necessary to include hydropower, major and medium irrigation, flood control and multipurpose projects in the national plan.

Constitution also allows the Parliament under Article 252 to legislate in any area in which states have exclusive rights to legislate, provided that the states' prior consent has been obtained. "Water (Prevention and Control of Pollution) Act, 1974" was enacted under this article to prevent water pollution and maintain and restore the water resources (Water (Prevention and Control of Pollution) Act 1974). The legislative competency concerned with water under the Constitution is State List-Entry 17, the Union List-Entry 56, and Article 262. Entry 17 in the State List provides for "water supplies, irrigation and canals, drainage and embankments, water storage and hydropower." But it is not an unqualified entry and its provisions are subject to the conditions of Entry 56 in the Union List, which includes "*Regulation and development of interstate rivers and river valleys to the extent to which such regulation and development under the control of Union are declared by Parliament by law to be expedient in the interest of the public*". Article 253 provides Union Government powers to legislate for giving effect to international agreements "*Notwithstanding anything in the foregoing provisions of this Chapter, Parliament has the power to make any law for the whole or any part of the territory of India for implementing any treaty, agreement or convention with any other country or countries or any decision made at any international conference, association or other body*" (Constitution of India 1996).

Legal Framework since Independence

The Constitution forms the basis for the legitimacy of all post-constitutional legislations that have been passed by the Union and States under constitutional powers. Since water is primarily a state subject, the state legislatures have passed a plethora of laws in areas like drinking water supply, irrigation, GW, mining, etc. The Union Government has been mainly concerned with specific areas like interstate water distribution, economic development of the environment, territorial waters and inland transport and in other areas like drinking water, sanitation, flood management, etc. its role has been advisory, i.e. policy-making, framing draft laws and schemes for helping and assisting state governments. The major legal instruments governing the water are discussed hereafter.

The River Boards Act, 1956

The River Boards Act, 1956" was enacted under Article 262 which empowers the Union Government to establish separate Boards for the regulation and development of interstate rivers and river valleys on the request of state government or as per the provisions of this Act (The River Boards Act 1956). Section 4 of the Act provides that every Board so constituted shall be a body corporate having perpetual succession and its 'area of operation', i.e. its jurisdiction shall extend to the boundaries of the river or river valley. The powers and functions of the Board (Section 13) include the preparation of schemes for regulating or developing the interstate river or river valley and advising the governments interested to undertake the measures for executing the schemes prepared by the board. So far, Union Govt. has constituted Betwa River Board, Tungabhadra Board, Bansagar Control Board, Brahmaputra Board for

smooth implementation of various projects (Ministry of Water Resources 1985).

Inter-State Water Disputes Act, 1956

Inter-State Water Disputes Act, 1956 was enacted to resolve the inter-state river waters and river valleys disputes that would arise in the use, control, and distribution of water of an inter-state river (Inter-State Water Disputes Act 1956, Sasidhar N 2011). The Act provides that when any request under Section 3 is received from any State Government in respect of any water dispute and the Central Government is of opinion that the water dispute cannot be settled by negotiations, it shall constitute a Water Disputes Tribunal for the adjudication of the water dispute by notification in the Official Gazette, within a period of not exceeding one year from the date of receipt of such request. The verdict of the Tribunal shall have the same force as an order or decree of the Supreme Court after its publication in the Official Gazette by the Central Government. Since the enactment of this Act, six Tribunals have been constituted for adjudicating water disputes in respect of the Cauvery, Krishna, Vasandhara, Mahadayi, Mahanadi, and Ravi-Beas rivers (Ministry of Water Resources 1985). An amendment in the ISWD Act 1956 was made through 'The Inter-State Water Disputes (Amendment) Act, 2002' to make it mandatory for the Union Government to constitute a Tribunal within one year on receipt of the application of any disputant State. It also empowered the Union Government to appoint a Tribunal, *suo-moto*, if necessary (Ministry of Water Resources 1985).

Water Pollution Control Framework

Water pollution is a phenomenon induced or caused by human activities which occurred for the first time about 10,000 years ago when mankind became sedentary and started settling in villages and farm the land. Today, several major rivers in India have become severally polluted. The expansion of agriculture and urbanization and their intensification due to population growth has been associated with serious GW pollution problems. The situation called for serious efforts for the protection and preservation of all the water sources on the national level.

The Water (Prevention and Control of Pollution) Act, 1974

Enacted by the Parliament under Article 252(1) of the Constitution, it was the first attempt to deal comprehensively with an environmental issue related to water (Water (Prevention and Control of Pollution) Act 1974). All the state legislatures have given their consent to the implementation of this Act (Divan and Rosencranz 2001). The main objectives of the Act as provided in the preamble are the prevention, control, and abatement of water pollution and the maintenance or restoring of wholesomeness of water (Water (Prevention and Control of Pollution) Act 1974). The Act provides for the constitution of Central, State, and joint Boardsem powered to take water samples and their analysis, cognizance of offenses, discharge of sewage or trade effluents, penalties, offenses by companies and government departments, etc. to check pollution.

The Central Pollution Control Board, which has been attached to Department of Environment, Forests and Wild life of Union Government (Central Pollution Control Board, Ministry of Environment, Forest and Climate Change 1974), advises it on various matters related to water pollution, coordinate the activities of 'State Pollution Control Boards', sponsor investigation and research concerning water pollution and develop an inclusive plan for control and prevention of water pollution." The Central Board is primarily responsible for ensuring the cleanliness of streams and wells in the States.

Section 17(1) of the Act enables the State Boards "to prescribe standards for the discharge of effluent or the quality of the receiving waters". The Act provides for a permit system or "consent" procedure to prevent and control water pollution. The Act "*prohibits disposal of polluting matter in the streams, wells, and sewers or on land over the standards established by the state boards*". It provides that "*a person must obtain consent from the state board before taking steps to establish any industry, operation or process, any treatment and disposal system or any extension or addition to such a system which might result in the discharge of sewage or trade effluents into the stream, well or sewer or onto land*". Other functions of the state boards specified by the Act include planning an all-inclusive programme for the prevention, control or abatement of pollution in the State, encouraging, conducting and participating in investigations and research of water pollution problems, inspecting facilities for sewage and trade effluent treatment and developing economical and reliable methods of treatment of sewage and trade effluents (Sections 17, 24, 25 of the Act). Anew section 33A was introduced in 1988 to empower the state boards to issue directions to any person, officer, or authority including orders to close, prohibit or regulate any industry, operation, or process and to stop or regulate the supply of water, electricity, or any other service (Water (Prevention and Control of Pollution) Act 1974).

The Water (Prevention and Control of Pollution) Cess Act, 1977

To cope with the financial constraints of pollution boards in discharging their statutory functions, "The Water (Prevention and Control of Pollution) Cess Act, 1977" was passed. The preamble of the Act provides for *"the levy and collection of cess on water consumed by persons carrying on*

certain industries and by local authorities to augment the resources of the Central Board and State Boards under the Water (Prevention and Control of Pollution) Act, 1974 for the preservation and control of water pollution."

The Act empowers the Central Government to impose a cess on water consumed by industries listed in Schedule I of the Act. Specified industries and local authorities are subject to the cess if they use water for purposes listed in Schedule II of the Act. The Act was amended in 1991 to provide for rebate of Cess where any person or local authority liable to pay the cess under this Act installs any sewage or effluent treatment plant, shall be entitled to a rebate of 25% on the cess payable (MC Mehta v. Kamal Nath 1997).

The Environment (Protection) Act, 1986

'The Environment (Protection) Act, 1986 was enacted under Article 253 of the Constitution "to provide for the protection and improvement of environment and matters connected therewith". This is umbrella legislation providing a framework to coordinate the activities of various authorities established under the previous laws such as 'the Water Act' and 'the Air Act'. The Act extends to control water pollution as Section 2 (A) of the Act states that "the environment should include water and the interrelationship which exists among and between water and human beings and other living creatures such as plants, micro-organisms, and property". Section 3(2) authorizes the Central Government to 'establish standards for the quality of the environment' and for 'emission or discharge of environment pollutants' from any source. The Central Government may delegate specified duties and powers under The Act to any officer, state government, or other authority. Section 19 of the Act lays down that "*no court shall take cognizance of an offence under this Act except on a complaint made by the Central Government or an officer or authority authorized in this behalf by the Central Government*". The Act makes it "*obligatory for the persons responsible for discharge and the person in charge of the place where such discharge takes place, to inform the authorities about the accidental discharge of any pollutant over the prescribed standards*". Act also provides for "*Stringent penalties are prescribed for the violation of the provisions of the Act*" and "*Jurisdiction of civil court is barred under the Act*" (The Environment (Protection) Act 1986).

The Central GW Authority

The Central Ground Water Authority (CGWA) was constituted by the Central Government in January 1997, in the Ministry of Environment & Forests, for regulation and control of GW development and management in the States and Union Territories which don't have their own GW Authorities (Ministry of Water Resources 1985). The Authority issues 'No Objection Certificate' (NOC) for GW extraction to industries or infrastructure projects or Mining Projects etc., and frames guidelines in this connection from time to time. In April2015, The Hon'ble National Green Tribunal (NGT) directed CGWA to ensure that every person shall obtain permission from it for operating a tube-well, or any means to extract GW and its operation shall be subject to the law in force, whether it is an existing unit or is yet to be established. NGT has also directed all industrial units linked to Common Effluent Treatment Plants to obtain a 'NOC' as per the law from CGWA through State Pollution Control Board. NGT has also directed CGWA in July 2017 that every industry should pay for the extraction of GW as per terms laid in the order permitting such extraction.

73rd and 74thConstitutional Amendments, 1992

The 73rd constitutional amendment Act 1992 regarding Panchayats introduced the subjects "Minor irrigation, Water management and Watershed development", "drinking water" and "maintenance of community assets", and 74th amendment regarding Municipalities introduced the subjects "water supply of domestic, industrial and commercial purposes" in the Eighth Schedule (Part IX), empowering the State governments and legislatures to devolve these functions to local governments (Constitution of India 1996, The Constitution (Seventy-third Amendment) Act 1992). With the allocation of drinking water, minor irrigation, watershed development, and sanitation, as well as fisheries to the Local Government institutions, Panchayats in rural areas and Municipalities in urban areas, are now given explicit powers and responsibilities about water and related issues. Though these crucial changes have not been effectively transferred at the local level so far, yet these most significant amendments to the Constitution can effectively recast the distribution of powers relating to GW use and management in favour of democratically elected local bodies (Constitution of India 1996, The Constitution (Seventy-third Amendment) Act 1992).

The Code of Criminal Procedure 1973

Sections 133-144 (Chapter X) of the Code of Criminal Procedure, 1973 deal with public nuisance (The Code of Criminal Procedure 1973). Section 133 deals removal of public nuisance through a conditional order. Any Executive Magistrate, the Sub-Divisional Magistrate, the District Magistrate, or a person authorized by the state government for this purpose has the power to take cognizance of certain acts, either on a police report or based on a complaint. It may conditionally order the person responsible for causing such nuisance or obstruction or any of the acts to remove these within the fixed time limit or prevent or stop from carrying on such activity or to fence such tank, well, or excavation. The order is conditional because it is only a preliminary order. The

order may be absolute or final only after giving the opposite party a reasonable opportunity of being heard. Section 133 Cr. P. C. provides a speedy and summary remedy in case of exigency where any act leads to or likely to damage the public interest or public health. In all proceedings started under this Section, the Magistrate is supposed to be acting virtuously in the interest of the public.

An order made under Section 136 Cr. P. C. and Section 144 of the Code without prior notice under Section 133(1) is bad. This section bars the jurisdiction of the civil court and provides that no order duly made by Magistrate shall be called in question in any civil court (Ramajogarao 2001). In the landmark Ratlam Municipality case, the Supreme Court did not consider the effect of the 'Water (Prevention and Control of Pollution) Act, 1974' on the availability of injunctive relief under the above-said section (Municipal Council Ratlam v Vardhichand, AIR 1980). However, the Kerala High Court in Tata Tea Ltd. V State of Keralaruled that “the court could not entertain a Section 133 action to await water pollution even where a state board was remiss” (Tata Tea Ltd. V State of Kerala1984).

Common Law

To maintain law and order and secure property rights, the British colonial rulers gradually imposed on India a general system of law (Parikh 2013) from the eighteenth century onwards. The judicial plan of 1772 by Warren Hastings laid the foundation of the Anglo-Indian judicial system on which superstructures were built by the later administrations (Jain 1972). Article 372(1) of the Indian Constitution allows the continuation of application of the common law introduced by the British in the country unless it has been modified or changed by legislation (Constitution of India 1996).

The Common Law remedies against environmental pollution in general and water pollution, in particular, are available under the Law of Torts (Tata Tea Ltd. V State of Kerala1984, Batra 1992). While commenting on the nature of wrong of pollution, the Apex Court observed that *“Pollution is a civil wrong. It is a tort committed against the public as a whole, by its very nature. A person, therefore, who is guilty of causing pollution has to compensate for restoration of the ecology and environment…The considerations for which "fine" can be imposed upon a person guilty of committing an offence are different from those based on which exemplary damages can be awarded*” (Mehta M C v Nath K and Others, AIR 2002).

The Supreme Court has evolved new principles of tort and gave a new shape to tortious liability in environment protection. The liability of polluters is one of the main and oldest legal remedies to reduce or control pollution under the Law of Tort. The significant liabilities for environmental or water pollution under the Law of Tort, in particular, are (a) Nuisance; (2) Trespass; (3) Negligence; and (4) Strict Liability (Jain 1972, Batra1992). The Supreme Court has added a new class based on the principle of absolute liability in the Case of M.C. Mehta v. Union of India (Mehta M C v Nath K and Others, AIR 2002) that if any harm results from the hazardous activity, the enterprises are liable to compensate for such harm. Such a rule ensures that hazardous industries should bear the burden of damage resulting from the escape of harmful substances (Thakur 2007).

National Water Policy 2012

The Ministry of Water Resources (MoWR) of the Government of India formulated the National Water Policy (NWP) to govern the planning and development of water resources and their optimum utilization in 1987. 'NWP' was reviewed and modified in 2002 and then in 2012 (Ministry of Water Resources 1985). The objective of the NWP is “*to take cognizance of the existing situation and to propose a framework for the creation of an overarching system of laws and institutions and a plan of action with a unified national perspective*” (53). The major provisions under the policy may be summed up as (a) resource planning and recycling for providing maximum availability; (b) preparation of guidelines for the safety of storage dams and other water-related structures; (c) regulating the exploitation of GW; (d) Setting water allocation priorities in the order of drinking water, irrigation, hydropower, navigation, industrial and other uses; (e) rationalization of water rates for surface water and GW taking into consideration the interests of small and marginal farmers; (f) participation of farmers and voluntary agencies; and (g) establishing a standardized national information system with a network of data banks and databases. The policy also deals with water quality, water zoning, conservation of water, flood and drought management, erosion, etc.

A Committee was constituted by MoWR in June 2013 under Dr. S.R Hashim, Former Member, Planning Commission for suggesting a roadmap for implementation of the NWP. The Committee submitted its report in September 2013 containing the Action Plan needed for implementation which also included the enactment of the National Water Framework Bill and River Basin Management Bill (Ministry of Water Resources 1985). Further, two documents, i.e. “Reassessment of Water Availability in India using Space Inputs” (Central Water Commission 2013) and “Master Plan for Artificial Recharge to Ground Water in India” (Central Ground Water Board 2013), were prepared to assess the availability of water in the country and its augmentation. A web-based Water Resources Information System (India

Water Resources Information System 1990) has been set up and all unclassified data of the Central Water Commission and Central Ground Water Board have been uploaded on the website. However, the NWP lacked in preparing the nation for the optimum management of water resources in the 21st century due to emerging challenges of water scarcity and climate change in the coming years (Seth 2013).

Recent Initiatives to strengthen legal Framework for Water

The existing responses of the Government to the GW crisis reflect the intricacies of the under-lying situation. A Committee on Restructuring the Central Water Commission (CWC) and Central Ground Water Board (CGWB) was set up which submitted its report titled, "*A 21st Century Institutional Architecture for India's Water Resources,"* to the central government in July 2016. The report recommended the merging the CWC and CGWB into a new, autonomous, and accountable organization called the National Water Commission (Khandwalla 2016), which would '*facilitate the formulation of a national water policy, secure the necessary data, and ensure effective governance of the entire machinery, central as well as state, operating the nation's water resources through incentives and expert advice*. The Union Government has recently taken some initiatives to develop and strengthen the legal and policy framework for water governance in the country.

The Water Conservation Authority of India Bill, 2016

Conservation of water resources is one of the most important aspects of water management but so far there has inadequate legislative support for this activity. The Water Conservation Authority of India Bill, 2016 has been framed to provide for the establishment of a Water Conservation Authority of India to formulate and execute a comprehensive action plan for the conservation of water of rivers, rainwater, and GW throughout the country. Other major functions of the Authority will include; (a) building an adequate number of reservoirs at conspicuous places in different parts of the country, particularly in desert and drought-prone areas; (b) constructing bunds and check dams on river beds; (c) de-siltation of existing reservoirs, ponds, canals, and such other water bodies; (e) building recharge shafts and construction of the sufficient number of trenches at appropriate places; (f) and advise the appropriate Governments to make rainwater harvesting compulsory, to diversify away from water-guzzling crops; to create awareness about the importance of water conservation. The bill has been introduced in the Rajya Sabha on 10th March 2017.

The Interstate River Water Disputes (Amendment) Bill 2019

To reduce the delay in the adjudication process for resolution of water disputes amongst the states under ISWD1956, an amendment Bill, '*The Interstate River Water Disputes (Amendment) Bill 2019'* has been drafted which seeks to constitute a permanent tribunal, so there will be benches and one bench would be able to look at more than one issue/dispute. The Bill is expected to usher in a new era in the country for quick resolution of river-water disputes. The Amendment Bill provides to set up one interstate river water tribunal for the entire country with different benches for different rivers, depending on the disputes. These benches comprising retired justices, officials, and experts would deliver time-bound verdicts, within a maximum of three years. This would ensure greater cohesion among the states and help in the effective utilization of water resources. It has been passed by the Lok Sabha and is pending before the Rajya Sabha.

River Basin Management Bill, 2016

The draft River Basin Management Bill proposes to facilitate inter-State coordination by establishing 13 River Basin Authorities for optimum developments of inter-State rivers. These Authorities will ensure scientific planning of land and water resources with a unified perspective (including soil moisture, ground, and surface water) taking basin/sub-basin as a unit, to achieve comprehensive and balanced development of command areas and the catchment. The proposed legislation is expected to result in an optimal development and management of waters of inter-State Rivers following the basin approach (River Basin Management Bill 2018).

National Water Framework Bill, 2016

The draft National Water Framework Bill, 2016provides for an overarching national legal framework with principles for protection, conservation, regulation, and management of water as a vital but stressed natural resource. The draft bill talks about sharing the river water by states without violating the rights of others. Water pricing and regulators, water as a right, drought management, flood management, water quality, and water conservation are other areas that the bill covers. Describing "water as part of life" Section 3 of the proposed Bill provides that *"every person has a right to sufficient quantity of safe water for life within easy reach of the household regardless of, among others, caste, creed, religion, community, class, gender, age, disability, economic status, land ownership and place of residence"* (Draft national water framework bill hopes to tackle conflict over water 2016). Abinding national water quality standard for every kind of use is proposed to be introduced. An integrated river basin development and management plan is supposed to be drawn up and all water resource projects in that basin or sub-basins need to conform to that plan. The draft law asks

the government to strive for rejuvenation of river systems by ensuring '*Aviral Dhara'* (continuous flow), '*Nirmal Dhara'* (unpolluted flow), and *'Swachh Kinara'* (clean and aesthetic river banks). A provision has been made for the metering and pricing of urban water supply on a volumetric basis. A participatory approach to irrigation management shall be encouraged, including the establishment of Water Users Associations which shall be accorded statutory powers to collect and retain a portion of Irrigation Service Fees. Section 29 of the Bill provides that an appropriate agency shall be set up for each river basin/sub-basin to collect and collate all data on regular basis about rainfall, the river flows, area irrigated by crops and by source, utilisations for various uses by both surface and groundwater (Water Policy and Action Plan for India 2020, Draft national water framework bill hopes to tackle conflict over water 2016.). As per the new law, the State, the citizens, and all categories of water users shall be duty-bound to protect and conserve the water resources.

New CGWA Guidelines 2018 for GW Extraction

The CGWA has notified the following guidelines applicable since June 2020 to control and regulate the GW extraction in the country (New CGWA Guidelines for GW Extraction 1970). The establishments of Armed Police and Armed Forces and individual consumers extracting GW for drinking and domestic use in urban and rural areas, GW withdrawals for agricultural purposes, and by Micro and Small Enterprises extracting GW less than 10 m^3/day are exempted from obtaining NOC for GW extraction. Government water supply and Group Housing agencies shall be granted NOC only for five years for the installation of wells for domestic water supply in urban areas where the local Government supply agency is unable to supply the required quantity of water. Where GW requirement exceeds 20 m^3/day, it will be mandatory to install Sewage Treatment Plants for recycling treated water for gardening, car washing, etc. The users will be liable to pay for the extracted GW at prescribed rates. Agriculture sector is exempted from obtaining 'NOC' for GW extraction. The States/UTs have been advised to substitute their free/subsidized electricity policy with a suitable water pricing policy and should work further towards crop diversification/other initiatives to reduce overdependence on GW. New major industries, except Micro, Small, and Medium Enterprises (MSME), will not be granted 'NOC' in areas assessed as over-exploited. Compulsory water audits of all industrial extractions of more than 100 m^3/day will be carried out annually. Expansion of existing industries in over-exploited units that involve an increase in the quantity of GW extraction will not be allowed. New MSME industries for packaged water will not be issued NOC in over exploited areas.

Groundwater (Sustainable Management) Bill 2017

The draft Model Bill, prepared by Ministry of Water Resources, River Development & Ganga Rejuvenation, provides a new template to the States for addressing the fast-increasing GW crisis faced by many of them. This Bill improves upon the earlier model bill circulated in 1970 and modified many times until 2005 which forms the basis of a dozen of existing GW Acts. But this template fails to provide for local-level regulation of GW use and conservation measures at aquifer level. The GW (Sustainable Management) Bill 2017 integrates various legal developments that have taken place during the last five decades such as recognition of water as a fundamental right and as a public trust. The proposed template provides a new framework for regulating GW as a public resource and to adopt aquifer level management practices which is crucial to address the GW over extraction and depleting water levels.

Revised Policy Framework for Water

In September 2019, the Union Water Resources Minister announced that the Government is planning to update the NWP 2012 and make key changes in the water governance structure and policy framework. A National Bureau of Water Use Efficiency is also on the cards, he said. As a follow-up, a drafting committee has been constituted in November 2019 to prepare a new NWP to address the present and future challenges in the water sector (National Water Policy 2012), and it is expected to give its report shortly.

CONCLUSION

India is facing a dire water crisis which is likely to get worse. Some new initiatives are being taken to tide over it but the existing governance structures, which focus on the construction of water supply systems, and the limitations of the current legal framework which only regulates GW use, need a sweeping re-orientation to enable these to address the concerns looming ahead. The challenge is to develop a governance structure that scrutinizes and regulates sustainable patterns of surface and GW allocation in a catchment, derived from a logical optimization of socio-ecological values based on spatio-temporal variations of water balance parameters, and the critical water demands of dependent entities. There is an utmost need for using each drop of water more efficiently by making a coherent policy and legal framework, incorporating all major rulings by the Apex Court regarding the recognition of water rights and the Public Trust Doctrine, for creating an effective water consumption culture, and taking into account the climatic advantages for the cultivation of crops.

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Marketing Pattern and Processes of Layer Eggs Production in Punjab

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Abstract: The study on layer eggs marketing was based on primary data which was collected face-to-face and the personal approach from wholesalers and retailers through interview schedule. The sale pattern of eggs were mainly supplied by medium and large eggs producer to wholesaler and retailer and small eggs producer mostly sold their products through direct to consumer. The percentage share of the net price received by the producer was highest for marketing Channel-IV Producer→Consumer (97.45) because in this channel there was no involvement of middlemen view in this fact the consumer purchased the eggs at a minimum price through this channel. The total marketing cost and price spread were maximum in the Channel-I (Producer→Wholesaler→Retailer→Consumer) because in this channel existing enrolment of wholesalers and retailers. The marketing efficiency ratio was 36.63 highest in marketing channel-IV as compared to other marketing channels. On the whole basis of the study, commercial poultry eggs farming in Punjab have still a profitable business opportunity for entrepreneurs.

Keywords: Marketing channels, Marketing cost, Marketing efficiency, Poultry eggs, Price-spread

Livestock production is probably going to undergo critical changes regarding population adjustment, production efficiency, commercialization, and intensification to react to the expanding demand for animal-based food items (Birthal and Parthasarathy 2004). The poultry business in India has developed as the most unique and quickly extending segment of livestock economy from the production level contacting around 40 billion eggs with a compound growth rate of 8 per cent. Almost 70 per cent of the total output of poultry farming is contributed by organized sector and rest by the unorganized sector. There are approximately 1000 hatcheries operating working in the country. India's poultry farming represents to a significant example of a success story and its growing at around 20 per cent every year and the domestic poultry market is right now assessed at around 49000 crores, with 2012 production arriving at a record 2.86 million tons of eggs (Ali 2015, Kaur et al 2017). The poultry sector in India is esteemed at around 80,000 crores (2015-16) comprehensively separated into two sub-areas like one with a profoundly organized commercial sector with around 80 per cent of the total market share and the other being unorganized with approximately 20 per cent. The unorganized area additionally alluded to as backyard poultry assumed a critical part in supplementary income generation and family sustenance to the most unfortunate of poor people. It is calculated that with a poultry population of 729 million (30 per cent layers at around 215 million) small and medium farmers are generally occupied with contract farming system under bigger integrators, and there are about 30 million farmers engaged in backyard poultry farming sector as per 19th Livestock Census (Analogous 2019, Garval and Sheikh 2020). The per capita accessibility of eggs in Punjab was 141 eggs when contrasted with 61 eggs in India. Because of the restricted extent of additional option to net area sown under crop farming in Punjab under large indebtedness, only allied activities like poultry farming has obtained importance for resolving the agrarian crisis of the state (Analogous 2019). High-value agrarian items which are livestock products form a significant part covered a range of goods whose ascribes are driven primarily by demand and by the way and cost of production (Gebremedhin et al 2007, Geta and Tilahun 2013). Furthermore livestock provide additional income to the farmers. A substantial amount of money was therefore generated from the different products. This, in turn had contributed enormously in improve the economy of the rural communities (Sangeetha et al 2016).

An egg is perceived as one of the significant commercial poultry products for an assortment of usages, and marketing management plays a crucial part in realizing returns to poultry units. There are various intermediaries engaged in the marketing of eggs and there are different marketing channels in the poultry sector for commercialization. Price spread examinations are useful in deciding the efficiency of the poultry marketing system. Various marketing margins are

held by the intermediaries which eventually decide the overall effectiveness of a specific marketing system if products can be moved from the producer to consumer at the minimum cost while keeping up a similar standard of service (Ramdurg et al 2020). This study was taken up to know the marketing performance of eggs in Punjab state. The tabular approach was used to analyze the data in the marketing of poultry eggs.

MATERIAL AND METHODS

Study area: The study was conducted in all the districts of Punjab state with a pre-tested well-structured interview schedule was prepared for marketing data collection from the poultry farmers through a personal interview method. The interviewer collects data legitimately from the interviewee by asking questions and record on instruments. Due to it being a very personal approach, this information collection technique is perfected when it has to assemble profoundly customized information. The 54 per cent layer farmers had maintained farm record with them, which was useful in getting the reliable and detailed information and rest of respondents gave the information based on their memory. The ten wholesalers and fifteen retailers were randomly selected from the major producing and consuming markets. The administered and required information on poultry framing was collected during the year 2018-19. The data on marketing aspects from wholesaler-cum-commission agents and retailers were collected by personal interview method with the help of a structured schedule on various aspects of marketing of poultry products such as disposal channels adopted, price spread, cost incurred by various functionaries involved in the disposable of eggs poultry product. The interview schedule for wholesaler includes labour charge for loading, transportation cost, shop rent, the mortality of birds, electricity bill, permanent labour charges, breakage and spoilage, packaging cost. The costs incurred by a retailer such as transportation cost, shop rent, wastage, water bill, electricity bill, feed cost, permanent labour charges, breakage and spoilage loss and packaging cost were also considered.

Marketing efficiency: The different aspects of marketing efficiency worked out and applied function which is given below:

Producer's price: This is the net price received by the producer farmer at the time of the first sale. This is equal to the wholesale price at the primary assembling centre, minus the charging borne by the producer farmer in selling his produce (Acharya and Aggarwal 2016).

$P_F = P_A - C_F$

where,

P_F = Wholesale price of eggs in the primary assembling market, P_A = Market cost incurred by layer producers, C_F = Producer's price (That is price fetched by layer producer)

Producer's share in consumer (Rupee): The producer's share in consumer rupee was worked out as price received by the poultry producer farmer expressed as a percentage of the retailer price may be expressed as follow:

$P_S = (P_F \div P_r) \times 100$

where,

P_S = Producer's share, P_F = Price received by layer producers, P_r = Retail price

Acharya approach: An ideal measure of marketing efficiency, particularly for comparing the efficiency of alternate markets/channels, should be such that it should take into account all the following:

$MME = [RP \div (MC + MM)] - 1$

$RP = FP + MC + MM$

where, MC = Total marketing costs, MM = Net marketing margins, FP = Prices received by the poultry farmer, RP = Prices paid by the eggs consumer

RESULTS AND DISCUSSION

Marketing channels of eggs production is mentioned in Figure 1.

Sale pattern of egg production through different marketing channels: The sale pattern of eggs through different marketing channels has been presented in Table 1 and Figure 1. Among different market channels, the sale of eggs through wholesaler was the highest on large layer farms (74.07 %) followed by medium layer farms and small layer farms which was reported in the previous worked out by (Sangeetha et al 2016). The sale of eggs through retailer and

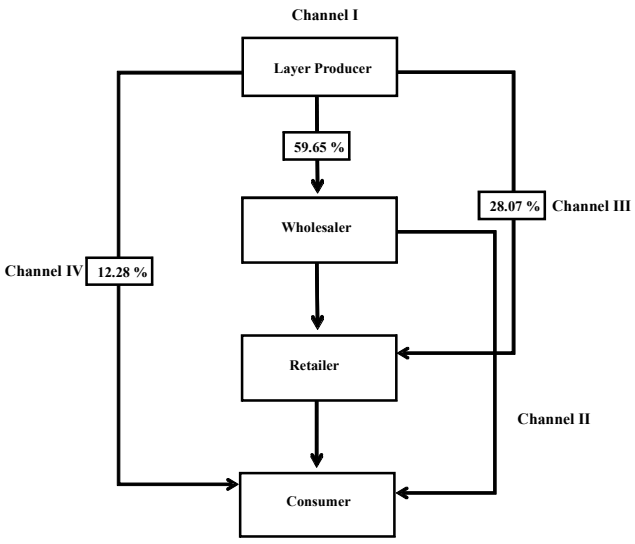


Fig. 1. Existing marketing channels of layer farming

direct to the consumer were highest for small layer farms (36.17 % and 17.02 %) as compared to medium layer farms and larger layer farms. Thus, the overall sale through wholesaler was 59.65 per cent higher than retailer and direct to consumer which was is confirmed from the study carried out by (Kaur et al 2017). The results of the sale pattern showed that the eggs were mainly supplied to the wholesaler by medium and large layer farms and the small layer farms mostly sold their produce to direct consumers. Similar results were found in the previous studies of (Bhullar et al 2012).

Costs and margins of market middlemen in different marketing channels: The net price received by producer was Rs. 389.34 per hundred eggs which accounted for 77.94 per cent of the consumer's rupee (Table 2). The findings were in line with the earlier study (Singh 2010). The percentage cost incurred by producer on package/eggs tray, breakage and spoilage, labour was 1.58, 0.67 and 0.02, respectively. The producer's sale price/wholesaler's purchase price was Rs. 400.65 per hundred eggs and percentage share to the total was 80.21. The costs incurred by wholesalers on labour charges for loading, transportation cost, shop rent, breakage and spoilage and permanent labour charges were estimated at 2.04, 5.14, 2.05, 1.50 and 1.95 per hundred eggs, respectively. The total marketing cost incurred by wholesaler was Rs. 13.14 and percentage share of this was 2.63. Similar, results were described by (Kaur et al 2017). The net margin earned by the wholesaler was Rs. 18.10 per hundred eggs which was 3.62 per cent of consumer's price. The wholesaler's sale price/retailer's purchase price of Rs. 431.89 per hundred eggs, was 86.46 per cent of the total market cost and similar results were reported by (Singh 2010). The cost incurred by retailer on transportation means, shop rent, packaging cost, breakage and spoilage and electricity bill were Rs. 2.71, 5.82, 1.14, 8.05 and 1.76 per hundred eggs, respectively. However, total cost incurred by retailer was Rs. 19.48 per hundred eggs and it was 3.90 per cent of the consumer's price. These finding are supported by earlier researcher of (Kaur et al 2017). The net margin earned by retailer was `48.16 per hundred eggs which comprised 9.64 per cent of the consumer's price and it confirmed by earlier work of (Singh 2010). Retailer's sale price/consumer's purchase price was Rs. 499.53 per hundred eggs in the study area.

Table 1. Sale pattern of egg production through different marketing channels

(Number)

Marketing channels	Farm size category			Total
	Small	Medium	Large	
Producer→wholesaler →consumer	22 (46.81)	26 (65.00)	20 (74.07)	68 (59.65)
Producer→retail→ consumer	17 (36.17)	10 (25.00)	5 (18.52)	32 (28.07)
Producer→consumer	8 (17.02)	4 (10.00)	2 (7.41)	14 (12.28)
Total	47 (100.00)	40 (100.00)	27 (100.00)	114 (100.00)

Note: Figures in the parentheses indicate percentage to the total

The net price fetched by producer was Rs. 389.34 per hundred eggs which constituted 88.31 per cent of the consumer's price. The percentage costs incurred by producer were 1.78, 0.76 and 0.02 on package/eggs tray charges, breakage & spoilage and labour, respectively. Similarly, in this channel, the producer's sale price/wholesaler's purchase price was Rs. 400.65 per hundred eggs and percentage share to the retailer's price was 90.87. These findings were fully supported by the study carried out by (Dinesh and Sharma 2019). The costs incurred by wholesalers were Rs. 2.04, 5.14, 2.05, 1.50, 0.46 and 1.95 per hundred eggs on labour charges for loading, transportation cost, shop rent, breakage & spoilage, electricity bill and permanent labour, respectively. Wholesaler total marketing cost and margin were Rs. 13.14 and 27.10 per hundred eggs and percentage share of total was 2.98 and 6.15, respectively. Similar findings were reported for eggs production in Namakkal district of Tamil Nadu by (Dinesh and Sharma 2019). Wholesaler's sale price/consumer's purchase price was Rs. 440.89 per hundred eggs.

The net price received by the producer in the supply chain was Rs. 400.67 per hundred eggs which constituted 80.21 per cent share in the final price of the produce. This aspect is supported by the study of (Singh 2010). The percentage costs incurred by producer on package/eggs tray charges, breakage & spoilage and labour were 1.58, 0.67 and 0.02, respectively. The producer's sale price/retailer's purchase price was Rs. 411.98 per hundred eggs and percentage share to the total was 82.47. The costs incurred by retailer on transportation charges, shop rent, packaging cost, breakage & spoilage and electricity bill were Rs. 2.71, 5.82, 1.14, 8.05 and 1.76 per hundred eggs to the consumer price. Total cost incurred by retailer was Rs. 19.48 per hundred eggs and share of 3.90 per cent to the total which was found almost similar as in the previous work done by (Kaur et al 2017, Dinesh and Sharma 2019). Net margin earned by retailer was Rs. 68.07 per hundred eggs which accounted for 13.63 per cent share to the retailer's sale price of Rs. 499.53 per hundred eggs. The findings were in line with a study of (Singh 2010).

The net price received by producer was Rs. 414.23 per hundred eggs which was highest of 97.34 per cent of the

Table 2. Costs and margins of market middlemen in different marketing channels

(₹100 eggs^{-1})

Particulars	Marketing Channels			
	I	II	III	IV
Net price received by producer	389.34 (77.94)	389.34 (88.31)	400.67 (80.21)	414.23 (97.34)
Cost incurred by producer				
Package/eggs tray	7.87 (1.58)	7.87 (1.78)	7.87 (1.58)	7.87 (1.85)
Breakage and spoilage of eggs	3.36 (0.67)	3.36 (0.76)	3.36 (0.67)	3.36 (0.79)
Labour charges	0.08 (0.02)	0.08 (0.02)	0.08 (0.02)	0.08 (0.02)
Total marketing cost of producer	11.31 (2.26)	11.31 (2.56)	11.31 (2.26)	11.31 (2.66)
Producer's sale price/wholesaler's purchase price	400.65 (80.21)	400.65 (90.87)	-	-
Cost incurred by wholesaler				
Labour charge for loading	2.04 (0.41)	2.04 (0.46)	-	-
Transportation cost	5.14 (1.03)	5.14 (1.17)	-	-
Shop rent	2.05 (0.41)	2.05 (0.46)	-	-
Breakage and spoilage	1.50 (0.30)	1.50 (0.34)	-	-
Electricity bill	0.46 (0.09)	0.46 (0.11)	-	-
Permanent labour	1.95 (0.39)	1.95 (0.44)	-	-
Total marketing costs of wholesaler	13.14 (2.63)	13.14 (2.98)	-	-
Wholesaler's net margin	18.10 (3.62)	27.10 (6.15)	-	-
Producer's sale price/wholesaler's sale price/retailer's purchase price	431.89 (86.46)	-	411.98 (82.47)	-
Cost incurred by retailer				
Transportation cost	2.71 (0.54)	-	2.71 (0.54)	-
Shop rent	5.82 (1.17)	-	5.82 (1.17)	-
Packaging cost	1.14 (0.23)	-	1.14 (0.23)	-
Breakage and spoilage	8.05 (1.61)	-	8.05 (1.61)	-
Electricity bill	1.76 (0.35)	-	1.76 (0.35)	-
Total marketing costs of retailer	19.48 (3.90)	-	19.48 (3.90)	-
Retailer's net margin	48.16 (9.64)	-	68.07 (13.63)	-
Consumer's purchase price	499.53 (100.00)	440.89 (100.00)	499.53 100.00	425.54 (100.00)

Note: Figures in the parentheses indicate percentages to the total cost

consumer's price in comparison to other channels. The costs incurred by producer on package/eggs tray charges, breakage & spoilage and labour were estimated at Rs. 7.87, 3.36 and 0.08 per hundred eggs, respectively. The total marketing cost incurred by producer was Rs. 11.31 per hundred eggs which was equivalent to 2.66 per cent share of consumer's price. Similar finding was also reported in previous study of (Singh 2010). The producer's sale price/consumers purchase price was Rs. 425.54 per hundred eggs. On comparing the costs incurred by different key actors in each supply chain, it is observed that the percentage share of net price received by producer was highest for Channel-IV as compared to Channel-II, Channel-III and Channel-I. The consumer purchased the eggs at minimum price through Channel-IV as compared to other channels.

According to different marketing channels the marketing cost, margin, price-spread and marketing efficiency in eggs production from layer farms have been depicted in Table 3. The producer's net price received through marketing Channel-IV was Rs. 414.23 highest as compared to Channel-III (Rs. 400.67) and Channel-I and II (Rs. 389.34 each). Similar findings were reviewed in the previous studies undertaken by (Kaur et al 2017, Garvel and Shaikh 2020). The total market cost which involved the market cost of produce, wholesaler and retailer incurred to highest in Channel-I (Rs. 43.93) followed by Channel-III (Rs. 30.79) and Channel-II (Rs. 24.45) and Channel-IV (Rs. 11.31). The total marketing margin of retailer and wholesaler was Rs. 68.07 maximum in Channel-III when contrasted with Channel-I of Rs. 66.26 and Channel-II of Rs. 27.10. The price-spread allude to difference between the two prices for example the price, that is, paid by consumer and price received by producer. The price-spread for Channel-I was Rs. 110.19 highest as compared to other marketing channels. The consumer got the final product at minimum cost in Channel-IV which was Rs. 425.54 less than Channel III and I (Rs. 499.53 each) and Channel-II (Rs. 440.89). The percentage of producer's share in consumer price and marketing efficiency index were 77.94 and 3.53 in Channel-I and 88.31 and 7.55 in Channel-II, respectively. The corresponding share and indices on Channel III and IV were 80.21 and 4.05 and 97.34 and 36.63, respectively. Similar results were confirmed in past and recent studies carried out by (Singh 2010, Kaur et al 2017, Garvel and Shaikh 2020).

Table 3. Channel wise cost, margin, price spread and market efficiency in layer farming

(₹100 eggs^{-1})

Particulars	Marketing Channels			
	I	II	III	IV
Producer's net price	389.34	389.34	400.67	414.23
Total market cost	43.93	24.45	30.79	11.31
Total market margin	66.26	27.10	68.07	-
Price-spread	110.19	51.55	98.85	11.31
Consumer's price	499.53	440.89	499.53	425.54
Producer's share in consumer price (%)	77.94	88.31	80.21	97.34
Marketing efficiency index	3.53	7.55	4.05	36.63

CONCLUSION

Poultry is a significant source of revenue and employment in the rural area. It helps to meet the equity of objective of rural development through their contribution to the cash income of small and marginal farmers and landless labourers. The percentage share of the net price received by the producer was highest in Channel-IV as compared to Channel II, III and I. The consumer purchased the eggs at a minimum price through channel-IV as compared to other channels. The price-spread was highest in Channel-I than other channels because many intermediaries such as wholesaler and retailer were involved in this channel. The market margin was lowest in the market Channel-III because in this channel the wholesaler sold the eggs at the lowest price as compared to other channels due to large quantity handled through this channel. The percentage of producer's share in consumer price and marketing efficiency index were highest in Channel-IV as compared to other marketing channels of layer farming because in this channel there was no involvement of middlemen. However, Producer→ Wholesaler→Consumer was the most important marketing channel from the sale point of view through which nearly 60 per cent of the produce was disposed. The length of the marketing channels increased the price spread and declined the market efficiency of layer eggs producer. However, the number of intermediaries should be decreasing in the marketing which may offer better price to the producer and availability of produce at most affordable price to the consumer. The cooperative system should be evolved in the marketing of eggs which would reduce the involvement of the middlemen. There is a need to reinforce government activities to prevent from leaving the layer farming and retaining them in activity especially in view of its contribution to track protein malnutrition at very reasonable cost.

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GIS-based Integrated Approach for Sustainable Management of Ecology and Environment with Green and Blue Spaces

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Abstract: The Andhra Pradesh state of India has announced a master plan for retaining and improving the green-blue network in the Amaravati Region as the green-blue areas play a potential role to mitigate the adverse effects of urbanization in a sustainable way. The present paper proposes an advanced scheme for improving the existing percentage of green space in the master plan through suitably pre-processing and extracting the green-blue spaces using Geographic Information System (GIS) technology. The proposed approach intends to strengthen the environmental dimension and to regain the balance of sustainable development. The urban green space per capita analysis and percentage area of green are determined for measuring greenness. The results from the study enable us to identify the critical areas with less percentage green and recommend possible changes in the planning and greening strategies to the existing master plan. From the analysis, it is suggested that the green space alone be increased by 30 per cent through proposing an additional allocation of vacant plots to linear greens and rooftop gardens. The proposed suggestions would certainly contribute to a liveable and sustainable city through integrated and holistic planning of the green and blue spaces and will eventually benefit the inhabitants of Amaravati.

Keywords: Urban planning, GIS, Rooftop gardens, Linear Greens, Sustainable city

Green and Blue spaces are an integral part of urban regions for maintaining environmental quality and sustainability (Panagopoulos et al 2016, Li et al 2017, Gonzalez et al 2020). Green space includes parks, gardens, urban forests, and the informal green spaces surrounding defunct industries, railway corridors and historical sites whereas blue space includes water bodies like lakes, oceans, rivers, etc. (Gupta et al 2012). The green and blue spaces are essentially the sites for recreational opportunities, social connection and enhanced ties, often providing respite in urban settings to assist mental and physical recuperation (Wolch et al 2014, Nutsford et al 2016, Barton and Rogerson 2017). Urban green space provides numerous benefits to the residents by acting as urban lungs through absorbing pollutants and releasing oxygen, eventually providing clean air, water and soil, and balancing the city's natural urban environment (Gupta et al 2012). Moreover, the green and blue spaces offer intentional or unintentional opportunities for social interaction which is linked to an improved state of moods (Miles et al 2012).

The utmost goal of the development authority in an evolving smart city concept is to preserve the biological system with diverse, developed, and balanced being productive over time for mankind through a natural way. For instance, Singapore is transformed from a small and densely populated city into a clean, green, sustainable and highly livable city where the urbanization proceeds in harmony with nature through long-term planning and good governance. Tengah is the first forest town in Singapore to be fully integrated with its surrounding ecosystem with greenery formations as the main structural foundation of the town (Russo and Cirella 2018). A growing number of scholars, organizations, and cities like Detroit are promoting green infrastructure as a way to provide multiple ecosystem services to residents, and as a strategy for enhancing urban sustainability and resilience (Meerow and Newell 2017). In Bucharest city, Romania, the identification of past urban waters and green spaces inspired planners to design strategies and restoration projects for improving green and blue infrastructure within their cities (Lojă et al 2018). Stuttgart has planned to exploit the role of natural wind patterns and dense vegetation in reducing problems of overheating and air pollution by recommending some planning and zoning regulations that aim to preserve open space and increase the presence of vegetation in densely built-up areas. Studies have been conducted on evaluating strategic rooftop green infrastructure benefitting in terms of the reduction of indoor temperatures and urban heat islands (Agarwal and Kumar 2020, 2021). The creative use of blue-green infrastructure is one of the most promising actions for

adaptation to rapidly changing human and environmental circumstances. This needs to be recognized in the planning process, especially in the formulation of regional spatial development strategies (Ghofrani et al 2017). Without a proper conceptual framework and planning, it is hard to determine the sustainability of the smart green city (Haque et al 2013, Debnath et al 2014, Mangi et al 2020). In addition to these advances in geospatial technologies permit a more precise quantification of the visibility of green and blue spaces (Nutsford et al 2015, Gascon et al 2017).

Concerning the strategic plan for urban development of Amaravati capital city in Andhra Pradesh, India, it has aimed towards a cohesive built environment for the excellent quality of life for its citizens. There are several attempts and case studies in Andhra Pradesh and Telangana region for restoring and managing the natural resources like surface and groundwater in an ecosystem by geospatial and remote sensing-based analysis (Asadi et al 2017a, Sujatha et al 2019, Ahamed and Agarwal 2019, Agarwal and Kumar 2019). The Geographic Information System (GIS) technology has been proven to be an efficient tool for mapping, extracting, analyzing and furnishing the database of the spatiotemporal topographical features for effective resources management (Asadi et al 2017b, Kesanapalli et al 2018, Kumar et al 2019). Hence, the GIS-based framework is preferred for executing green & blue space management and identifying the new areas for the green and blue network (Bellamy et al 2017, Stessens et al 2017). The present paper proposes possible improvements in the percentage of urban green spaces along with simultaneous analysis of blue space management at the master plan level using geospatial technology. To attract public awareness about green and blue space uses and benefits, few training campaigns along with a community survey are conducted by distributing the questionnaire to people in Amaravati, the results showed their 100% willingness to actively participate in the implementation. Increasing urban green space area would benefit the newer generations for attaining a sustainable newly planned Amaravati region to flourish years together (Agarwal et al 2021).

MATERIAL AND METHODS

The study area chosen for the present work is Amaravati capital city in Andhra Pradesh having a spread of 217.23 km^2 and a population of 1,03,000 lakhs as per census 2011 (census C.D.2011 of Andhra Pradesh). Location map of Amaravati capital city in Andhra Pradesh is shown in Figure 1. The study area covers 25 villages which come under 3 mandals: Thulluru, Tadepalli and Mangalagiri. The Krishna River flows on the northern fringes of Amaravati region. The existing land use pattern consists of agriculture, grazing land, fruit and flower plantations, village settlements and village ponds, etc. Hence, the Amaravati master plan development promotes green and blue open space.

In the urban development plan of Amaravati, it has been divided into 28 townships. They are further divided into sectors, colonies, blocks and plots. The returnable plots (residential & commercial) are distributed to local farmers who contributed their lands for Amaravati through the land pooling scheme. The remaining vacant plots are mapped performing parcel fabric, spatial analysis and join tools in ArcGIS. Geoprocessing tools are used to extract green & and blue spaces from the master plan, zonal development plan, revenue survey record and re-settlement register files. Vacant plots are of residential and commercial categories. The chunks of these vacant sites are in irregular shapes and can be conveniently used for incorporating linear greens.

Green and blue statistics of Amaravati: Amaravati is described as a greenfield city with 68.13 per cent of green space and 15.36 percent of blue space. In the present study, the green and blue space statistics before Amaravati planning are considered from the existing zonal development plans and revenue survey records. Amaravati master plan design principles focus on delivering a mixed-use urban environment giving priority to green and blue spaces. The green and blue spaces in Amaravati region follow zoning regulations as per Amaravati Zonal Regulations (ZR) notified in February 2016. It suggests the following parameters to be maintained in a good condition: a) the minimum percentage green cover should be within 15-20 percent case to case basis by Andhra Pradesh Capital Region Development Authority and b) the minimum width as organized, open space for recreation is 3 m. These parameters are implemented for all notified zones in Amaravati as mentioned in the master plan;

Residential (R1, R2, R3, R4)
Commercial (C1, C2, C3, C4, C5 and C6)
Industrial (I1, I2, I3)
Open Spaces and Recreation (P1, P2, P3)
Institutional Facilities (S1, S2, S3)
Infrastructure Reserve (U1, U2).

Where, the blue space is provided in the protected area (P3) zone to conserve and protect sensitive areas which are rich in nature and biodiversity.

The data sets of revenue survey records, zonal development plans and the master plan for Amaravati region are used for extraction and analysis of green-blue spaces. Satellite imagery of world view-II of about 0.4 m resolution along with drone imagery 10 m resolution is used for visual interpretation and verification of green and blue spaces.

Figure 2 depicts the methodology adopted for green and blue space management using GIS. The GIS platform integrates the master plan corresponding to urban planning and revenue survey records for analysing the existing green and blue space and allocating possible development sites at regional and microclimate levels with the state-of-art people's participation.

Considering the concepts of urban planning, a master plan is designed for the Amaravati region. As per the proposal of Amaravati master plan, there is a decline in the percentage of green-blue spaces as compared to statistics before the master plan. Hence, it is necessary to increase the green and protect blue spaces. The use of geospatial tools in the planning phase helps to extract & pre-process the green-blue spaces for better management of both entities. Upon analysis, the statistics revealed that the management of both the spaces is necessary for a newly formed region to progress towards sustainability. Hence, an action plan for green space management has been initiated by the government authority to satisfy the future ecosystem requirements along with the continued urban growth.

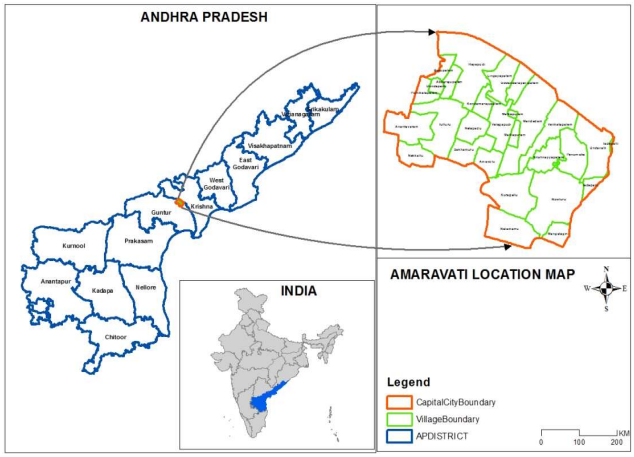


Fig. 1. Location map of Amaravati capital city in Andhra Pradesh, India

For enhancement of green space, methods like linear greens, rooftop gardens, plug-in greens are proposed. A community survey is done by distributing questionnaires in Amaravati region to involve people's participation and to create awareness of the benefits of green space. Blue space management is to protect and conserve the existing water bodies. The workflow was adopted to ensure that both the green & blue space management together contribute to the sustainability of Amaravati region.

RESULTS AND DISCUSSION

To retain the amount of green and blue space which prevailed prior to planning, many attempts have been made

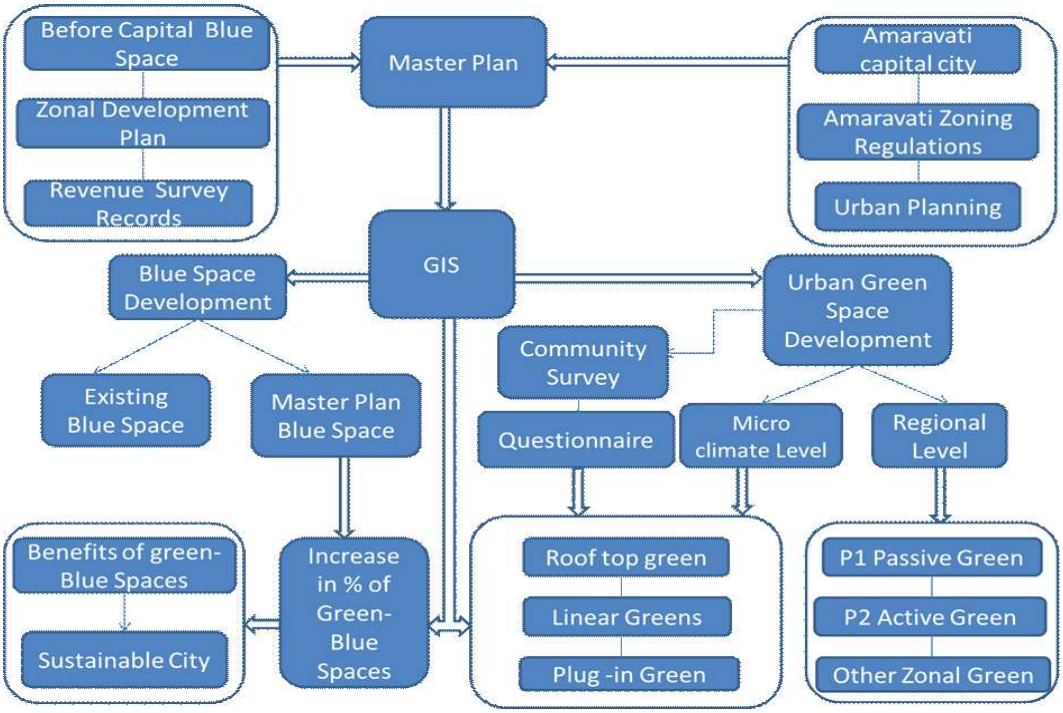


Fig. 2. Methodology of green & blue space management using GIS

while designing the master plan. This is achieved by an increase of 3 per cent in the master plan provided blue space planned in the Amaravati region by retaining the water flow through a canal network (Fig. 3). Blue network and the waterfront city were planned with interconnecting green blue nodes of the city with blue space proposed as P3 Protected zone of 19.22 per cent. Percentage of green can be increased by proposing the allocation of vacant plots to linear green spaces, rooftop gardens, plug-in greens, etc. The proposed master plan intends to achieve about 30 per cent green and 20 per cent blue spaces in the Amaravati region to assure a sustainable environment. Hence, the pre-existing urban green space of 19.19 per cent is improved to 30 per cent of the total Amaravati area by allocating the vacant plots. The percentage of green space is calculated by;

Green percentage = Total green space area (hectares) / Total capital city area (hectares) * 100

The attributes used are P1 passive green, P2 active green, P3 protected zone-hills, PGN-G plug-in green, R1 village planning zone, R4 high-density zone, SR2 low-density housing, SR4 high density private, C1 mixed-use zone, C3 neighbourhood centre zone, C4 town centre zone, C5 regional centre zone, C6 central business district zone, S3 special zone, SS3 special zone, SP1 passive zone, SP2 active zone (Table 3). It can be observed from the table that the existing Master plan green space combined with the proposed rooftop green, linear green and plug-in greens increase the percentage green space from 19.19 to 30.88 per cent.

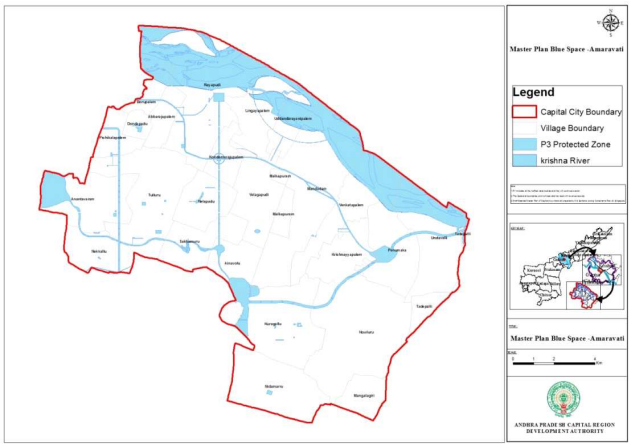


Fig. 3. Proposed blue space network at master plan level in Amaravati

Table 1. Statistics of green and blue space prior to Amaravati planning

Type of blue space	Blue space before capital city (hectares)	Amaravati area (hectares)	Percentage (%)
Water bodies	274.84	21709.13	15.24
Streams	245.61		
Krishna river	2814.05		
Type of green space	Green space before capital city (hectares)		68.13
Agriculture land	14791.25		

Table 2. Statistics of green and blue space according to the master plan of Amaravati

Type of blue space	Blue space before capital city (hectares)	Amaravati area (hectares)	Percentage (%)
P3 Protected zone	4171.51	21709.13	19.22
Type of green space	Master plan green space (hectares)		19.19
P1 Passive green	1987.69		
P2 Active green	1598.43		
P3 Hill green	580.67		

Proposed development of green spaces in Amaravati region: Amaravati is proposed to be developed with a theme of green-blue concept by considering the key parameters of hierarchy, availability, accessibility and visibility, which further creates an overall ecological impact on flora and fauna of adjoining green and blue areas. Amaravati region planning sets the proposed limit of urban green space of 12.6 m^2 per person compared to the World Health Organisation (WHO) benchmark of 9 m^2.

Green space management: The existing land use pattern consists of agriculture, grazing land, kharif, rabi crops, fruit and flower plantations, village settlements and village ponds,

Table 3. Statistics showing enhancement in green space percentage by implementing proposed methods along with master plan greens

Type of green space	Total green area (hectares)	Amaravati area (hectares)	Percentage %
P1 passive green	1987.69	21709.13	30.88
P2 active green	1598.43		
P3 hills	580.67		
Plugin green	2.23		
R1R4SR2SR4 green	90.23		
C1C3C4C5C6 green	129.36		
S3 SS3 green	280.32		
SP1 green	50.62		
SP2 green	173.52		
Industrial green	126.14		
Institution green	19.79		
Rooftop green	1547.23		
Linear green area	116.48		

etc. The land use pattern and 29 village settlements should not be neglected while existing habitations can develop green spaces around ponds, schools, hospital surroundings and government property buildings (Kumar et al 2018, Agarwal et al 2019).

Development of green spaces in existing habitation: In order to develop green spaces in the existing habitation, all possibilities of deployment are explored. The green space around the ponds is deployed as green walking tracks for public use whereas the school and hospital boundary green space are considered to indulge kids and patients to expose to a clean and healthy environment. The government property buildings are considered to develop green space in the open spaces and surrounding areas as part of a 30 percent contribution of green space development as per Amaravati zonal regulations. Unaccounted green area development in the individual household is encouraged by bringing awareness in the public about the benefits of green spaces. A minimum green buffer of 30 m is proposed to be reserved along all major canals. The plantation zone is the prolongation of the canopy behind the edge of the building that creates a real connection to the surrounding green environment. Only native and local species are selected for green belt. Each industry is proposed to develop a green belt in 33 percent of the total land area through the Central Pollution Control Broad (CPCB) guidelines. To protect the green cover from damage, the green buffer areas are restricted to any activities. The existing R1 zone covers an area of 1728.82 hectares including a built-up area of 33.18 hectares. It is observed that by implementing the rooftop gardens concept in R1 zone, an increase of 3.2 percent of built-up area green is achieved covering a spread of 56.66 hectares. Through the zoning guidelines, the residential and commercial plot sizes between 500-4000 m^2 are instructed to reserve green coverage a minimum of 15-20 percentage of the total area.

Development of green space in master plan: Green space contributes to the long-term sustainability of the Amaravati in terms of environmental, social, economic dimensions. Green Space development has to be prioritized over other land use development as it contributes to an improved quality of life. Green space development at the master plan level is done in two-fold level: i) Greenery development at the regional level, and ii) Greenery development at the microclimate level.

Greenery development at regional level: Accessible green is Passive Green P1 and Active Green P2 around 3585.92 hectares constituting about 17 per cent of the total area. Master plan provided greens P1-Passive Zone; P2-Active Zone as shown in Figure 4 has more scope for development at the regional level. The green buffer of 30 m and an estimated area of 283.28 hectares of green buffer along 34 master plan roads are proposed in the master plan. Few native species apart from foreign species are selected for the green region. The hierarchy of parks and open spaces are categorized as the city-level park, botanic garden, town and neighbourhood parks. The green species are identified along with their botanical and local names which are then classified into 24-climbers, 49-shrubs, 57-trees, 82-herbs for the green development at a regional level. These greens are used with topographic alignment such as trees are planted along sides of the roads, canals, parks & recreations whereas climbers, shrubs, herbs are for lawns, dividers, botanical gardens, etc.

Greenery development at microclimate level: The green development at the microclimate level consists of linear greens, rooftop gardens, plug-in greens, etc. Figure 5 depicts the pockets of the residential area concept plan with the proposed methods of a) linear green, b) rooftop garden and c) plug-in green. Households in Amaravati are encouraged to implement rooftop gardens. The proposed rooftop gardens are generated following the Amaravati zoning regulations. Considering the setbacks of a building, buffer area is removed from the total plot size and an inner buffer is generated for rooftop garden using buffer tool in ArcGIS. The total available rooftop garden space is about 1,547.11 hectares, i.e., 7 percent of the total capital city area. There is one more proposed method "plug-in green" which contributes 2.23 hectares to urban green space. The plug-in green is ideally placed adjacent to residential and commercial plots to restrict access to priority roads. With the proposal of linear greens of about 116.15 hectares, there is a nearly two percent increase in total green spaces. Layout parks are developed for the use of the public to improve air quality and to facilitate the connection with nature along with recreation. It allows city dwellers to utilize the chance for healthy outdoor exercise and enjoy the fresh air. The idea is to inculcate people participation facilitating physical exercise, and reduction of stress levels. This is a convenient way of engaging people's interaction with the green space to seamlessly enjoy the benefits of nature.

Proposed development of blue spaces in Amaravati region: Blue network planned in the Amaravati retains the water flow permanently in the channels to form a canal network. Water network and water front city is planned which interconnects green blue nodes of the city. There is no proper demarcation of boundaries of blue space which leads to encroachment of the existing blue spaces and unregulated runoff resulted in a loss of storm and rain water to drainages, nallas, etc. The development of blue space is to be done at a two-fold level such as a) development of blue space at existing habitation and b) development of blue space at the proposed master plan.

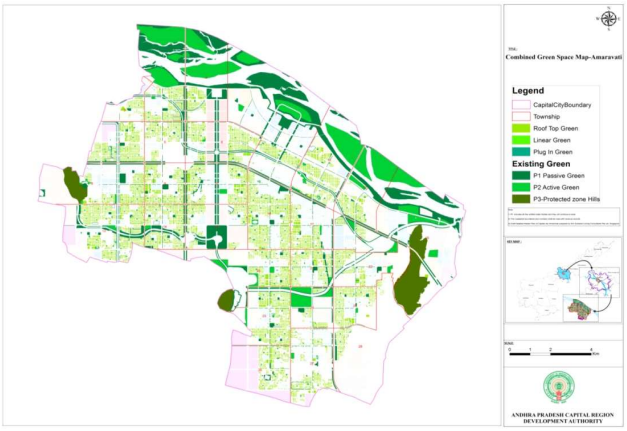


Fig. 4. Combined urban green space map showing the existing and proposed green development area along with the capital city boundary and township

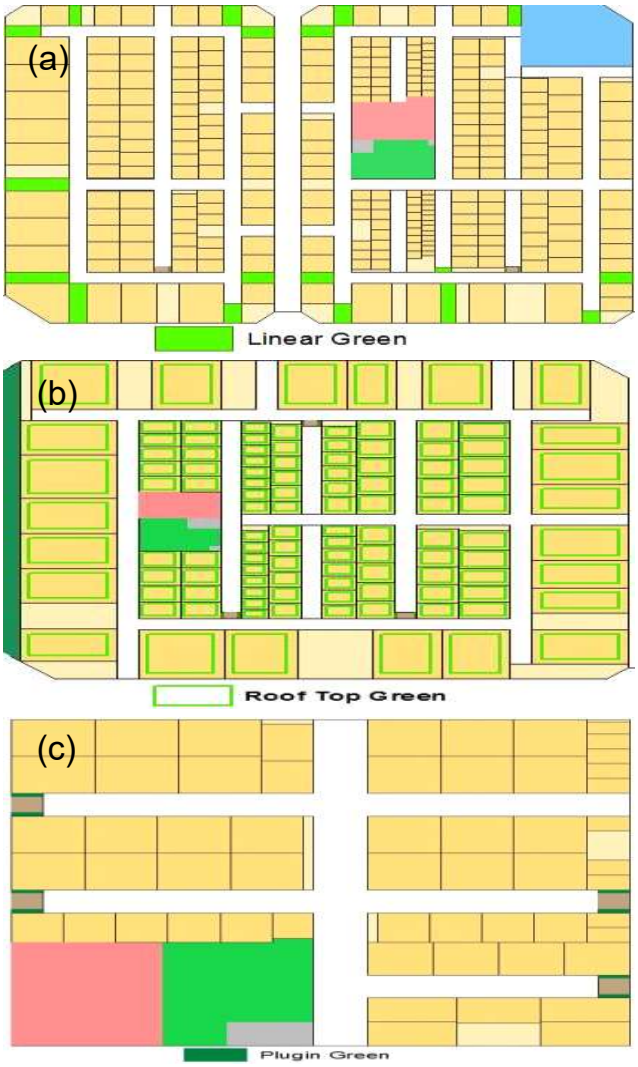


Fig. 5. Pockets of residential area concept plan showing proposed methods of a) linear green, b) rooftop garden, and c) plug-in green

Development of blue spaces in existing habitation: Blue spaces are demarcated as per revenue survey records and attempts are made to protect the water bodies from encroachments. Ponds are surrounded by green buffer and walking tracks are developed as part of protection measures to control runoff. The rain water, as well as storm water runoff, is regulated to fill the ponds to retain water. Few streams along with 18 small water bodies are retained as it is in the Amaravati region.

Development of blue spaces in master plan: In the Master plan, the blue space protected zone P3 is to be preserved and conserved as per Amaravati zonal regulations. Existing water bodies including rivers, canals, irrigation channels and reservoirs have been carefully protected and integrated with the green spaces. As part of the blue space protection and conservation plan, river management, flood management, layout tanks, structured blue-network is proposed at the master plan level.

River management: Amaravati is located on the banks of the Krishna River and existing water bodies including rivers, canals, irrigation channels and reservoirs have been carefully protected and integrated with the green spaces. The 22 km river Krishna waterfront has to be developed for the in-house city's iconic civic core and central business district. As part of the river management, small islands in the Krishna River are integrated into 6 major islands. A green buffer is proposed to regulate the river course and strengthen the bund along the Krishna river.

Flood management: Management of flood waters along with surface runoff discharges into the Krishna river is taken care of as part of the flood management. Reinforce and realign the existing Krishna river bund which is 3-5 m above the highest recorded flood level to protect the land area between the Krishna river and seed area from flood inundation. A minimum buffer of 30 m is proposed to be reserved along all the major canals. Blue network series of permanent channels is proposed to retain water permanently to form a canal network. Detention ponds of internal and external type are to detain storm water runoff during heavy rainfall and then to discharge slowly in reservoirs for water conservation and also to detain water upstream close to the source helps to reduce surface run-off. Three reservoirs R1, R2 and R3 will augment the water supply to the Amaravati region by providing water storage. A comprehensive system of sluice gates and pumps is provided where the excess surface run-off discharges into Krishna River. The rising of platform levels for future developments should be set at +25 m (AMSL) or a level higher than the historic flood level.

Layout tanks development: Development of layout tank area facilitates microclimate within the premises of the tank

area. The tank area is to be protected and preserved from encroachment and to see that the tanks are filled with water throughout the year. About 45 species of plants are selected for tank development that could protect the tank boundary from soil erosion. Demarcation of tank area is done from revenue survey records to preserve it from the local encroachment. Walking tracks are demarcated along the boundary area to seamlessly provide the public to experience the microclimate change within the vicinity of the tank area. Various types of trees, fruit trees, shrubs of the large and small category are used for the development of greenery at the layout tank area.

In brief, the research is the first of its kind for the Amaravati region after the smart city proposal. There is a need to increase the green space provision by comparing the percentage of green space before and after planning of Amaravati region. Incorporating proposed methods along with the master plan for allocation of linear greens and rooftop gardens resulted in about 10pecent increase in green space. Moreover, improvement in the green space coverage is essential for long-term sustainability and has benefits in terms of their economic, social and environmental value. The townships having green percentage values which are less than 0.5 percent are critical areas where green space can be improved by implementing alternate methods such as tot lots, Walgreens, plazas, vertical gardens, sky gardens, green parking lot pavers, community garden or communal farming, etc. Blue space management in the Amaravati region is for the conservation and protection of blue spaces. Amaravati planning authority has plans to organize special training and community surveys to educate people on the enhancement and benefits of green spaces. Necessary steps are taken to provide better accessibility to urban green spaces in Amaravati and to get benefited from them in all aspects to improve the quality of life. The recommendation for allotment of plots for linear green space is based on the availability of plots and subject to higher authority's decision making. Better awareness is needed to maximize the benefits of green & blue space provision for individuals.

Nevertheless, the urban green space contributes to the long-term sustainability of the new capital in terms of environmental, social, economic dimensions. To achieve the vision for a population of 3.5 million by 2050, the city focuses on world-class infrastructure, jobs and homes for all, clean and green, quality living, efficient resource management, identity and heritage.

CONCLUSION

The statistics of green-blue spaces in the Amaravati region are extracted and analysed from revenue survey records, zonal development plans and the master plan using geospatial tools, supported by visual interpretation and verification from Satellite (world view-II with 0.4 m resolution) and drone imagery (10 m resolution). The analysis reveals a decline in the percentage of green-blue spaces as compared to statistics prior to the capital city master plan deployment and proposes an intensification of green spaces and protection of blue spaces for a sustainable ecosystem in the future. The vacant plots and critical zones in Amaravati region with less percentage of green areas are identified and proposed for green enhancements at regional (climbers, shrubs, trees and herbs) and micro-level (linear greens, rooftop gardens and plug-in greens), following community surveys and people's participation. This would result in a significant increase in the green space from 19.19 to 30.88 percent of the total area of Amaravati region. Similarly, the blue spaces in the existing habitation are demarcated to protect the water bodies from encroachments whereas river management, flood management, layout tanks and structured blue-network are proposed at the master plan level. The proposed methods would certainly contribute to a liveable and sustainable environment in the Amaravati region.

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Evaluation of Technical Efficiency of Agricultural Growers in Mid Hills of Himachal Pradesh

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Abstract: The present study aimed to investigate the technical efficiency of agricultural growers in Mid-Himalayan areas of Himachal Pradesh using Cobb-Douglas Stochastic Frontier model. A sample of 140 adopters (involved with watershed development activities) and 140 non-adopters (outside the watershed activities) was selected using multistage random sampling technique. The study reveals that a one per cent increase in the use of quantity of each input resources such as seed, fertilizer, plant protection, farm yard manure and irrigation, on an average increased the technical efficiency by 0.414, 0.301, 0.025, 0.012, 0.194 and 0.019 per cent respectively on adopter farms, whereas in case of non-adopter farms, a one per cent increase in the use of quantity of each input resources such as seed, fertilizer, farm yard manure, labor and irrigation, on an average increased the technical efficiency by 0.263, 0.309, 0.194, 0.317, and 0.021 per cent. The mean technical efficiencies of the adopters and non-respondents respondents were found 83 and 79 per cent. Thus, there is a potential for adopters and non-adopters respondents to increase their efficiency by 17 and 21 per cent, if they use their existing farm resources efficiently. We concluded that inadequate training, exposure, knowledge gap and extension service to farmers in study area were the reasons that farmers were using their resources inefficiently.

Keywords: Agricultural growers, Resources, Stochastic frontier model, Technical efficiency

Agriculture tends to dominate the economic scene of India, accounting for about one-third of gross domestic product (GDP) and one-fifth of foreign exchange. More than 40% of the overall labour force in the country is employed in this sector. Furthermore, its forward and backward linkages with other sectors of the economy are well established in development economics literature. As a result, sustainable production of the agricultural sector is needed to achieve an increased rate of economic growth. According to international comparisons, agricultural production in India is comparatively poor. For instance, despite having the most cereal cultivation area (99.22 million ha), India's average cereal yield in 2019 (2652 kg ha^{-1}) was lower than the world average for that year (3425 kg ha^{-1}). One significant cause of low productivity is the fact that many farmers have low literacy rates. Inadequate physical infrastructures face difficulties in understanding new technologies and, as a result, fail to fully exploit these technical opportunities. In the light of these facts, it is clear that an increase in agricultural production can come from an increase in production efficiency. Hence, it is necessary to assess how the existing inputs are being used and what possibilities exist for improving efficiency of agricultural production in India, given the resource constraints.

The efficiency of a farm can be measured in terms of technical efficiency and technical efficiency is the ratio between actual and potential output of a production unit. A few empirical studies provide the estimates of technical efficiency of raising a particular crop (mostly paddy) within a state/region. For instance, Shanmugam and Palanisamy (1993), Tadesse and Krishnamoorthy (1997) and Mythili and Shanmugam (2000), estimated the technical efficiency of rice farms in Tamil Nadu. Mithiya et al (2019) measured the technical efficiency of agriculture in West Bengal while Bahta et al (2020) and Shanmugam and Venkataramani (2006) measured the technical efficiency. In this study, we attempt to measure the technical efficiency of major agricultural crops production in Mid-Himalayan areas of Himachal Pradesh. According to the literature, the efficiency of a farm can be measured either with respect to its normatively desired performance or with the performance of another farm. Thus, measures of efficiency are essentially computed by comparing observed performance with some specified standard notion of performance. The “production frontier” serves as one such standard in the case of technical efficiency. Technical efficiency can be defined as the ability and willingness of a production unit to obtain the maximum possible output with a specified endowment of inputs (represented by a frontier production function), given the surrounding technology and environmental conditions.

Aigner et al (1977) and Meeusen and Broeck (1977), independently developed a stochastic frontier approach to

measure technical efficiency. This approach introduces technical efficiency as a multiplicative shift variable within a production function framework. This means that the input coefficients of the conventional production function and that of the frontier function are the same and only the intercept term changes. In practice, with cross-section data, the distribution of the technical efficiency term must be specified as half-normal, truncated normal, or otherwise. In this background, the present paper investigates; the technical efficiency prevailing in agricultural growers in Mid-Himalayan areas of Himachal Pradesh.

MATERIAL AND METHODS

Purposive sampling was used to select six districts namely Sirmaur, Bilaspur, Hamirpur, Kangra, Chamba and Kullu districts out of 10 districts, because these six district represent 28 watershed development blocks comprises 60.9 per cent of the total command area, which lies between 30°22′33″ to 32°04′30″N latitude to 76°37′20″ to 77°23′15″E longitude (Fig. 1). To obtain data for the research survey, a sample is usually required. The reason being, the population may be so large as to make it difficult to get to every individual. Therefore, the population should be sampled to keep the confinements due to time and money. The multistage random sampling technique was applied to select the sample in the selected districts. The entire sampling plan consisted of several stages. At the first stage, 25 per cent watershed development blocks were selected randomly, out of selected 28 watershed development blocks. At the second stage, list of panchayats from the selected watershed development blocks where the land and water development activities by project were carried out were prepared and two panchayats from each watershed development block were selected randomly. Thus, 14 panchayats were selected from the selected watershed development block. At the third stage, a sample of ten farmers from each panchayat was selected randomly. Thus, a sample of 140 farmers was selected from 14 panchayats. Simultaneously, a sample of 140 farmers was also selected from the adjacent panchayats unaffected by project activities (Fig. 1). To achieve the objectives of the study, based on the nature and extent of availability of data collected from the sampled households during 2019-2020, the following functional analysis was used for the analysis of the data.

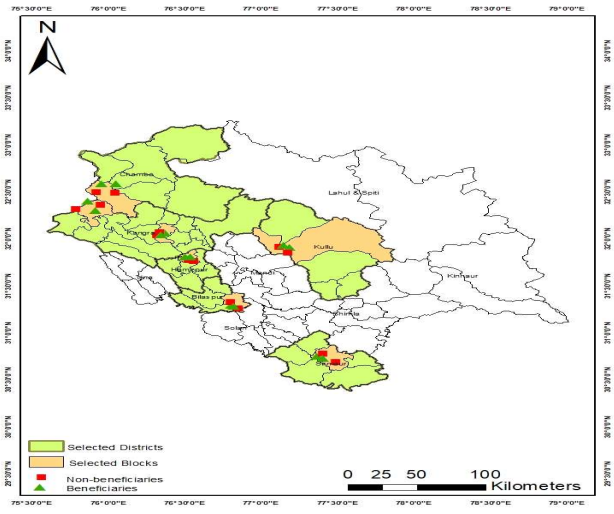


Fig. 1. Location map of the study area

Estimation of technical efficiency: It is a principal component in economic profitability as it measures the ability of the farms to produce maximum output from a given level of inputs. This will be reflected in average cost of operation and hence, will directly affect the competitive position of the farms. The formulation of the Stochastic Frontier (Aigner et al 1977 and Meeusen and Broeck 1977) model in terms of general production function could be specified as:

$$Y_i = f(X_i, \beta)$$

Where,

Y_i = Scalar output of i^{th} farmers,

X_i = Vector that collects directs inputs

β= Vector of parameters to be estimated

v_i = Two sided 'noise' component and

u_i = Effect of random shocks beyond the control of farmers

To measure farm level technical efficiency, different production functions were used in the study. Results of Cobb-Douglas production were found to be best; hence Cobb-Douglas Frontier production was used to measure the technical efficiency of major agricultural crops grown. Selected production form was estimated through Maximum Likelihood Estimation (MLE) method by using the statistical software STATA 13.1.

The empirical model used in this research was Cobb-Douglas Stochastic Frontier model and is given as:

$$\ln Y_i = \beta_0 + \beta_1 \ln X_{1i} + \beta_2 \ln X_{2i} + \ldots + \beta_6 \ln X_{6i} + (v_i - u_i)$$

Where, Y is gross returns (Rs/farm), X_1 is seeds (Rs/farm), X_2 is fertilizers (Rs/farm), X_3 is plant protection (Rs/farm), X_4 is farm yard manure (Rs/farm), X_5 is Expenditure on labour (Rs/farm), X_6 is irrigation (Rs/farm).

RESULTS AND DISCUSSION

Estimation of Cobb-Douglas stochastic frontier production function normal/half normal model: The optimal combination of inputs to achieve a given level of output or the optimal output that can be produced given a set of inputs is considered technical efficiency. When a farm is operating on its production frontier, its technical efficiency is defined as the ratio of actual output produced to potential

output produced from a given level of inputs. When this ratio is equal, the maximum technical efficiency is achieved. Farrell (1957) introduced a measure of technical efficiency, which is an input-oriented measure of how much inputs could be reduced while maintaining the current level of output. An output-oriented measure of how much outputs could be increased while using the same level of inputs is another way to think about technical efficiency. The measure of technical efficiency (input and output oriented) has been extended to accommodate multiple inputs and outputs. This approach to measure technical efficiency yields a relative measure. It compares the efficiency of adopter farms relative to non-adopter farms. Farrell argued that this is more appropriate as it compares a farms performance with best actually achieved rather than with some unattainable ideal (Fraser and Cordina 1999).

Agricultural output levels which are technically inefficient, reduces farmers' income and profit. Estimation of technical efficiency of farming helps farmers to determine whether their farms are technically efficient or not subject to the available resources. The analysis of technical efficiency is likely to enlighten the farmers about the better use of the farming inputs and enhances their production efficiency through higher level of production. A vital question in this context is how to improve farmers' technical efficiency using the resources available to them. In order to find a solution to this problem the study further analyzes the determinants of technical efficiency (Mithiya et al 2019). The focus of the analysis was to provide the empirical evidence of the technical efficiency determinants at the farm level for all adopters and non-adopters. The study explored farm specific factors that influenced the technical efficiency of major agricultural crop growers'. The parameters of the various variables in the technical efficiency effect model that are supposed to determine efficiency differences among the farmers were estimated through maximum likelihood method with the Cobb-Douglas Stochastic Frontier Production normal/half-normal model and the results are shown in Table 1 and Table 2.

It can be seen from the Table 1 that the entire explanatory variable such as seed, fertilizer, plant protection, farm yard manure, labour and irrigation were contributed to technical efficiency and found to be statistically significant at 1, 5 and 10 per cent of probability level for all farm categories of adopters. It is further reported that the signs of the slope coefficients of all explanatory variables are positive except for labour that has a negative coefficient implying that increasing the labour affects major crops production negatively for marginal and small farm categories of adopter. The signs of the slope coefficients of all explanatory variables

Table 1. Maximum likelihood estimates with Cobb-Douglas stochastic frontier production of technical efficiency for major agricultural crops in adopter farms

Particulars	Marginal	Small	Medium	Overall
Constant	1.631** (0.224)	1.90** (0.0001)	1.86** (0.299)	1.41** (0.144)
Seed (X_1)	0.405** (0.056)	0.274** (0.0001)	0.346*** (0.099)	0.414** (0.041)
Fertilizer (X_2)	0.037 (0.191)	0.351** (0.0002)	0.095 (0.168)	0.301*** (0.106)
Plant protection (X_3)	0.375*** (0.143)	0.340** (0.0001)	0.698** (0.0001)	0.025** (0.008)
FYM (X_4)	0.127 (0.511)	0.086** (0.0001)	-0.174** (0.002)	0.012 (0.009)
Labour (X_5)	-0.037 (0.132)	-0.009** (0.0001)	0.266** (0.019)	0.194*** (0.072)
Irrigation (X_6)	0.073** (0.023)	0.024** (0.0001)	0.416** (0.008)	0.019** (0.001)
Sigma_v (σ_v)	0.0267	0.0722	0.0705	0.0423
Sigma_u (σ_u)	0.0095	0.0376	0.0448	0.0294
Lambda (λ)	0.3589	0.5218	0.6382	0.6935
Log likelihood	143.25	117.46	42.81	263.37

Figures in parentheses are standard errors
*** Significance at 1 percent probability level
**Significance at 5 percent probability level
* Significance at 10 percent probability level

Table 2. Maximum likelihood estimates with Cobb-Douglas stochastic frontier production of technical efficiency for major agricultural crops in non-adopter farms

Particulars	Marginal	Small	Medium	Overall
Constant	0.868*** (0.262)	1.357** (0.224)	1.69** (0.209)	1.19** (0.185)
Seed (X_1)	0.197** (0.079)	0.236** (0.062)	0.448** (0.069)	0.263** (0.051)
Fertilizer (X_2)	0.217** (0.109)	-0.0226 (0.148)	0.569** (0.119)	0.309** (0.073)
Plant protection (X_3)	-0.115* (0.06)	0.0213 (0.140)	-0.176 (0.149)	-0.134*** (0.047)
FYM (X_4)	0.487** (0.205)	0.432** (0.177)	-0.156 (0.163)	0.194* (0.117)
Labour (X_5)	0.213 (0.165)	0.201** (0.092)	0.122** (0.048)	0.317** (0.065)
Irrigation (X_6)	0.026* (0.014)	0.0208 (0.0202)	0.122 (0.081)	0.021** (0.009)
Sigma_v (σv)	0.0794	0.0254	0.0491	0.0922
Sigma_u (σu)	0.0387	0.0164	0.0252	0.0501
Lambda (λ)	0.4865	0.6472	0.5146	0.5437
Log likelihood	110.42	111.19	55.70	248.41

Figures in parentheses are standard errors
*** Significance at 1 percent probability level
**Significance at 5 percent probability level
* Significance at 10 percent probability level

are positive except for farm yard manure that has a negative coefficient implying that increasing the farm yard manure affects major crops production negatively for medium farm category of adopters. At overall level, a one per cent increase in the use of quantity of each input resources such as seed, fertilizer, plant protection, farm yard manure and irrigation, on an average increased the technical efficiency by 0.414, 0.301, 0.025, 0.012, 0.194 and 0.019 per cent, respectively. The results of the table also revealed that relative proportion of random noise to inefficiency variance (λ) were found to be positive and highest (0.6382%) in medium category followed by small (0.5218%) and marginal category (0.3589%), respectively, which indicated that the variation in output of major agricultural crops is due to the differences in technical inefficiency among agricultural crops growers in the study area. This implies that higher variation in output of major agricultural crops among the farmers is due to random shocks such as unfavorable weather conditions and other factors not under the control of farmers.

Table 2 revealed that all explanatory variables such as seed, fertilizer, plant protection, farm yard manure, labour and irrigation contributed technical efficiency and were found to be statistically significant at 1, 5 and 10 per cent of probability level for all the farm category of non-adopters. It is further observed that the signs of the slope coefficients of all explanatory variables are positive except for plant protection that has a negative coefficient implying that increasing the plant protection affects major crops production negatively for marginal farm category of non-adopters. Whereas, the signs of the slope coefficients of all explanatory variables are positive except for fertilizer that has a negative coefficient implying that increasing the fertilizer affects major crops production negatively for small farm category of non-adopters. Similarly, the signs of the slope coefficients of all explanatory variables are positive except for plant protection and farm yard manure that have a negative coefficients implying that increasing the plant protection and farm yard manure affects major crops production negatively for medium farm category of non-adopters. The results were in the line with the findings of Konja et al (2010), who observed that factors such as farm size, quantity of weedicide and fertilizer used have positive effects on output of rice. At overall level, a one per cent increase in the use of quantity of each input resources such as seed, fertilizer, farm yard manure, labor and irrigation, on an average increased the technical efficiency by 0.263, 0.309, 0.194, 0.317, and 0.021 per cent, respectively. The results of the table also revealed that relative proportion of random noise to inefficiency variance (λ) were found to be highest (0.647%) in small category followed by medium (0.5146%) and marginal category (0.425%), respectively, which indicated that the variation in output of major agricultural crops is due to the differences in technical inefficiency among agricultural crops growers in the study area. This implies that higher variation in output of major agricultural crops among the farmers is due to random shocks such as unfavorable weather conditions and other factors not under the control of farmers. Similar results were found by Shanmugam and Venkataramani (2006).

Technical efficiency scores of adopter and non-adopter respondents are shown in Figure 2 and 3 and it shows that the estimated technical efficiencies for adopter respondents ranged from 51 to 99 per cent and that for non-adopters was 43 to 98 per cent, i.e. minimum (51%) and maximum (99%) technical efficiencies of adopters respondents and minimum (43%) and maximum (98%) of non-adopters respondents, respectively. The mean technical efficiencies of the adopters and non-respondents respondents were found 83 and 79 per cent. Thus, there is a potential for adopters and non-adopters respondents to increase their efficiency by 17 and 21 per

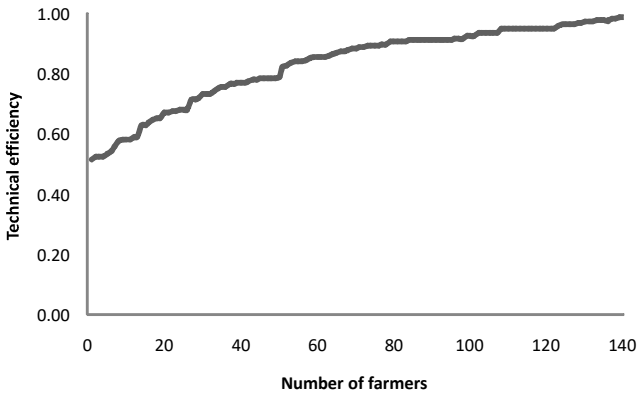


Fig. 2. Scatter diagram of technical efficiency for adopter's farmers

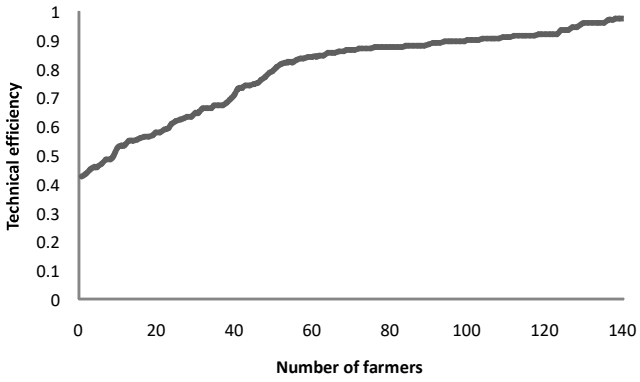


Fig. 2. Scatter diagram of technical efficiency for non-adopter's farmers

cent, if they use their existing farm resources efficiently. This result is similar to study by Bahta et al (2020).

CONCLUSIONS

The study reveals that the variation in output of major agricultural crops as indicated by inefficiency variance (λ) is due to the differences in technical inefficiency among agricultural crops growers in the study area. This implies that higher variation in output of major agricultural crops among the farmers is due to random shocks such as unfavorable weather conditions and other factors not under the control of farmers. This study concludes that there is also potential for adopters and non-adopters respondents to increase their efficiency if they use their existing farm resources efficiently. It is recommended that the farmers involved in agriculture farming in the study area should be provided with additional proper technical knowledge for optimum utilization of resources which would help to increase the production and return of major agricultural crops.

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Problems and Factors Affecting Adoption of Natural Farming in Sirmaur District of Himachal Pradesh

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Abstract: Natural farming supports agroecological principles, chemical free farming and sustainable farming. NF is also seen as the most cost effective farming and also known as “Zero Budget Natural Farming." NF focus is to reduce cost of cultivation, improve food quality, chemical free food, improve soil fertility, food and nutritional security. The present study was carried out in Sirmour district of Himachal Pradesh by taking representative samples of 60 farmers through simple random sampling technique. This study mainly focused on the constraints and factors affecting adoption of Natural Farming. The problems were analyzed by using Garrett Ranking technique. The major problems were non-availability of a specialized market (1st rank), labour intensive farming (2nd rank) and unfair price for produce in market (3rd rank). Also “disease occurrence” in the Natural Farming field was ranked lowest (15th rank) which means NF is successful in controlling diseases in the field. The multiple response percentage for various problems identified by Chi square test includes higher wage rate (70%), price fluctuation (56.67) labour intensive farming (56.60) and non availability of specialized market (58.53%). Factors affecting adoption of NF were measured by using Logistic Regression model. Significant variables for adoption of NF were increased gross returns, decreased pest attack in NF and increased soil fertility variables. They have a significant role for adoption of NF.

Keywords: Natural farming, Sustainable agriculture, Agroecology, Chemical free, Nutritional security

Agriculture is the important sector of economy in India, which accounts 18 per cent of Gross Domestic Product and provides jobs to 50 per cent of the country's workforce (Anonymous, 2019a). The most widely adopted farming system globally is a Chemical farming system, as it often produces 98 per cent of the world's food (Tal 2018). It has several hazardous effects, such as contamination of food, soil, surface water, ground water, air, turf and other vegetation. Also pesticides are harmful to birds, fishes and beneficial vegetation. The widespread use of chemicals leads to the pest genetic mutation, hence resistant to pesticides (Shetty 2009). Use of chemicals in agriculture to maximize production is vicious to food nutritional value, high cost of production and decreasing prices of agricultural produce, which leads to suicide crisis. Thousands of farmers have committed suicide across the India, at least 16,196 peasants committed suicide in India, taking the cumulative number since 1997 was 199 and 132 according to the National Crime Records Bureau (NCRB). The five states Maharashtra, Andhra Pradesh, Karnataka, Madhya Pradesh, and Chhattisgarh are also known as 'suicide belts', in 2008 these states had 66.6 per cent of the country's total farmer suicides (Mishra 2008). Cancer is widely spread in Punjab due to over usage of pesticides in agricultural practices (Kumar and Kaur 2014). Furthermore, it has also been shown that modern agriculture can't be sustainable in the long term due to adverse environmental and ecological changes. These consequences are also experienced by declining crop yields and crop instability (Chand et al 2011). There is a need for an alternative method of agriculture that can operate in a friendly eco-system while maintaining and increasing crop productivity is now being realized. The farming system needs sustainability in order to improve the factors of production and human health or the farming system, which has no hazardous effects on the earth environment and human health. Natural Farming also known as Zero budget natural farming (ZBNF) or known as Subhash Palekar Natural Farming (SPNF) in some regions is best-known alternative to chemical farming (Munster 2016). This recommends a place as an answer to the agrarian crisis and the growing epidemic of farmers' suicides in India (Babu 2008). The Union Budget for 2019 declared that the Government had intended to give priority to Zero Budget Natural Farming. It is an extreme version, which does not shy away from suggesting that without any need of any external inputs all inputs must be locally organized from and around the village. Palekar claims that both the dung and urine of native livestock (*Bosindicus*) should be used to make *Jivamrit* as it has a superior micro culture especially in comparison to that of European breeds (Palekar 2005). ZBNF relies primarily on use of materials such as *Jivamrit, Bijamrit and Acchadana* (natural mulch) to encourage

microbial development, seed health and soil fertility. Although ZBNF appears to be hitting the right notes when it comes to environmental protection (Khadse et al 2017). The aim of natural farming is to reduce the cost of production to almost zero and to come back to the "pre-green revolution" style of agriculture (Khadse et al 2019). This would seem to lead growers out of loans by putting a stop to agricultural chemicals practices. The central government has implemented a policy to encourage farming methods throughout India. The state governments of Andhra Pradesh, Chhattisgarh, Himachal Pradesh, Uttarakhand, Kerala and Karnataka asked *Padma Shri* Subhash Palekar to educate their farmers for Natural Farming (Anonymous 2016).

Agriculture is the primary source of income for the people of Himachal Pradesh and plays a major role in the state's economy. About 12.73 percent of the total State Income (GSDP) comes from agriculture and its allied sectors. Agriculture and horticulture employ nearly 69 percent of the state's overall population. (Economic survey, Himachal Pradesh 2019-20). The average farm size in Himachal Pradesh is approximately 1.2 hectares (Anonymous, 2018). In order to promote ZBNF in Himachal Pradesh, a scheme *'Prakritik Kheti-Khushhal Kisan'* was initiated with a budget allocation of Rs. 35 crore (2019-20). Under this scheme, peasants will be supported with training, the required machinery, to achieve the objective of sustainable farming doubling farmers' incomes, improved soil fertility and low input costs. Himachal Pradesh has changed the name of ZBNF to Subhash Palekar Natural Farming (SPNF) (Anonymous 2019b). A few years ago, SPNF was adopted in Himachal Pradesh. As a result, there is no true data on problems and adoption of natural farming. In view of these factors, the a study on problems and factors affecting adoption of natural farming in Sirmour District of Himachal Pradesh is carried out to strengthen the base of natural farming.

MATERIAL AND METHODS

This chapter outlines the characteristics of the study area, the methods adopted in selection of the sample, the nature and sources of data and the various statistical tools and techniques employed in analyzing the data and have been described under the following sub-heads.

Selection of the study area: Sirmaur district of Himachal Pradesh was purposively selected for the present study. Sirmaur district a southern most district of Himachal Pradesh, is largely mountainous and rural. Total area of Sirmaur district is 2,825 Sq.km. with a population of 5,29,855. The district comprises of six development block Rajgarh, Pachhad, Nahan, Renuka, Shillai and Paonta and 4 sub-tehsils viz. Dadahu, Kamraoo, Pajhota and Nohra.

Sampling design and sample size: Simple random sampling design was adopted to select the ultimate sample of the farmers practicing natural farming respondents. A list of farmers practicing Subhash Palekar Natural Farming was procured from the Project Director ATMA, Nahan (Simaur). Fifteen farmers each from four blocks Rajgarh, Paonta sahib, Pachhad and Nahan were selected randomly. Thus a sample of sixty farmers were selected for the study.

Distribution of sampled farmers practising natural farming according to their size of land holding: For the analysis of data the total respondents were divided according to the size of their land holdings into three classes, viz., marginal (<1 ha), small (1-2 ha), and medium (2-4 ha). The distribution of the sampled farmers is present in Table 1.

Nature and sources of data

To meet the objectives of the present study, both primary as well as secondary data were collected**.**

Primary data: Primary data were collected from the farmers practicing natural farming by survey method using a well-structured and pretested schedule. Data were collected to analyse Problems faced by farmers in various aspects of production and adoption of natural farming.

Secondary data: Secondary data were collected in terms of numbers of registered farmers practicing natural farming from the Project Director, ATMA, Nahan (Sirmaur)

ANALYTICAL FRAMEWORK

To fulfill the specific objectives of the study, based on the nature and extent of availability of data, the following analytical tools and techniques have been employed for the analysis of the data.

Logit model for Adoption: Mathematically, the logit model is represented as:

$L_i = \ln = \beta_1 + \beta_2 X_i + u_i$

Where;

X_i =Represents all the independent variables and β represents the effect of changes in X

L_i =Represent logit in the probability of adoption

The model will estimated by using formula:

Table 1. Distribution of sampled households according to their land holdings

Category of farmer	No. of farmers	Average land holding (ha)
Marginal (< 1 ha)	41 (68.33)	0.51
Small (1 – 2 ha)	11 (18.33)	1.09
Medium (2 – 4 ha)	8 (13.34)	2.02
Total	60 (100)	1.20

$Y=\beta_0+\beta_1X_1+\beta_2X_2+\beta_3X_3+\beta_4X_4+\beta_5X_5+\beta_6X_6$

Where;

Y = If the producers have adopted Natural farming in their farms (0 if No, 1 if yes),

X_1 = Chemical fertiliser's cost

X_2 = Gross returns

X_3 = Numbers of years experience in farming

X_4 = Farm size in hectare

X_5 = A dummy variable indicating for a producer if pest attack decreasing (0 if No, 1 if yes)

X_6 = A dummy variable indicating for a producer if soil fertility increasing (0 if No, 1 if yes)

X_7 = A dummy variable indicating for a producer if production cost was low in natural farming (0 if No, 1 if yes)

Production and Marketing Problems

To study the various problems associated with the production and marketing of natural farming it was assumed that, the extent of a particular problem varies from place to place and farmer to farmer. The multiple responses of producers reporting various problems were taken into consideration for analysis.

Garret ranking technique:

The Garret ranking technique was used for examination of constraints. It is important to note here that these constraints were focused on the response of all sample farmers. The respondents were asked to rank the problems in turmeric and cotton production, processing and marketing. In the Garrett's ranking technique, these ranks were converted into percent position by using the formula

Where**,**

R_{ij} = Ranking given to the ith attribute by the jth individual

N_j = Number of attributes ranked by the jth individual.

By referring to the Garrett's Table, the percentage positions estimated were converted into scores. Thus for each factor, the scores of the various respondents were added and the mean values were estimated. The mean values thus obtained for each of the attributes were arranged in descending order. The attributes with the highest mean value was considered as the most important one and the others followed in that order

Chi-square test:

To test whether there was any significant difference among marginal, small and medium farms of sirmaur for the problems faced by them. Chi-square test in (m x n) contingency table was applied where m and n are the number of marketing problems faced by the farmers of natural farming in sirmaur district. O = Observed values E = Expected values K = number of problems L = number of farm size groups.

Limitations of the Study

The production and marketing of natural farming have not been documented by any institution/government in the state. Since, the data were collected by survey method; the inherent lacunae associated with this type of inquiry have crept into the study, even though the estimates were provided by the recall memory because of the non-maintenance of the farm records. Sincere efforts have been made to elicit accurate and It may however, be recognized that the finding of the study need not be generalized beyond the boundaries of the area under investigation and applicable to such other areas having similar agro-climatic and socio-economic conditions. The study was based on the data collected for one year only (2019-20), which may not necessarily hold true for other periods as well.

RESULTS AND DISCUSSION

This chapter is for research findings, which is present systematic analysis and interpretation of data. For better understanding this chapter is sub divided into following heads:

Factors affecting adoption of natural farming: Factors for adoption of natural farming technique were measured by using Logistic Regression model. The explanatory variables taken for adoption of natural farming were chemical fertilizers costs, gross returns from natural farming, experience in farming, total farm size, decrease in pest attack, increase in soil fertility, low cost of production in natural farming. The results of Logistics Regression model are present in Table 2. The significant variables for adoption were gross returns, decreased pest attack in natural farming and increased soil fertility variables have significant role for adoption of natural farming with coefficient value (0.000048), (1.60) and (1.94), respectively. Decrease in the pest attack by one per cent in crops shows there is possibility of 0.36 per cent increased in adoption of natural farming. This means adoption of natural farming influenced by lesser pest attack if pest attack increases than farmer will not adopt natural farming. Increase in one per cent in the soil fertility there is possibility of 0.45 per cent increase in the adoption of natural farming. Which means more increase in soil fertility more farmers will adopt natural farming. Gross returns, decrease in pest attack and increase in soil fertility were significant variable for adoption of natural farming.

Chemical fertilizer costs, experience and farm size were statistically non significant in the adoption of natural farming. The dummy variable representing low production cost was not statistically significant but had a positive relationship with adoption of natural farming.

Problem Faced by the Natural Farming Producer

Garret ranking technique: The Garret ranking technique

was used for examination of constraints natural farming systems. It is important to note here that these constraints were focused on the response of all sampled farmers.Table 3 points out the constraints faced by different groups of farmers in this regard. Several problems faced by farmers in the study region in the production and marketing of natural farming.

The fifteen major constraints were identified first and then farmers' were ask to gave rank to the problems according to superiority of problems between 1 to 15 in such a way that rank given by farmers to problem does not repeat. The non availability of specialized market (Organic product market) were found 1st ranked problem with the 33.59 Garret mean score followed by labour intensive problem (33.54), unfair price for produce in market (32.86), high wage rate (32.68), the knowledge of package of practices (31.59), lack of inadequate information (31.55), consumer awareness about SPNF produce (31.47), lack of extension facilities (31.25), inadequate training facilities (31.02), shortage of skilled labour (30.80), wholesalers not taking consent while selling (28.72), higher commission (26.52), irrigation facility not available (25.03), lack of transport facilities (25.03). The disease occurrence in the natural farming (21.15) system ranked last (15^{th}) which means natural farming was successful to control diseases in field.

Chi-square test: Chi square test is used to check significance of problems faced by farmers within different category farms. Chi square test shows that a problem faced by farmers was varying between farms category. Significant problem shows that a problem faced by farmers vary in all category farms or multiple response for a particular problem is different within category of farms. Non-significant problems show that a problem occur in all farms category or problem does not depend upon size of farms. Multiple responses percentage of farmers for various problems are present in Table 4. The biggest problem faced by the growers was the higher wage rate (70%). Unfair price for natural products (60%). Non-availability of specialised market (58.35%).

Lack of information (58.10%). Price fluctuation (56.67%) of agriculture produce, i.e. major problem in agriculture all over the country. It is very difficult to farmers getting a good price for their produce. Labour intensive farming (56.60%) because in natural farming intercultural operations require more labour, while in chemical farming due to fast reaction of chemicals, labour requirement was low. Consumer awareness about natural farming produce (50%). Knowledge of package of practices (48.33%), because natural farming was newly introduced and farmers experience in natural farming was less. Shortage of skilled labour (30%), Lack of extension facilities (26.67%) and Storage facility (26%),

a) Various significant problems such as Lack of government support (62.65%) in medium category farms which means marginal and small category farms does not faced this problem as much as compare to medium category farms. Disease problem (12.50%) in natural farming crops was maximum in medium

Table 3. Production and marketing constraints in sampled farmers

Problem Name	Garret mean score	Rank
Non availability of specialized market	33.59	I
Labour intensive	33.54	II
Unfair price for produce in market	32.86	III
Higher wages rates	32.68	IV
Knowledge of package of practices	31.59	V
Lack of inadequate information	31.55	VI
Consumer awareness about SPNF produce	31.47	VII
Lack of extension facilities	31.25	VIII
Inadequate training facilities	31.02	IX
Shortage of skilled labour	30.80	X
Wholesalers not taking consent while selling	28.72	XI
Higher commission	26.52	XII
Irrigation facility not available	25.83	XIII
Lack of transport facilities	25.03	XIV
Diseases	21.15	XV

Table 2. Logit regression model for natural farming growers

Adoption factors	Coefficient (β)	Standard Error	Wald	Significance	dy/dx
Constant	-7.64*	2.21	-3.44	0.001	
Chemical fertiliser cost	0.00082	0.0003	0.28	0.780	0.00002
Gross returns	0.000048*	0.000014	3.47	0.001	0.000012
Experience	0.059	0.042	1.42	0.155	0.014
Farm size	-0.35	0.223	-1.58	0.113	-0.09
Pest attack Decrease	1.60*	0.94	1.71	0.088	0.36
Soil fertility increase	1.94*	0.89	2.18	0.029	0.45
Low production cost	1.27	0.86	1.41	0.157	0.29

Table 4. Farm category wise problem faced by natural farming producer in natural farming

(Multiple response percent)

Problems	Farm size				
	Marginal	Small	Medium	Overall	Chi-square
No. of farmers	41	11	8	60	60
Shortage of skilled labour	34.15	18.18	25.00	30.00	4.98
Higher wages rates	68.29	72.73	75.00	70.00	0.32
Non-availability at peak operation time	7.32	18.18	12.50	10.00	4.66
Price fluctuation	56.10	54.55	62.50	56.67	0.61
Lack of government support	36.59	18.18	62.50	36.67	25.36*
Inadequate training facilities	39.02	45.45	37.50	40.00	0.87
Lack of extension facilities	26.83	27.27	25.00	26.67	0.11
Labour intensive	53.66	54.55	75.00	56.60	4.77
Inputs application on time	12.20	27.27	25.00	16.67	6.14*
Knowledge of package of practices	51.22	45.45	37.50	48.33	2.12
Disease	9.76	0.00	12.50	8.33	11.63*
Irrigation facility not available	17.07	18.18	25.00	18.33	1.83
Storage facility	21.95	36.36	37.50	26.00	4.70
Higher commission	19.51	27.27	25.00	21.67	1.33
Wholesalers not taking consent while selling	2.44	0.00	0.00	1.67	4.87
Consumer awareness about SPNF produce	51.22	45.45	50.00	50.00	0.37
Non availability of specialized market	56.10	63.64	62.50	58.35	0.55
Lack of transport facilities	7.32	18.18	12.50	10.00	4.66
Unfair price of produce in market	53.66	63.64	87.50	60.00	8.87*
Lack of information	51.22	72.73	75.00	58.10	5.19

category farms. Unfair price for natural farming produce were varies from 53.66 to 87.50 per cent in marginal to small farmers.

b) A non-significant problem means a problem is faced by all category farms. Non-significant problems such as shortage of skilled labour (30%). High wage rate (70%). Non-availability of labour at peak operation time (10%). Price fluctuation (56.67%). Inadequate training facilities (40%). Lack of agriculture extension facilities (26.67%). Knowledge of package of practices (48.33). Labour intensive farming (56.60). Irrigation facility not available at time (18.33).

CONCLUSION

The major problems were non-availability of a specialized market (1st rank), labour intensive farming (2nd rank) and unfair price for produce in market (3rd rank). Also "disease occurrence" in the Natural Farming field was ranked lowest (15th rank) which means NF is successful in controlling diseases in the field. The multiple response percentage for various problems identified by Chi square test includes higher wage rate (70%), price fluctuation (56.67) labour intensive farming (56.60) and non availability of specialized market (58.53%). Factors affecting adoption of NF were measured by using Logistic Regression model. Significant variables for adoption of NF were increased gross returns, decreased pest attack in NF and increased soil fertility variables. They have a significant role for adoption of NF. Natural farming growers face many constraints / difficulties mostly during growing and marketing phase. In order to resolve these all problems and difficulties, farmers expect a wide range of support from government, private and cooperative societies.

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Effect of Methyl Jasmonate on the Production of Furanocoumarins in Callus Cultures of *Ruta graveolens* L.

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Abstract: This project was designed to study the effect of different concentrations of the abiotic elicitor Methyl Jasmonate (MeJA), on the production of furanocoumarins, from callus cultures of *Ruta graveolens* L. The concentrations of MeJA 0.0, 25, 50, 75 µM L^{-1} were used. The callus cultures were induced on Murashige and Skoog medium enriched with 2.0 mg L^{-1} 2,4-dichlorophenoxy acetic acid (2,4-D) combined with 0.5 mg L^{-1} Kinetin (Kin).The results obtained by using fast liquid column chromatography (FLCC), showed that addition of MeJA at the above concentrations to Murashige and Skoog growth medium significantly affect the production of furanocoumarins. The concentration of 75 µM L^{-1} MeJA gave the highest concentrations of psoralen (2.881 mg g^{-1}) and bergapten (6.524 mg g^{-1}), compared with the control treatments (0.913 mg g^{-1} 3.983 mg g^{-1}) and increase was 3.2, and 1.6-fold respectively. However, the highest xanthotoxin concentration of 0.610 mg g^{-1} was at 25 µM L^{-1} MeJA compared with control treatment (0.244 mg g^{-1}).

Keywords: Abiotic elicitors, Callus cultures, Furanocoumarins, *Ruta graveolens* L.

Ruta graveolens L. is a perennial medical plant belongs to Rutaceae family, which has a long history in traditional medicine for more than 1500 years (Kannan and Babu 2012). It is widely distributed in temperate and tropical regions including South Africa, North America and North Iran (Sharifi et al 2019) and it produces many types of secondary metabolites such as flavonoids, furanocoumarins, essential oils and alkaloids which give medical and pharmaceutical importance in addition to its odroferous properties (Ahmad et al 2020). Plant cell and tissue culture is considered as the fastest and ideal source for the production of in vitro large and continuous pharmaceutical compounds (Karuppusamy 2009). Synthesis and accumulation of secondary metabolites occur in the plants when exposed to different stressful biotic and abiotic conditions. These compounds allow these plants to survive the stressful conditions in their environment. The production of these compounds is enhancing *in vitro* by factors known as elicitors (Yue et al 2016). The use of abiotic elicitors such as MeJA, is important signal in the plants defense responses and promotion of secondary metabolites production in the plant cell cultures (Singh and Dwivedi 2018). In addition to its role in activating phenolic compounds metabolism in the plant as a whole and in cell suspension and callus cultures of different plant families (Manivannan et al 2016). Furanocoumarins are considered as a class of phenolic compounds (Bourgaud et al 2006), found mainly in four families of higher plants of Apiacea, Rutaceae, Moraceae and Fabaceae (Ojala et al 2000). In general, these compounds are most abundant in the fruits, flowering plants and mature seeds (Poutaraud et al 2000) and are produced in the plants as a defense tool against like insects, mammals and fungi, (Guo et al 2012). The aim of this study was to extract, identify and estimate furanocoumarins concentrations from callus cultures of *Ruta graveolens* L and investigate the effect of different concentrations of MeJA on the production of furanocoumarins by the induced callus cultures.

MATERIAL AND METHODS

Ruta graveolens L. seedling were obtained and processed as described by Ahmad et al (2020). Seedlings were supplied by Baladroze Agricultural Department, Diyala, Iraq- and transferred to the green house at the Department of Biology, University of Diyala. The plants were monitored and were classified by IBN-AL-HAITHAM herbarium, University of Baghdad. For callus induction, stem pieces of *Ruta graveolens* were cut off, washed in a running tap water for 20 minutes prior to sterilizing with sodium hypochlorate (NaOCl 6%, active Cl_2) using 1.0 volume of sterilizing material to 9.0 volumes of sterile distilled water for 20 minutes with shaking and plant pieces were finally washed with sterile distilled water three times for 5 minutes each time. Sterilized stem pieces were cut into 1.0 cm segments and were transferred on 20 ml of Murashige and Skoog (1962) medium supplemented with 0.0, 0.5, 1.0, 1.5, 2.0 mg L^{-1} 2,4-D combined with 0.5 mg L^{-1} Kin. Ten pieces were used for each

treatment and the experiment was done in triplicate. The samples were kept in a growth room at 25 ± 2°C under photoperiod (16 h light/ 8 h dark) of 2000 lux, (Ahmad et al 2020) and after 30 days fresh weight of callus was recorded.

To study the effect of different concentrations of MeJA on the growth of callus cultures and content of furanocoumarins, 10 mM solution of Methyl Jasmonate (MeJA) obtained from Sigma-Aldrich company was prepared in 50% ethyl alcohol (V/V), then filtered and sterilized using filters having pores of 0.22 µm in diameter, prior to its addition to callus induction medium cultures enriched with 2.0 mg L^{-1} 2,4-D combined with 0.5 mg L^{-1} Kin. Different concentrations of MeJA sterilized solution (0.0, 25, 50 and 75 µM L^{-1}) were added to the callus induction medium. Then 1.0 g of induced callus from stem segments was transferred to glass vials containing 20 ml of such prepared media. All cultures were kept in the growth room for 30 days. Fresh weights, texture and colour of callus samples were recorded and their contents of furanocoumarins were estimated. Furanocoumarins contents in callus samples were estimated, their identification and quantitative estimation were performed by using method described by Manjula and Sushma (2016), using fast liquid column chromatography (FLCC), type Shimadzu 10AV-LC (Japan), which is supplied with two pumps type Shimadzu LC-10A equipped with metallic separation column which has the properties - stationary phase C18-DB, length of the column 50 mm, internal diameter of the column 4.6 mm, diameter of matrix granules 3 µm. (mobile phase V:V 0.1% phosphoric acid: methanol: acetonitrile (10: 45: 45), flow speed of the mobile phase 1ml/ minute, volume of the injected sample 25 microliter, temperature of Separation 30°C). The eluted peaks were monitored by UV-Vis 10A-SPD spectrophotometer at wave length of 280 nm.

The isolation and identification of furanocoumarins were based on the standard sample retention time and area under the curve (Fig. 1). The standard solution used is made of xanthotoxin, psoralen and bergapten from Carl Roth (Karlsruhe, Germany) at a concentration of 100 mg/gfor each compound. The concentrations of the furanocoumarins in the samples were calculated using the following equation:

$$(X)\ \text{Concentration} = \frac{\text{Area under the curve of the samples}}{\text{Area under the curve of the standard}} \times \text{Concentration of the standard} \times \text{Dilution factor}$$

RESULTS AND DISCUSSION

The stem pieces grown on MS medium supplemented with the growth regulators were superior in their ability for callus induction compared with control (Table 1, Fig. 2). Increasing the concentrations of 2,4-D in MS medium significantly increase the percentage of callus formation, callus fresh weight and size. MS medium enriched with 1.5 and 2.0 mg L^{-1} 2,4-D combined with 0.5 mg L^{-1} Kin stimulated callus induction and achieved the highest callus formation (100%), compared with the control treatment (0%). The highest average of callus fresh weight was 1.785 and 2.584 g $piece^{-1}$ at 1.5 and 2.0 mg L^{-1} 2,4-D combined with 0.5 mg L^{-1} Kin respectively compared to the other treatment. The explants grown on free- PGRs medium were characterized by swollen shape (Fig. 2a), whereas the shape of the stem pieces grown on MS medium supplemented with 2.0 mg L^{-1} 2,4-D combined with 0.5 mg L^{-1} Kin became distorted shape, because callus tissue was formed at the cutting regions and characterized by friable texture and pale green color (Fig. 2D

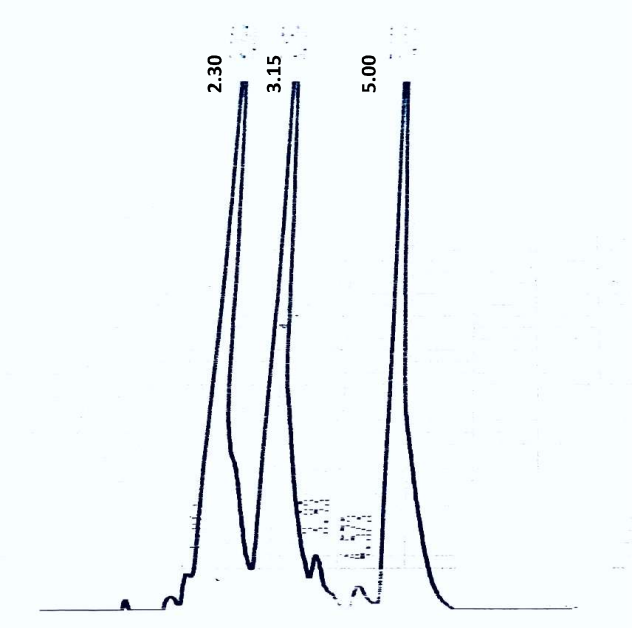


Fig. 1. Standard curve for furanocoumarins using FLCC

Table 1. Induction of callus derived from sterilized stem explant of Ruta graveolens, on MS medium supplemented with different concentrations of 2,4-D + 0.5 mg L^{-1} Kin

Concentrations of growth regulators (mg L^{-1})		Induction (%)	Average of fresh weight (g $piece^{-1}$)	Callus size
2,4-D	Kin			
0.0	0.5	0	0.065 d	- - -
0.5		50	0.116 c	+ +
1.0		50	0.178 c	+ +
1.5		100	1.785 b	+ + +
2.0		100	2.584 a	+ + +

Values having same letter have no significant differences according to Duncan test at the probability level of 0.05

and E). The explants were transformed into a piece of callus after 30 days of growth on callus induction medium supplemented with 0.5, 1.0, 1.5 mg L^{-1} 2,4-D combined with 0.5 mg L^{-1} Kin. Callus was characterized by its solid texture and green color.

Auxin has important role in callus induction through its effect on increasing the cells activity, of basic growth materials synthesis. Under in vitro conditions, the explant proliferation depends on the specific balance of PGRs, auxins and cytokinins (Hartmann et al 2011). Auxins work on the expansion of the cell wall and on increasing nucleic acids metabolism especially RNA, which are important for the cell division and reproduction. Cytokinins affect protein regulation and carbohydrate metabolism, and therefore stimulate cells for division (Mahesh 2008). In addition have important role in increasing callus fresh weight, however, their significant effects are expressed by increasing cells division, as they work on increasing the meristemic and parenchymal cells divisions. These cells lost their differentiation and transformed to meristematic cells which lead to increasing the volume of different tissues that belong to the plant organs whether they are connected to their mother plant or separated and grown in sterilized nutritional media (Delloloio 2007). The effect of different concentrations of MeJA, act as an elicitor on growth of callus induced from one gram of stem segment cultured on MS callus induction medium indicate no significant differences among the treatments on callus fresh weight after 30 days of culture (Table 2).

Chaichana and Dheerranupattana (2012) observed that the absence of significant variations between callus weights after 30 days of culture, despite the presence of concentrations of MeJA as abiotic elicitor, and was due to its effect on induction of the biosynthetic processes as a typical plant defense response such as the production of phytoalaxins without affecting cells weight. Many studies also reported that the addition of various MeJA concentrations, to the cellular cultures media or by using spraying the plants with MeJA at different growth periods caused increased fresh or dry mass, and this increase was low and not significant as compared with the control (Zhang et al 2010. Onrubia et al 2010, Divya et al 2014). The addition of MeJA as abiotic elicitor has a significant effect on increasing concentrations of psoralen, xanthotoxin and bergapten in callus cultures grown on callus induction MS medium (Table 3). The increasing in concentration of MeJA up to 75 µM/L resulted in significant increase of the furanocoumarins (psoralen, xanthotoxin and bergapten) concentrations in callus cultures. The highest psoralen (2.881 mg g^{-1}) and bergapten (6.524 mg g^{-1}) were recorded at 75 µM L^{-1} MeJA (Table 3, Fig. 3 B) compared with the control treatment (0.913 mg/g and 3.983 mg/g) respectively (Fig. 3 A). However, the highest value of xanthotoxin (0.610 mg g^{-1}) was with 25 µM L^{-1}MeJA.

The addition of MeJA as an abiotic elicitor to callus culture medium, resulted in increasing the production and accumulation of furanocoumarins in callus (Table 3). The

Table 2. Effect of different MeJA concentrations on the fresh weight of callus induced from the stem segment of the plant *Ruta graveolens* L.

MeJA Concentration (µM L^{-1})	Callus fresh weight (g)
0.0	6.774 a
25.0	7.050 a
50.0	7.360 a
75.0	5.146 a

Values with the same letter do not differ significantly according to Duncan test at the probability level of 0.05

Table 3. Effect of different concentrations of MeJA on furanocoumarins, [psoralen (P), xanthotoxin (X) and bergapten (B)]concentrations in callus culture maintained by MS callus induction medium

Source of the furanocoumarins	Dilution number			Retention time (minute) for furanocoumarins			Area under the curve of the furanocoumarins (mAU x minutes)			Existence of furanocoumarins (mg g^{-1})		
	P	X	B	P	X	B	P	X	B	P	X	B
Standard sample	-	-	-	2.30	3.15	5.00	178214	178168	182082	100	100	100
Induced callus from the stems after 30 days (control)	100	100	100	2.31	3.12	4.93	65134	17421	290105	0.913c	0.244D	3.983b
Induced callus to which 25 µM/LMeJA was added	100	100	100	2.29	3.13	4.96	106616	43515	360018	1.495b	0.610A	4.943ab
Induced callus to which 50 µM/.LMeJA was added	100	100	100	2.34	3.15	5.00	114009	28156	405371	1.599b	0.395C	5.565ab
Induced callus to which 75 µM/.LMeJA was added	150	150	150	2.29	3.05	4.12	136931	21638	316803	2.881a	0.469B	6.524a

Values within the same column, with the same letter do not differ significantly according to Duncan test at the probability level of 0.0 5

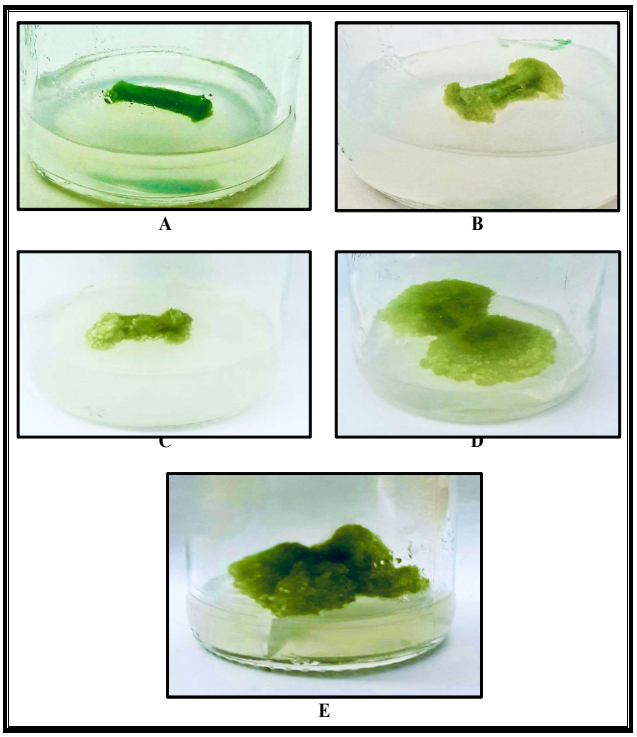


Fig. 2. Effect of different concentrations of 2,4-D + 0.5 mg L^{-1} Kin on callus induction from stem segment of *Ruta graveolens* L.(A): control treatment (B): 0.5 mg L^{-1}2,4-D + 0.5 mg L^{-1}Kin (C): 1.0 mg L^{-1}2,4-D + 0.5 mg L^{-1} Kin (D): 1.5 mg L^{-1} 2,4-D + 0.5 mg L^{-1} Kin (E): 2.0 mg L^{-1} 2,4-D + 0.5 mg L^{-1} Kin

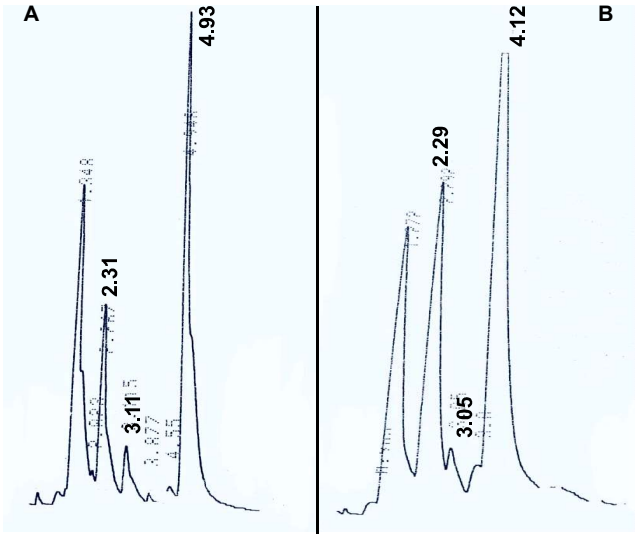


Fig. 3. Curves showing retention time and area of furanocoumarins from callus cultures maintained with 2.0 mg L^{-1} 2,4-D combined with 0.5 mg L^{-1}Kin, as affected by adding different MeJA concentrations. (A): 0.0 µM/.LMeJA (B): 75 µM/LMeJA

psoralen and bergapten concentrations were gradually increased with the increasing of the elicitor concentrations up to 75 µM L^{-1} MeJA. However, xanthotoxin highest concentration was obtained, with 25 µM L^{-1} MeJA. Ahmad et al (2020) observed that the addition of MeJA to the cell suspension cultures of *Ruta graveolens* resulted in increasing the production of furanocoumarins. MeJA as an abiotic elicitor has a strong effect on the biosynthesis of phenylpropanoid compounds, and has a strong effect on stimulating the primary phenylalaninne ammonia lyase (PAL) enzyme activity which converts phenylalanine to cinnamic acid and stimulates the activities of both cinnamic acid 4-hydroxylase and isomerase enzymes. These enzymes are involved in the coumarins biosynthetic pathways and also in expression of the genes that are related to the formation of these compounds (Sahu et al 2013, Ahn et al 2014). Ram et al (2013) mentioned that the addition of 50 µM L^{-1} MeJA to callus cultures of *Rosa hybrid* L. stimulated fast accumulation of anthocyanin compounds in callus cultures of rosa without increasing cells biomass.

CONCLUSION

The concentration of MeJA to produce the highest amount of psoralen and bergapten from induced callus cultures of *Ruta graveolens* L. was 75 µM L^{-1}. However, the highest concentration of xanthotoxin produced when 25 µM L^{-1} MeJA was added. The study, supported the potential use of callus cultures, as excellent alternative source to field plants for the production of furanocoumarins from *Ruta graveolens.* Further studies should be carried out on the molecular level, to investigate the effect of methyl jasmonate on the gene expression of the enzymes involved in the pathways of furanocoumarins production.

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