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Agroforestry as Scientific Tool for Promoting Sustainable Livelihood in Rural Communities: A Review

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***Abstract*:** Agroforestry, the integrated cultivation of trees and shrubs alongside crops and livestock, has emerged as a scientifically grounded and multifunctional land-use system that supports sustainable rural livelihoods. This review explores the scientific foundations and socio-economic impacts of agroforestry, highlighting its role in soil fertility enhancement, climate change mitigation, water management, and biodiversity conservation. It also emphasizes innovative approaches such as silvi-medicinal systems, geospatial monitoring tools, and participatory methods that empower rural communities. Having several benefits, agroforestry faces challenges also including limited financial support, insecure land tenure, and inadequate extension services. Addressing these issues through education, capacity building, and policy support can ensure the successful adoption of agroforestry as a climate-resilient and economically viable strategy for sustainable rural development Agroforestry contributes significantly to carbon sequestration, biodiversity conservation, and sustainable resource management. Through a synthesis of empirical evidence and case studies, the study highlights agroforestry's transformative potential when scientifically informed and locally adapted. It reinforces agroforestry as a strategic tool for advancing rural development and achieving long-term sustainability in alignment with global development goals.

***Keywords*:** Agroforestry, Climate change mitigation, Carbon sequestration, Biodiversity conservation, Rural development, Sustainability

Traditionally, people raised trees, crops, and animals together on the same land to meet family needs through mixed farming. Agroforestry is a collective term for land use systems, practices, or technologies that combine woody perennials with agricultural crops and/or animals in the same piece of land, either in some form of spatial and temporal sequence. Agroforestry is a land-use system that offers deliberate retention and incorporation of trees or other woody perennials in crop-animal production fields to get maximum return from the resultant ecological and economic interactions. The National Agroforestry Policy (2014) describes agroforestry as a combination of land-use systems which collectively combines trees and shrubs on farmlands and rural landscapes with/without livestock to improve productivity, profitability, diversity, and ecosystem sustainability. Agroforestry is deeply intertwined with scientific principles, as it is based on understanding the interactions between trees, crops, livestock, and the environment. Various researchers, scientists explore how these components interact at various levels (biological, ecological, social, and economic) to improve sustainability, productivity, and resilience in agricultural systems (Pancholi et al., 2023). Agroforestry is a scientifically improved practice to the farmers to expand the ecological, economic, environmental as well as social status of the community as a whole (Roghan et al., 2024). In keeping the exclusivity and sustainability of agroforestry system, management practices have played an important task. Supervision of the agroforestry system is complex because of the diverse mixed species as compared to monoculture (Manna et al., 2018). Agroforestry contributes in a way to enhance carbon sequestration, soil fertility, water management, climate change mitigation, and biodiversity conservation (Thakur et al., 2011, Bhusara et al., 2016, Thakur et al., 2017a, Kumar et al., 2020, Kumar et al., 2025). Integrating traditional knowledge with innovative scientific techniques, agroforestry offers multifaceted strategy that supports food security, income diversification, and climate resilience, especially for smallholder farmers in low- and middle-income countries (Kumar et al., 2023).

The aim of this review is to synthesize empirical and scientific research on agroforestry's role in enhancing rural livelihoods. We discuss ecological and economic mechanisms, innovative scientific techniques, socio-environmental outcomes, and policy implications - particularly for smallholder farmers in low- and middle-income countries.

MATERIAL AND METHODS

The article primarily based on a comprehensive review about the agroforestry system that enhance livelihood benefits in rural area by integrating traditional practices of farming with different scientific techniques. This review collectively analyzed different information from rich source of relevant literature spanning 26 years to get a vivid depiction of agroforestry and its contribution towards rural livelihood

RESULTS AND DISCUSSION

Agroforestry as Scientific Approach for Sustainable Rural Development

Soil fertility enhancement: Trees play a crucial scientific role in promoting rural livelihoods by enhancing soil fertility through the addition of organic matter, their leaf litter, root decomposition, and biomass from pruning contribute significantly to soil organic carbon content, which improves soil structure, nutrient availability, soil health through enhanced flora and fauna and overall agricultural productivity (Aldeen et al., 2013, Rachel et al., 2012, Singh et al., 2010, Sharma et al., 2019, Prajapati et al., 2022a,b). It also minimizes soil erosion (Table 1), improve soil quality, vegetative cover, land productivity and lift the farmer's level of living through sustained farm productivity (Chakraborty et al., 2015, Dissanayaka et al., 2024).

Study in the central Punjab, India revealed that integration of poplar and wheat agroforestry system in the winter season and green gram in the summer season increases the net soil organic carbon, there was an increase of 0.36 per cent in the sole crop in agriculture soil whereas 0.66 per cent increase was in the agroforestry soil and same addition increases with tree age (Gupta et al., 2013). Yadav et al. (2019) and Solanki et al., (2015) also observed in their study that these leaf litters or organic matter have high carbon content, which further increase porosity and soil's water holding capacity that enhances overall microbial biodiversity and soil quality. Similar observations were found by Sharma et al. (2017), where organic carbon content in soil was more and decreases as the distance from trees increases. Prajapati et al. (2022a, b) also reported enhanced soil biota under agroforestry systems (*Melia dubia*+ *Sorghum bicolor* x *Sorghum bicolor* var. *Sudanese/* hybrid Napier) as compared to sole cropping (sole tree or sole grass).

Climate change mitigation: Agroforestry systems and their

Table 1. Impact of agroforestry system on degraded land

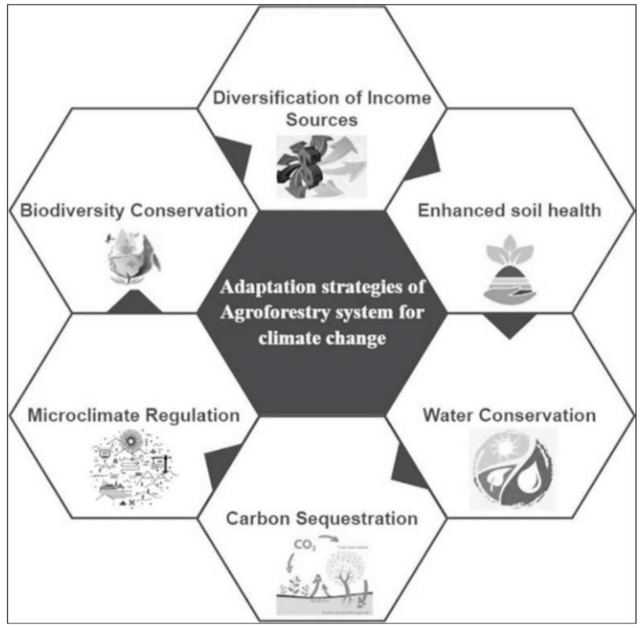
Type of degraded land	Location	Agroforestry system	Impact	Reference
Degraded sloping land	North-East India	Hedgerow cropping	Reduced soil loss and runoff by 94% and 78%, respectively	Saha et al. (2012)
	Dehradun	Silvipasture system	No soil loss with an annual return of about Rs. 4,000 ha^{-1} $year^{-1}$ from commercial grass alone besides additional returns from Eucalyptus.	Sharda and Venkateswarlu (2007)
	Shivalik hills	Horti-pasture system	*Emblica officinalis* + *Chrysopogon fulvus* Horti-pasture system saved water and soil by 4.9–30.7 cm and 862–2,818 kg ha^{-1}	Prasad et al. (2012)
	Karnataka	Ley farming (Vegetative barriers)	*Cenchrus ciliaris* and *Cymbopogon martini* reduced the runoff by 38% and soil loss by 16%	Ramajayam et al. (2007)
	Kashmir	Silvi-agriculture	Reduced scorching heat and the same time reduced soil erosion, besides increased crop production	Mughal and Makaya (2000)
Gullied and ravine lands	Gujarat	Agri-horticulture system with soil moisture conservation practices	They revealed that sapota with trenches and bench terraces reduced runoff by 16%–34% and soil loss by 15%–25%	Kumar et al. (2020)
	Gujarat	Agroforestry system of cowpea + castor + sapota	Reduced total soil loss and runoff by 37.7 and 19.1% and system productivity increased by 81.9% compared to sole tree plantation	Jinger et al. (2022)
	Uttar Pradesh	Agri-horticulture system	Recorded higher yield of Ber, pearl millet, wheat and fuel wood	Prakash et al. (2011)
	Rajasthan	Alley cropping	Higher yield, land equivalent ratio and soil organic carbon were recorded in *Leucaena*-based alley-cropping systems	Dhyani et al. (2007)
Shifting cultivation land	North-East India	Multipurpose tree plantation (fast- growing nitrogen-fixing trees) in fallows	Reduction in bulk density by 15.9% and erosion ratio by 39.5%, and increase in SOC by 96.2%, aggregate stability by 24.0%, porosity by 10.9%, and available soil moisture by 33.2%	Saha et al. (2012)
	Odisha	Alley cropping	The runoff and soil loss was reduced by 23%–32% and 49%–52%, respectively	Adhikary et al. (2017)
	East India	*Gliricidia sepium* hedgerow and grass filter strip	The runoff and soil loss was reduced by 32 and 35%, respectively	Lenka et al. (2012)

Source: Jinger et al. (2023)

services can be used as strategies for climate change mitigation as indicated in Figure 1.

Agroforestry has developed as a key approach to increasing climate resilience by integrating agriculture and forestry to create synergistic advantages (Mbow et al., 2014). Implementation of agro-forestry practices has larger potential to increase carbon sequestration of mainly agroforestry dominated lands than monocrop agriculture (Lee and Jose 2003, Nair 2003, Morgan et al., 2010, Panwar et al., 2022) (Table 2). Trees are capable of storing about 50-60% of carbon in the above-ground biomass on the other hand pasture grasses store only 10% above-ground, (Houghton and Hackler 2000, Sharrow and Ismail 2004). In agroforestry systems, trees and shrubs act as carbon sinks, absorbing carbon dioxide and storing it in their biomass and soil (Thakur et al., 2011, Bhusara et al., 2016, Handa et al., 2020).

Agroforestry is more effective than sole cropping in sequestering CO_2 and improving soil quality, tree-crop diversification boosts carbon sequestration and supports



Source: Barman et al. (2024)

Fig. 1. Agroforestry system for climate change

Table 2. Carbon sequestration through agroforestry in different regions of the country

Agro-climatic zones	Agroforestry system	Carbon sequestration potential (Mg C ha^{-1} year^{-1})	References
Central Plateau & Hill Region	Agri-silviculture (*Acacia* + greengram-mustard)	3.70	Newaj et al. (2008)
West Coast Plains & Ghats Region	Agri-silvi-horticulture (*Artocarpus heterophyllus* + *Acacia auriculiformis* + black pepper)	9.90	Kunhamu et al. (2012)
		11.3	
Eastern Plateau & Hills Region	Agri-silviculture (*Albizia procera* + wheat)	5.70	Newaj et al. (2012)
Upper Gangetic Plains Region	Agri-silviculture (*Dalbergia sisso* + mustard)	2.83	Newaj et al. (2012)
Lower Gangetic Plains Region	Agri-silviculture (*Eucalyptus tereticornis* + rice-wheat)	10.7	Sirohi and Bnagrawa (2017)
Southern Plateau and Hills Region	Silvipasture system (*Leucaena leucocephala* + *Gliricidia sepium Stylosanthes hamata*)	23.2	Handa et al. (2019)
East Coast plains & Hills region	Horti-silviculture *(Acacia mangium* + pineapple)	5.51	Handa et al. (2019)
The Island Regions	Horti-pasture (*Cocos nucifera* + *Calliandra calothyrsus*)	3.50	Joy et al. (2019)
Western Plateau & Hills Region	Agri-silviculture (*Ailanthus excelsa* + cowpea-mustard)	9.64	Handa et al. (2019, 2020)
Western Himalayan Region	Agri-horticulture (*Prunus armeniaca* + *Ocimum sanctum*)	1.80	Handa et al. (2020)
	(*Prunus persica* + *Ocimum sanctum*)	2.0	
Western Dry Region	Silvipasture system (*Ailanthus* + *Cenchrus ciliaris/ Panicum antidotale*)	9.64	Handa et al. (2020)
Eastern Himalayan Region	Silvi-pasture (*Morus alba* + *Setaria anceps* grass)	1.55	Handa et al. (2020)
Middle Gangetic Plains Region	Agri-silviculture (*Tectona grandis* + sorghum/groundnut)	2.32	Handa et al. (2020)
Trans-Gangetic plains Region	Agri-silviculture (*Populus deltoides* + wheat/potato/turmeric)	9.12	Chavan et al. (2022)
Gujarat Plains & Hills Regions	Silvo-aromatic (*Melia dubia* + lemon grass)	20–25	Jinger et al. (2022)

Source: Jinger et al. (2023)

both climate change mitigation and adaptation (Aggarwal and Kumar 2020). Climate changes become more challenging day by day and the key solution is to increase the forest and tree cover by practicing agroforestry system with increasing resilience of the farming system by the sole crop adopters of the farmers (Dhyani 2014). Agroforestry systems play an important role in moderating the microclimate. Carbon sequestration stores carbon component from atmosphere and mitigates greenhouse gas emissions, which is a chief element of Climate-Smart Agriculture (Riyadh et al., 2021). Agroforestry sequesters up to 30% more carbon than monoculture farming, simultaneously mitigate climate change and enhance soil health (Fahad et al., 2022).

Water management and climate adaptation: Trees act as natural reservoirs, soaking up excess rain and releasing water stored within them during droughts, hence mitigating both flood and drought risks (Dubashi 2025). Unlike in annual systems where the land lies bare for extended periods, agroforestry systems with perennial tree components can make use of the water remaining in the soil after harvest and the rainfall received outside the crop season (Table 3). Secondly, agroforests rise the productivity of rain water by seizing a larger proportion of the annual rainfall by reducing the runoff and by using the water deposited in deep layers. Thirdly, the changes in microclimate (lower air temperature, windspeed and saturation deficit of crops) decrease the evaporative demand and make more water available for transpiration (Rao et al., 2007). The trees also tend to develop or redirect their roots to the upper soil layers, if water recharge below the root zone is infrequent as it occurs in low rainfall years and in the absence of plant existing nutrients (Rao et al., 2004). Agroforestry systems increase water holding capacity by promoting soil structure, organic matter levels, and decreasing surface runoff (Fahad et al., 2022). It was also observed that soils are not capable of holding sufficient moisture as a consequence of lower litter content in the field (Islam et al., 2016). Therefore, combination of trees with crops are preferable.

Biodiversity conservation: Agroforestry systems enhance species richness owing to its varied structure and composition, resources and services (Fig. 2) which is devoid in monoculture systems. Its integration into agricultural practices offers a sustainable pathway to maintain and enhance biodiversity (Thakur et al., 2005, Thakur et al.,

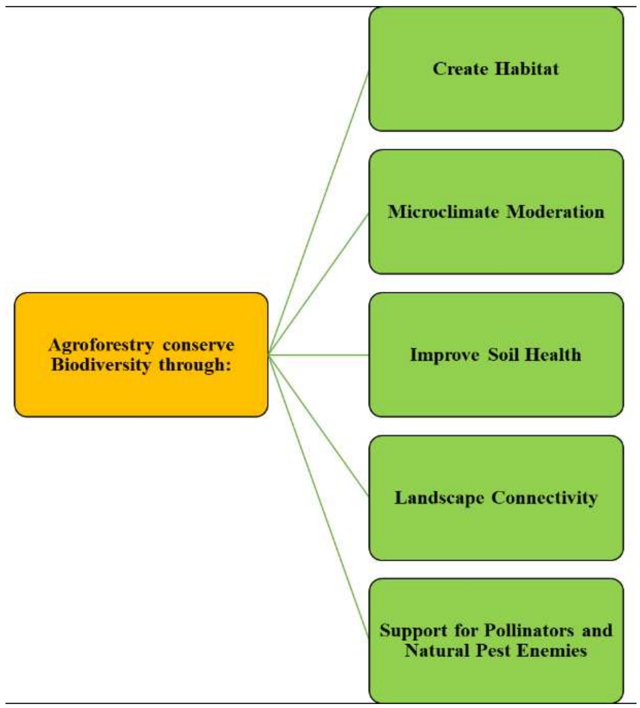


Fig. 2. Role of Agroforestry to conserve biodiversity

Table 3. Water use efficiency and transpiration loss of different tree species

Name of species	Water use	Transpiration loss	References
Acacia nilotica	1,248 mm $year^{-1}$	–	Khanzada et al. (1998)
Prunus armenica	–	1.5–2.37 L day^{-1}	Barradas et al. (2005)
Populus euphratica	–	2.0 mm day^{-1}	Khamzina et al. (2006)
Acacia tortilis		2.63 m mol.$m^{-2} s^{-1}$	Akram et al. (2008)
Punica granatum	1,255–3,671 L $year^{-1}$	–	Bhantana and Lazarovitch (2010)
Eucalyptus grandis	13,184–77,031 kg $ha^{-1} day^{-1}$	–	Kallarackal (2010)
Dalbergia sissoo		2.67–3.28 m mol. $m^{-2} s^{-1}$	Prasath et al. (2014)
Azadirechta indica		2.88 ± 0.2 gm $leaf^{-1} h^{-1}$	Pagare et al. (2014)
Eucalyptus tereticornis	–	0.28–4.0 mm day^{-1}	Venkatraman and Ashwath (2016)
Acacia mangium	–	0.45–4.0 mm day^{-1}	Venkatraman and Ashwath (2016)
Pongamia pinnata	–	0.1–2.64 mm day^{-1}	Venkatraman and Ashwath (2016)

Source: Jinger et al. (2023)

2017a, Udawatta et al., 2019). One of the purposes of agroforestry tree domestication is improvement of stability and productivity of agro-ecosystems by expanding on-farm tree species composition (presence and abundance). Diversification and strengthening of land use through domestication of agroforestry trees is one of the three pillars of the research of the World Agroforestry Centre (Kindt and Lengkeek 1999, ICRAF 2000). Agroforestry permits for co-occurrence of numerous species, minimizes pest infestation, and ensures the protection of threatened plant and animal species, eventually enhancing ecosystem resilience to environmental changes (John et al., 2024). Agroforestry is distinctively suited to deliver eco-agriculture solutions that successfully combine purposes for increased food security and biodiversity conservation (Atta-Krah et al., 2004, Garrity 2004, McNeely 2004, Simons and Leakey 2004). Agroforestry reduces the degradation of protected areas, by increasing biodiversity within working landscapes, and/or introducing different trees species in farming systems (Garrity 2004, Thakur et al., 2004).

Agroforestry for rural livelihood security: Agroforestry plays a vital role in providing abundant income streams for the farming households or farm manager (Fig. 3) and simultaneously fulfilling daily needs of people, such as fodder, fuel-wood, and dietary supplements from fruit–trees, highlights its multiple benefits to rural livelihoods (Jose et al., 2004, Thakur et al., 2015, Tiwari et al., 2017).

Forests and tree-based agricultural systems contribute providing both the facility of direct and indirect ecosystem services which is reflected by greater access to livelihood capitals (Arnold et al., 2011, Bansal et al., 2021).

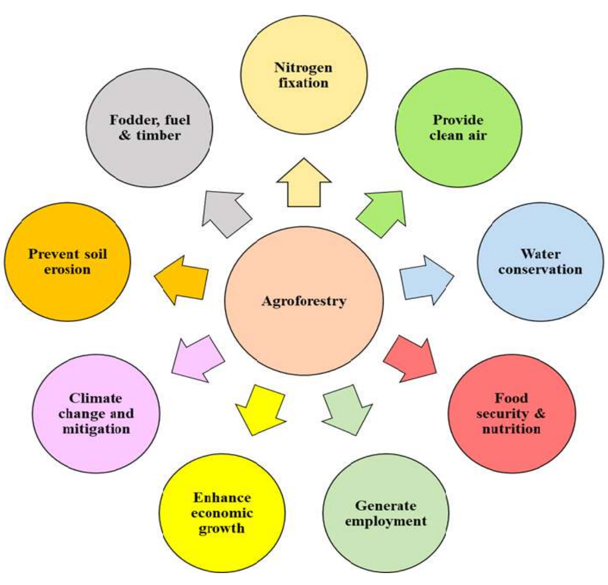


Fig. 3. Benefits of Agroforestry

Agroforestry-based businesses such as mushroom farming, beekeeping and non-timber forest products increase additional income sources that enhancing sustainable rural development (Kumar et al., 2021) and also mitigating the adverse impact of climate change (Islam and Quli 2016). Agroforestry systems generate employment in rural areas by enlarged supply of wood in the market a substantial dealing with wood and wood-based products (Dhyani and Handa 2013). Tree-crop based systems expand soil stability and prevent erosion through several processes. Increased ground cover from leaf litter and "tree mulch" intercepts rainfall, decreases the velocity of runoff water, reduces evapotranspiration, and limits soil crusting (Sepulveda and Carillo 2015). Its different components act as an alternate source of income, as loss in market value of one product can be compensated by better prices of other products, such as timber, crops, fruits, nuts, mushrooms, forages, livestock, biomass, Christmas trees, and herbal medicine (Wilson and Lovell 2016, Thakur et al., 2017b).

Gum-yielding trees like *Acacia senegal*, *Acacia nilotica*, *Butea monosperma*, and *Boswellia serrata* are valuable for agroforestry models and should be promoted widely to ensure sustained income and livelihood security for resource-poor rural communities (Chavan et al., 2016). Kanwal et al., 2022 also concluded higher overall productivity in agroforestry system as compared to sole agriculture especially in hilly states.

Study reported that in western Uttar Pradesh, fuelwood was more than 50% of the farmer's major source of income, which also reduced the dependence of the other conventional fuel followed by additional income 25% of farmers adopted the agroforestry model (Dwivedi et al., 2010). The estimated fuelwood consumption in different villages of Chamoli districts of Garhwal Himalayas estimated during summer per village is 83.41 kg/day to 535.40 kg/day and in winter 150.70 kg/day to 757.05 kg/day and the utilization of fodder tree 301.05 kg/day to 1009.15kg/day in the summer and in the winter 650.50 kg/day to 2011.50 kg/day which is supplemented by traditional agroforestry trees (Rawat et al., 2016).

Innovative technologies in agroforestry for rural sustainability: Innovative agroforestry practices blend modern science with traditional practices helping rural communities improve land management, boost productivity, and support sustainable livelihoods while protecting the environment (Table 4).

Sanwal et al., (2018) estimated seven medicinal plants and found *Anacyclus pyrethrum* (Akarkara), *Mucuna* (Kaunch), *Solanum virginianum* (Kantkari), and *Andrographis* (Kalmegh) economically suitable in mountain regions. *Spilanthes, Mucuna*, and Solanum showed highest yields on northern slopes, with net returns up to Rs. 34,639/ha in 4-6 months. Similarly, lower Himachal Himalayas Verma et al. (2010), Verma and Thakur (2010, 2011), Thakur et al. (2012), Thakur and Verma (2012) and Thakur et al. (2017b) reported *Ocimum sanctum, Withania somnifera and Mucuna pruriens* as ecologically and economically sound agroforestry combinations. Such silvi-medicinal systems offer promising alternate livelihoods for communities ranging from mountains to plans and coastal areas (Suvera et al., 2015, Suvera and Thakur 2016, Kumar et al., 2016, 2017). The All India Coordinated Research Project (AIRCP) on Agroforestry and ICAR-Central Agroforestry Research Institute Jhansi suggested *Morus* and *Grewia-based* system for the western Himalayas, alder-based for the North Eastern Hill region, aonla, *Ailanthus, Hardwickia* and *Prosopis* based for the semi-arid and arid regions, poplar and eucalyptus-based for the Indo- Gangetic region and *Gmelina, bamboo, Acacia*-based system for Humid and Sub-humid regions and, teak-based for the tropical region (Handa et al., 2024). Innovative agroforestry interventions in the North Western Himalayas include bamboo-based agri-silvicultural systems, bamboo for construction, silvi-medicinal models using native medicinal plants, spice-based systems to counter crop loss from wildlife, sea buckthorn cultivation in high-altitude areas, and Van Silk (forest-based sericulture) to support forest-dependent communities-offering diverse livelihood and enterprise opportunities (Sanwal et al., 2019)

Scientific research methods for community empowerment: Agroforestry, combined with Remote Sensing technology using indices like NDVI, SAVI, LAI, and NDMI, enable precise monitoring of vegetation health, moisture, and productivity, supporting sustainable agroforestry, carbon finance, and ecosystem restoration-key elements in improving farmer incomes and advancing climate resilience (Ghosh and Sharma 2024). Agroforestry adoption was significantly enhanced through participatory methods that built trust, addressed local needs, and empowered communities with knowledge and skills (Suparwata et al., 2021). Agroforestry enhanced livelihood security by adopting practices like lac cultivation and sericulture. Traditional lac host trees such as *Ber (Zizyphus mauritiana)* and *Palas (Butea monosperma)* can be planted along field bunds, while fast-growing species like *Flemingia semialata* are also promising. Sericulture can be supported through agroforestry species that serve as host plants for silkworms-*Terminalia tomentosa*, *T. arjuna* and *Shorea robusta* for Tasar; *Morus* species for mulberry silkworms (Handa et al., 2016). Active participation is considered as one of the effective methods for community empowerment. This ensures that the strategies are tailored to the specific needs and preferences of the community, leading to better acceptance and more sustainable outcomes (Mayo 2004).

Table 4. Innovative agroforestry system in rural livelihood

Agroforestry system	Benefits	References
Agrisilviculture system (Woody perennials- Trees/shrubs + Agricultural crops)	Actively indulge in climate change and mitigation as agrisilvicultural systems have the potential to minimize direct N2O and CH4 emissions by up to 2.0 times.	Kwak et al. (2019)
	It positively enhances earthworm abundance, and organic matter in soil.	Cardinael et al. (2019), Marsden et al. (2020)
Agri-silvipastoral system (agricultural crops + timber/forest trees + pasture)	This complex tri component structure improves ecological sustainability and livelihood resilience, predominantly for smallholders and rural communities in diverse Agroclimatic zones.	Singh and Panday (2011)
Horti-silviculture System (fruit trees + timber/forest trees)	It increases both farm income and economic sustainability by optimal use of land.	Nair (1993)
	It also enhances microbial biodiversity- like in oleaginous tree species *Elaeis guineensis* + *Theobroma cacao*.	Ashraf et al. (2018)
Silvipastoral Systems (Trees/shrubs + pasture/grasses + livestock)	These systems are predominantly practiced in arid and semi-arid areas.	Kumar (2006)
	System fulfils the demands of fuel and fodder in rural areas and reduces the impact of climate change.	Dhyani (2013)
Home Gardens (multi-strata agroforestry system/ kitchen garden)	This system is known for its high species richness, vertical structure, and constant food and fodder production throughout the year.	Nair (1993)
	It improves and maintains the food and nutritional security in both rural and urban areas.	Nair (2008)
Alley Cropping (hedgerow intercropping of annual crops+ trees/shrubs)	This system widely practiced for soil fertility enhancement, control of soil surface runoff in marginal lands.	Young (1989)
	Many studies under agroforestry research show the importance of alley cropping in improving soil fertility and promote efficient nutrient cycling.	Adhikary et al. (2017, Jakhar et al. (2017 and Lenka et al. (2012)

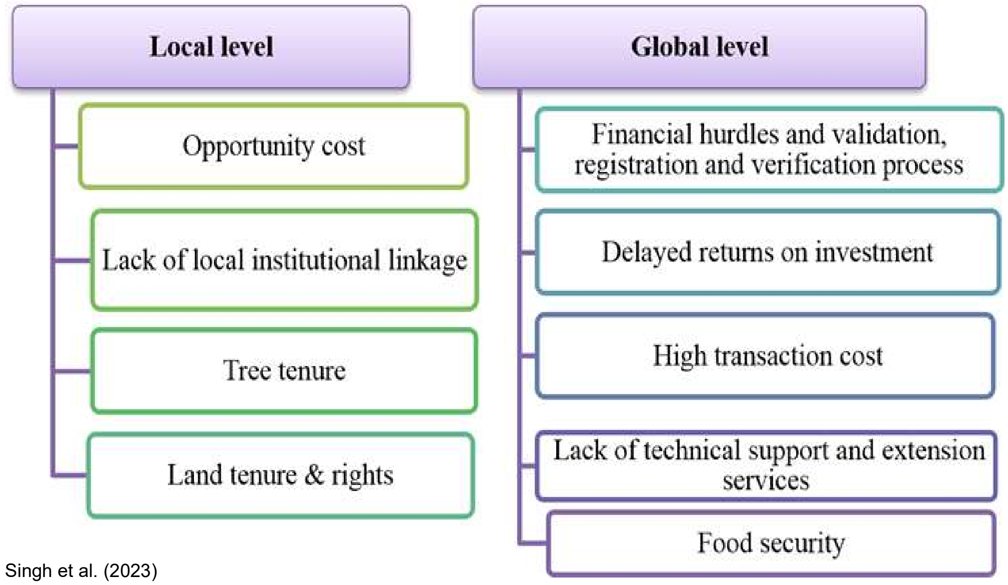


Fig. 4. Challenges in Agroforestry

Another pivotal strategy is capacity building. By equipping community members with the necessary skills, knowledge, and resources, they can effectively manage their resources, engage in profitable ventures, and mitigate potential risks (Hastings and Saunders 2001).

Challenges: Despite of several benefits agroforestry system still has challenges (Fig. 4). The inadequate availability of credit facilities and incentives is one of the key challenges affecting the use of inputs on farms and the planting of trees (Alemagi et al., 2015, Makee 2016).

Oduro et al. (2018), mentioned financial barriers to tree stock development on farms are often mentioned by farmers as being one of the major hindrances, and providing incentives to farmers such as grants and inputs is an effective way to reassure them to plant trees on their farms (Oduro et al., 2018). Plant species for intercropping, if not accurately selected may cause interspecific competition and minimize its environmental benefits (Jose et al., 2004). Adesina and Chianu 2002 stated in their study that because of limited contact with extension agents (demonstration days) proved a barrier to agroforestry systems adoption for landowners.

CONCLUSION

Agroforestry is a sustainable, science-based land-use system that enhances rural livelihoods by improving soil health, conserving biodiversity, mitigating climate change, and providing diverse income sources. With innovations like geospatial tools and participatory methods, it supports climate resilience and food security. However, challenges like limited credit, insecure land tenure, and inadequate support services must be addressed. Agroforestry represents a scientifically robust and socially inclusive approach to rural development. By organizing education programmes and sharing experiences among farmers can be useful method to achieve effective implementation of profitable agroforestry System. When effectively implemented, agroforestry offers a powerful solution for sustainable rural development and environmental conservation. Agroforestry is a system or modern scientifically enhanced technique for the cultivators to improve our safety of socioeconomic conditions and environment cleanliness by the fixed size of the land cultivated all components in the same field. It is clearly shown that traditional and present-day's scientific agroforestry practices primarily have different positive assets for the gaining profit of improved biodiversity, which helps environment reformation and economic return of output for the producers across the world.

AUTHOR'S CONTRIBUTION

Monika Sharma: writing, review, methodology, data collection, editing and conceptualization; Meenakshi Gupta: supervision and review; K.K. Sood: supervision and resources. Lalit Mohan Gupta**:** review and editing.

REFERENCES

Adesina AA and Chianu J 2002. Determinants of farmers' adoption and adaptation of alley farming technology in Nigeria. *Agroforestry Systems* **55**(2): 99-112.

Adhikary PP, Hombegowda HC, Barman D, Jakhar P and Madhu M. 2017. Soil erosion control and carbon sequestration in shifting cultivated degraded highlands of eastern India: performance of two contour hedgerow systems. *Agroforestry Systems* **91**(4): 757-771.

Agarwal YK and Kumar H 2020. Climate change mitigation through agroforestry. In: *Climate Change Mitigation Through Agroforestry* pp. 35-41.

Akram S, Kashkouli HA and Pazira E 2008. Sensitive variables controlling salinity and water−table in a biodrainage system. *Irrigation and Drainage Systems* **22**(3): 271-285.

Aldeen HS, Majid NM, Azani A M, Ghani ANA and Mohamed S 2013. Agroforestry impacts on soil fertility in the Rima'a Valley, Yemen. *Journal of Sustainable Forestry* **32**(3): 286-309.

Alemagi D, Duguma L, Minang P A, Nkeumoe F, Feudjio M and Tchoundjeu Z 2015. Intensification of cocoa agroforestry systems as a REDD+ strategy in Cameroon: Hurdles, motivations, and challenges. *International Journal of Agricultural Sustainability* **13**(3): 187-203.

Arnold JEM, Powell B, Shanley P and Sunderland TCH 2011. Forests, biodiversity and food security. *International Forestry Review* **13**(3): 259-264.

Ashraf M, Zulkifli R, Sanusi R, Tohiran K, Terhem R, Moslim R, Norhisham A, Ashton A and Azhar B. 2018. Alleycropping system can boost arthropod biodiversity and ecosystem functions in oil palm plantations. *Agriculture, Ecosystems and Environment* **260**: 19-26.

Atta-Krah K, Kindt R, Skilton JN and Amaral W 2004. Managing biological and genetic diversity in tropical agroforestry. *Agroforestry Systems* **61**(1-3): 183-194.

Bansal V, Joshi V and Meena SC 2021. Agroforestry for sustainable rural livelihood: A review. *Turkish Online Journal of Qualitative Inquiry* **12**(10): 2529-2537.

Barman A, Dutta S, Bera A, Saha P, Roy J, Roy Choudhury M, Bera M and Das S 2024. Synergizing sustainability: A critical review on harnessing agroforestry for biomass, carbon sequestration, and water-food-energy nexus. *Energy, Ecology and Environment* **9**(6): 579-613.

Barradas VL, Nicolas E, Torrecillas A and Alarcon JJ 2005. Transpiration and canopy conductance in young apricot (*Prunus armenica* L.) trees subjected to different PAR levels and water stress. *Agricultural Water Management* **77**(3): 323-333.

Bhantana P and Lazarovitch N 2010. Evapotranspiration, crop coefficient and growth of two young pomegranate (*Punica granatum* L.) varieties under salt stress. *Agricultural Water Management* **97**(5): 715-722.

Bhusara JB, Thakur NS and Hegde HT 2016. Biological yield and carbon sequestration in prominent traditional agroforestry systems in Valsad District, Gujarat, India. *Indian Journal of Ecology* 43(1): 318-320.

Brenya R, Akomea−Frimpong I, Ofosu D and Adeabah D 2022. Barriers to sustainable agribusiness: A systematic review and conceptual framework. *Journal of Agribusiness in Developing and Emerging Economies* **13**(4): 570-589.

Cardinael R, Hoeffner K, Chenu C, Chevallier T, Béral C, Dewisme A and Cluzeau D 2019. Spatial variation of earthworm communities and soil organic carbon in temperate agroforestry. *Biology and Fertility of Soils* **55**: 171-183.

Chavan SB, Dhillon RS, Sirohi C, Keerthika A, Kumari S, Bharadwaj KK, Jinger D, Kakade V, Chichaghare AR, Zin El−Abedin TK, Mahmoud EA, Casini R, Sharma H, Elansary HO, Yessoufou K 2022. Enhancing farm income through boundary plantation of poplar (*Populus deltoides*): An economic analysis. *Sustainability* **14**(14): 8663.

Chavan SB, Uthappa AR, Sridhar KB, Keerthika A, Handa AK, Newaj R, Kumar N, Kumar D and Chaturvedi OP 2016. Trees for life: Creating sustainable livelihood in Bundelkhand region of Central India. *Current Science* **111**(6): 994-1002.

Das PK, Singh PK and Quli SMS 2011. Economic analysis of agroforestry model adopted by tribal of Orissa, India. *The Indian Forester* **137**(5): 535-543.

Dhyani SK 2014. National agroforestry policy 2014 and the need for area estimation under agroforestry. *Current Science* **107**(1): 9-10.

Dhyani SK and Handa AK 2013. India needs agroforestry policy urgently: Issues and challenges. *Indian Journal of Agroforestry* **15**(2): 1-9.

Dhyani SK, Handa AK and Uma. 2013. Area under agroforestry in India: An assessment. *Indian Journal of Agroforestry* **15**(1): 1-11.

Dhyani SK, Samra JS, Handa AK and Uma 2007. Forestry to support increased agricultural production: Focus on employment generation and rural development. *Agricultural Economics Research Review* **20:** 179-202.

Dissanayaka DMNS, Udumann SS and Atapattu AJ 2024. Synergies between tree crops and ecosystems in tropical agroforestry. In: *Agroforestry*, pp. 49-87.

Dubashi A 2025. *Sustainable watershed strategies*. Educohack Press.

Dwivedi RP, Kareemulla K, Singh R, Rizvi RH and Chauhan J 2010. Socio−economic analysis of agroforestry systems in western Uttar Pradesh. *Indian Research Journal of Extension Education* **7**(2-3): 18-22.

Fahad S, Chavan SB, Chichaghare AR, Uthappa AR, Kumar M, Kakade V, Pradhan A, Jinger D, Rawale G, Yadav DK, Kumar V, Farooq TH, Ali B, Sawant AV, Saud S, Chen S and Poczai P 2022. Agroforestry systems for soil health improvement and maintenance. *Sustainability* **14**(22): 14877.

Garrity DP 2004. Agroforestry and the achievement of the Millennium Development Goals. *Agroforestry Systems* **61**(1): 5-17.

Ghosh S and Sharma JV 2024. Advancing India's agroforestry potential: Leveraging technology and community approaches for sustainable development. *Asian Research Journal of Agriculture* **17**(4): 1053-1058.

Handa AK, Arunachalam A, Sirohi C and Bhaskar S 2022. Livelihood security and employment opportunities through agroforestry based smart agriculture. In: *XV World Forestry Congress*, Food and Agriculture Organization of the United Nations (FAO).

Handa AK, Chavan SB, Kumar V, Vishnu R, Ramanan SS, Tewari RK, Arunachalam A, Bhaskar S, Chaudhari SK and Mohapatra T 2020. Agroforestry for income enhancement, climate resilience and ecosystem services. *Technical Bulletin* No. CAFRI/01/2020. Indian Council of Agricultural Research, New Delhi.

Handa AK, Chavan SB, Sirohi C and Rizvi RH 2020. Importance of agroforestry systems in carbon sequestration. In: *Proceedings of the National Agroforestry Symposium*.

Handa AK, Dev I, Rizvi RH, Kumar N, Ram A, Kumar D, Kumar A, Bhaskar S, Dhyani SK and Rizvi J 2019. *Successful agroforestry models for different agro−ecological regions in India.* Jointly published by the Central Agroforestry Research Institute (CAFRI), Jhansi, and the South Asia Regional Programme of World Agroforestry (ICRAF), New Delhi

Handa AK, Dev I, Rizvi RH, Kumar N, Ram A, Kumar D, Kumar A, Bhaskar S, Dhyani SK and Rizvi J 2019. *Successful agroforestry models for different agro−ecological regions in India.* ICAR−Central Agroforestry Research Institute, Jhansi & World Agroforestry Centre.

Handa AK, Toky OP, Dhyani SK and Chavan SB 2016. Innovative agroforestry for livelihood security in India. *World Agriculture* **7**: 7-11.

Hastings R and Saunders RP 2001. Strategies for police accountability and community empowerment. In: *Poverty and the Law*, pp. 35-56. Hart Publishing.

Houghton RA and Hackler JL 2000. Changes in terrestrial carbon storage in the United States. 1. The role of agriculture and forestry. *Global Ecology and Biogeography* **9**(2): 125-144.

International Centre for Research in Agroforestry (ICRAF) 2000. *Paths to prosperity through agroforestry: ICRAF's corporate strategy 2001-2010.* 43 pp.

Islam M, Salim SH, Kawsar MH and Rahman M 2016. The effect of soil moisture content and forest canopy openness on the regeneration of *Dipterocarpus turbinatus* C.F. Gaertn. (Dipterocarpaceae) in a protected forest area of Bangladesh. *Tropical Ecology* **57**(3): 455-464.

Islam MA and Quli SMS 2016. Motivation strategy for agroforestry intensification among small holders. *Advances in Life Sciences* **5**(10): 3878-3883.

Jakhar P, Dass A, Adhikary PP, Sudhishri S, Naik BS, Hombegowda HC, Madhu M and Lenka NK. 2017. Multitier agroforestry system for integrated resource conservation on uplands of Eastern Ghats region in India. *Agroforestry Systems* **97**(5): 697-712.

Jinger D, Kaushal R, Dinesh D, Singh G and Singh AK 2022. Silvo-aromatic system for enhancing ecosystem services in Mahi ravines of Central Gujarat. *Proceedings of National Conference on Landscape Management for Preventing Flood and Reservoir Sedimentation*, Ranchi, India, 22-24 September 2022: 39.

Jinger D, Kaushal R, Kumar R, Paramesh V, Verma A, Shukla M, Chavan SB, Kakade V, Dobhal S, Uthappa AR, Roy T, Singhal V, Madegowda M, Kumar D, Khatri P, Dinesh D, Singh G, Singh AK, Nath AJ, Joshi N, Joshi E & Kumawat S. 2023. Degraded land rehabilitation through agroforestry in India: *Achievements, current understanding, and future prospectives. Frontiers in Ecology and Evolution* **11**: 1088796.

Jinger D, Kumar R, Kakade V, Dinesh D, Singh G, Pande VC, Bhatnagar PR, Rao BK, Vishwakarma AK, Dinesh K and Singhal V 2022. Agroforestry system for controlling soil erosion and enhancing system productivity in ravine lands of Western India under climate change scenario. *Environmental Monitoring & Assessment* **194**(4): 267.

John A, Kaur A, Bhat KA, Ganie SA, Nugroho C, Handoko I and Wani AK 2024. Adapting to climate extremes: Implications for insect populations and sustainable solutions. *Journal for Nature Conservation* **79**: 126602.

Jose S, Gillespie AR and Pallardy SG 2004. Interspecific interactions in temperate agroforestry. *Agroforestry Systems* **61-62**(1-3): 237-255.

Joy J, Raj AK, Kunhamu TK, Jamaludheen V and Jayasree K 2019. Fodder production and carbon stock of Calliandra under coconut plantation. *Range Management and Agroforestry* **40**(2): 109-117.

Kallarackal J 2010. *Water use by Eucalyptus grandis plantations in comparison with grasslands located in the downhill areas of Mannavan Shola in the Western Ghats of Kerala.* Kerala Forestry Research Institute, Report.

Kanwal MS, Yadava AK and Vishvakarma SCR 2022. Crop Productivity and Soil Properties under Agroforestry System in Kosi Watershed of Kumaun Himalaya. *Indian Journal of Ecology* **49**(1): 21−30.

Khamzina A, Lamers JPA, Martius C, Worbes M and Vlek PLG 2006. Potential of nine multipurpose tree species to reduce saline ground water tables in the lower Amu Darya River region of Uzbekistan. *Agroforestry Systems* **66**(2): 129-141.

Khanzada AN, Morris JD, Ansari R, Slavich PG and Collopy JJ 1998. Groundwater uptake and sustainability of Acacia and Prosopis plantations in southern Pakistan. *Agricultural Water Management* **36**(2): 121-139.

Kindt R and Lengkeek A G 1999. Tree diversity on farm – use it or lose it. In: *Proceedings of the National Workshop on Agricultural Biodiversity Conservation*, Nairobi: ITDG, pp. 75-85.

Kumar A, Shabnam S and Malik MS 2021. *Doubling farmers' income through agroforestry*. Scientific Publishers.

Kumar BM and Nair PKR. 2006. *Tropical Homegardens: A Time-Tested Example of Sustainable Agroforestry*. Springer, Dordrecht, Netherlands.

Kumar M, Thakur NS, Bardhan Kirti and Bhusara JB 2017. Effect of teak (*Tectona grandis* L)-*Ocimum* spp-based silvi-medicinal systems on growth and physiological parameters of *Ocimum* spp. *International Journal of Farm Sciences* **7**(1): 8-14.

Kumar Mukesh, Thakur NS and Hegde HT 2016. Fresh herb, essential oil yield and net returns from *Ocimum* spp. grown under teak (*Tectona grandis* L.f.) based silvi-medicinal systems in south Gujarat, India. *Indian Journal of Ecology* **43**(1): 306-311.

Kumar R, Bhardwaj AK, Rao BK, Vishavkarma AK, Bhatnagar PR, Patra S, Kakade V, Dinesh D, Singh G, Pande VC, Dobhal S & Sharma NK 2020. Development of degraded ravine lands of Western India via Sapota (*Achras zapota*) plantation with terracing vs. trenching−on−slope-based conservation measures. *Land Degradation & Development* **32**(1): 101-111.

Kumar R, Kumar R, Karmakar S, Kumar A, Singh AK, Kumar A and Singh J 2023. Impact of amide fertilizer on carbon sequestration under the agroforestry system in the eastern plateau region of India. *Sustainability* **15:** 9775.

Kumar S, Bijalwan A, Singh B, Yewale AG, Rawat D, Rana K and Riyal MK 2020. Diversity parameters of *Quercus leucotrichophora* based agroforestry systems and pure forest in Garhwal Himalaya. *Indian Journal of Agroforestry* **22**(2): 62-70.

Kumar S, Kumar S, Khanduri VP, Singh B, Joshi R, Riyal MK, Rawat D and Kumar KS 2025. Tree diversity, carbon sequestration and production potential of Oryza sativa L. in traditional agroforestry systems of Garhwal Himalaya, India. *Carbon Research* **4**(1): 6.

Kunhamu TK, Kumar BM and Jamaludheen V 2012. Utility of multipurpose trees as black pepper (*Piper nigrum* L.) standards in the humid tropics of Kerala. *Indian Journal of Agroforestry* **14**(1): 17-22.

Kwak JH, Lim SS, Baah-Acheamfour M, Choi WJ, Fatemi F, Carlyle CN, Bork EW and Chang SX. 2019. Introducing trees to agricultural lands increases greenhouse gas emission during spring thaw in Canadian agroforestry systems. *Science of the Total Environment* **652**: 800-809.

Lee KH and Jose S 2003. Soil respiration and microbial biomass in a pecan-cotton alley cropping system in southern USA. *Agroforestry Systems* **58**(1): 45-54.

Lenka NK, Dass A, Sudhishri S and Patnaik US 2012. Soil carbon sequestration and erosion control potential of hedgerows and grass filter strips in sloping agricultural lands of eastern India. *Agriculture, Ecosystems and Environment* **158**: 31-40.

Lundgren B and Raintree JB 1982. Sustained agroforestry. In: Brady N C (ed), *Advances in Agronomy*, vol. 34, pp. 37-75.

Makee LA 2016. On-farm tree planting and management guidelines for medium to high potential areas of Kenya. *Journal of Forest and Environmental Science* **32**(4): 392-399.

Manna MC, Ghosh PK and Acharya CL 2018. Sustainable crop production through management of soil organic carbon in semiarid and tropical India. *Journal of Sustainable Agriculture* **21**(3): 85-114.

Marsden C, Martin-Chave A, Cortet J, Hedde M and Capowiez Y 2020. How agroforestry systems influence soil fauna and their functions: A review. *Plant and Soil* **453**: 29-44.

Mayo M 2004. Exclusion, inclusion and empowerment: Community empowerment? Reflecting on the lessons of strategies to promote empowerment. In: *The Politics of Inclusion and Empowerment: Gender, Class and Citizenship*. pp. 139-158.

McNeely JA 2004. Nature vs. nurture: Managing relationships between forests, agroforestry and wild biodiversity. *Agroforestry Systems* **61**(1): 155-165.

Morgan JA, Follett RF, Allen LH, Del Grosso S, Derner JD, Dijkstra F, Franzluebbers A, Fry R, Paustian K and Schoeneberger MM 2010. Carbon sequestration in agricultural lands of the United States. *Journal of Soil and Water Conservation* **65**(1): 6A-13A.

Mughal AH and Makaya AS 2000. Suitable agroforestry models for the degraded and wastelands of Srinagar district of Kashmir. In: *Environment Biodiversity and Conservation*. Ed. Khan MA. APH Publishing Corporation, New Delhi: 493-500.

Nair PKR and Nair VD 2003. Carbon storage in North American agroforestry systems. In: Kimble JM, Heath LS, Birdsey RA and Lal R (eds), *The potential of U.S. Forest soils to sequester carbon and mitigate the greenhouse effect*. pp. 333-346.

Nair PKR 1993. *An Introduction to Agroforestry*. Kluwer Academic Publishers, Dordrecht, Netherlands.

Nair PKR 2008. Agroecosystem management in the 21st century: It is time for a paradigm shift. *Journal of Tropical Agriculture* **46**(1&2): 1-12.

Nair PR 1985. Classification of agroforestry systems. *Agroforestry Systems* **3**: 97-128

Newaj R, Dar SA, Yadav RS, Shanker AK and Dhyani SK 2008. Management effect on growth, biomass, carbon, and nitrogen accumulation in *Albizia procera* at 4-years age in agroforestry system. *Journal of Tropical Forestry* **23**(1): 73-80.

Newaj R, Dhyani SK, Alam B, Prasad R, Rizvi RH, Handa AK & Singh R 2012. Role of agroforestry for mitigating climate change – some research initiatives. Technical Bulletin No. 5, National Research Centre for Agroforestry (NRCAF), Jhansi, India; 45 pp

Oduro KA, Arts B, Kyereh B and Mohren G 2018. Farmers' motivations to plant and manage on-farm trees in Ghana. *Small-Scale Forestry* **17**(3): 393-410.

Pagare RL, Pawar K and Nirgude V 2014. Evapotranspiration and transpiration rate of some tropical tree species. *International Journal of Scientific Research in Biological Sciences* **1**(1): 1-2.

Pancholi R, Yadav R, Gupta H, Vasure N, Choudhary S, Singh MN and Rastogi M 2023. The role of agroforestry systems in enhancing climate resilience and sustainability: A review. *International Journal of Environment and Climate Change* **13**(11): 4342-4353.

Panwar P, Mahalingappa DG, Kaushal R, Bhardwaj DR, Chakravarty S, Shukla G, Thakur NS, Chavan SB, Pal S, Nayak BG et al. 2022. Biomass production and carbon sequestration potential of different agroforestry systems in India: A Critical Review. *Forests* **13**: 1274.

Prajapati DR, Thakur NS, Gunaga RP, Patel VR, Mahatma Lalit and Patel DP 2022a. *Melia dubia* tree spacing influence growth, yield and proximate principles of *Sorghum bicolor* x *Sorghum bicolor* var. *Sudanese* and soil microbial status. *Range Management and Agroforestry* **43**(2): 283-291.

Prajapati DR, Thakur NS, Patel VR, Gunaga RP, Mahatma Lalit and Patel DP 2022b. Influence of spatial configurations *Melia dubia* on quantitative and qualitative performance of hybrid napier (*Pennisetum purpureum x P. americanum*) and soil biota status. *Indian Journal of Ecology* **49**(1): 9-20.

Prakash O, Dubey RK, Dubey SK and Deshwal JS 2011. Evaluation of Ber (*Zizyphus mauritiana* Lamk.) based Agri-horti systems under various tree root management practices on reclaimed Yamuna ravines. *Indian Journal of Soil Conservation* **39**(1): 59-62.

Prasad R, Yadav RP and Panwar P 2012. Aonla based agroforestry systems for soil and water conservation in Shivaliks. In: *Agroforestry System for Resource Conservation and Livelihood Security in Lower Himalayas*. Eds. Panwar P, Tiwari AK and Dhadwal KS. New India Publishing Agency, New Delhi: 171-178.

Prasath CNH, Balasubramanian A, Radhakrishnan S, Sudarshan A and Jaisankar I 2014. Eco-physiological behaviour of 2-year grown afforested tree in Tamil Nadu, South India. *Journal of Andaman Science Association* **19**(2): 181-184.

Raj A and Chandrawanshi S 2016. Role of agroforestry in poverty alleviation and livelihood support in Chhattisgarh. *South Indian Journal of Biological Sciences* **2**(3): 339-343.

Ramajayam D, Mishra PK, Nalatwadmath SK, Mondal B, Adhikari RN and Murthy BKN 2007. Evaluation of different grass species for growth performance and soil conservation in Vertisols of Karnataka. *Indian Journal of Soil Conservation* **35**(1): 54-57.

Rao KPC, Verchot LV and Laarman J 2007. Adaptation to climate change through sustainable management and development of agroforestry systems. *SAT e Journal* **4**(1): 1-30.

Rao MR, Palada MC and Becker BN 2004. Medicinal and aromatic plants in agroforestry systems. *Agroforestry Systems* **61**(1): 107-122.

Rawat V, Lal SB, Khare N and Umrao R 2016. Socio-economic feasibility of some of the villages of Chamoli district of Garhwal Himalayas. *International Journal of Forest Crop Improvement* **7**(1): 61-66.

Riyadh ZA, Rahman MA, Saha SR, Ahamed T and Current D 2021. Adaptation of agroforestry as a climate-smart agriculture technology in Bangladesh. *International Journal of Agricultural Research, Innovation and Technology* **11**(1): 49-59.

Roghan HB, Murugesh M, Sekar I, Suganya K, Hemaprabha K, Kiruba M, Tilak M, Ramesh KR, Vaiyapuri K, Sivakumar B and Kumar P 2024. The current role and importance of agroforestry: A review article. *Applied Ecology and Environmental Research* **22**(5): 3907-3918.

Saha SR, Chaudhary RS and Somasundaram J 2012. Soil health management under hill agro ecosystem of North East India. *Applied and Environmental Soil Science* 2012: Article ID 696174.

Sanwal CS, Dhakate PM, Joshi KK, Kumar R and Dobhal S 2018. Innovative agroforestry interventions for alternative economically viable livelihood development to support climate resilient mountain agriculture. *Sustainable Forestry* **1**(3): Article 965.

Sepulveda RB and Carrillo AA 2015. Soil erosion and erosion thresholds in an agroforestry system of coffee (*Coffea arabica*) and mixed shade trees (*Inga* spp. and *Musa* spp.) in Northern Nicaragua. *Agriculture, Ecosystems & Environment* **210**: 25-35.

Sharda VN and Venkateswarlu B 2007. Crop diversification and alternate land use systems in watershed management. In: *Proceedings of the Comprehensive Assessment of Watershed Programs in India*, ICRISAT, Andhra Pradesh, July 23-27: 332.

Sharma H, Thakur CL, Bhardwaj DR and Prabhakar M. 2017. Growth and yield performance of maize (Zea mays) and tomato (*Solanum lycopersicum*) under *Grewia optiva* Drummond based agroforestry system. *Indian Journal of Ecology* **44**(Special Issue 6): 771-776.

Sharma KL, Ramachandra Raju K, Das SK, Prasadrao BRC, Kulkarni BS, Srinivas, Kusuma GKJ, Madhavi M, and Gajbhiye PN 2019. Soil fertility and quality assessment under tree-, crop- and pasture-based land-use systems in a rainfed environment. *Communications in Soil Science and Plant Analysis* **40**(9-10): 1321-1339.

Sharrow SH and Ismail S 2004. Carbon and nitrogen storage in agroforests, tree plantations, and pastures in western Oregon, USA. *Agroforestry Systems* **60**(2): 123-130.

Simons AJ and Leakey RRB 2004. Tree domestication in tropical agroforestry. *Agroforestry Systems* **61**(1): 167-181.

Singh AK, Singh BK, Kumar NM, Karada MS, Agnihotri D and Singh R 2023. Agroforestry as a mechanism for reforestation: Scenarios within REDD+. *Biological Forum – An International Journal* **15**(7): 370-377.

Singh B, Gill RIS and Gill PS 2010. Soil fertility under various tree species and poplar−based agroforestry system. *Journal of Research, Punjab Agricultural University* **47**(3-4): 160-164.

Singh P and Pandey DN. 2011. Agroforestry systems in India: livelihood security and ecosystem services. *Indian Forester* **137**(11): 1174-1182.

Singh V, Raj A, Jhariya MK and Thakur S 2022. Economic evaluation of agroforestry and non-agroforestry systems in Eastern Uttar Pradesh, India. *Vegetos: An International Journal of Plant Research and Biotechnology* **35**(3): 810-815.

Sirohi C and Bnagrawa KS 2017. Effect of different spacings of poplar-based agroforestry system on soil chemical properties and nutrient status in Haryana, India. *Current Science* **113**(7): 1403-1407.

Solanki RB and Arora S 2015. Leaf litter dynamics in agroforestry system affecting microbial activity in saline soils. *Journal of Soil and Water Conservation* **14** (4), 333-339.

Suparwata DO, Indranti MA, Djibran MM and Mokoginta M 2021. Dulamayo Barat Village community empowerment in agroforestry system development. *Journal of Universal Community Empowerment Provision* **1**(1): 1-12.

Suvera AH, Thakur NS and Jha SK. 2015. Herbage and essential oil yield of *Ocimum* spp. intercropped under *Pongamia pinnata* based silvi-medicinal systems in Gujarat, India. *The Bioscan* **10**(1): 81-85.

Suvera AH and Thakur NS 2016. Financial flows from herbage and essential oil of *Ocimum* spp. grown under Karanja [(*Millettia Pinnata* (L.) Panigrahi)] based silvi-medicinal systems in Gujarat. *Indian Journal of Arecanut, Spices and Medicinal Plants* **18**(3): 13-20.

Thakur NS and Verma KS 2012. Financial flows from sacred basil (*Ocimum sanctum*) based agroforestry land use systems in mid hills of Western Himalayas. *Indian Forester* **138**(7): 638-645.

Thakur NS, Attar SK and Chauhan RS 2017b. Horti-medicinal agroforestry systems: A potential land use for commercial cultivation of medicinal and aromatic plants. In: Gupta SK, Panwar P and Kaushal R (Eds), *Agroforestry for increased production and livelihood security in India*. New India Publishing Agency New Delhi, India. pp. 163-184.

Thakur NS, Attar SK, Hegde HT and Bhusara JB 2017a. Diversity and importance of shrubs in traditional agroforestry systems in India. In: Gupta S K, Panwar P and Kaushal R (Eds), *Agroforestry for increased production and livelihood security in India*. New India Publishing Agency New Delhi, India. pp. 379-400.

Thakur NS, Gupta NK and Gupta B 2004. Phytosociological analysis of woody and non-woody components under some agroforestry systems in Western Himalaya: A case study. *Indian Journal of Agroforestry* **6**(1): 65-71.

Thakur NS, Gupta NK and Gupta B 2005. An appraisal of biological diversity in agroforestry systems in North-Western Himalaya. *Indian Journal of Ecology* **32**(1):7-12.

Thakur NS, Gupta NK and Gupta B 2011. Biomass, carbon stocks and CO_2 removal by shrubs under different agroforestry systems in Western Himalaya. *Indian Journal of Ecology* **38**(1): 14-17.

Thakur NS, Verma KS and Attar SK 2015. Fodder production from tree-legume-grass based agroforestry systems in sub-tropical hills of Western Himalayas, India. *Journal of Tree Sciences* **34**(1): 49-55.

Tiwari KR, Bajracharya RM, Raut N and Sitaula BK 2017. Agroforestry system: An opportunity for carbon sequestration and climate change adaptation in the mid–hills of Nepal. *Octa Journal of Environmental Research* **5**(1): 22-31.

Udawatta RP, Rankoth LM and Jose S 2019. Agroforestry and biodiversity. *Sustainability* **11**(10): 2879.

Venkatraman K and Ashwath N 2016. Transpiration in 15 tree species grown on a phytocapped landfill site. *Hydrology: Current Research* **7:** 236.

Verma KS and Thakur N. 2010. Economic analysis of ashwagandha (*Withania somnifera* L.) based agroforestry land use systems in mid hills Western Himalayas. *Indian Journal of Agroforestry* **12**(1): 62-70.

Verma, KS and Thakur NS 2011. Economic appraisal of kewach (*Mucuna pruriens*) based agroforestry land-use systems in mid hills of Western Himalayas. *Journal of Non-Timber Forest Products* **18**(1): 47-54.

Verma, KS, Thakur NS and Rana RC 2010. Effect of tree crop combinations and nitrogen levels on herbage yield of sacred basil (*Ocimum sanctum* L.) grown in agri-horti-silvi-pasture system in mid hill Himalayas. *Indian Journal of Agroforestry* **12**(1): 71-76.

Wilson M and Lovell ST 2016. Agroforestry-The next step in sustainable and resilient agriculture. *Sustainability* **8**(6): 574.

Yadav M, Umrao R and Rout S 2019. Effects of organic, inorganic, and bio-fertilizers on the growth of maize under subabul (*Leucaena leucocephala*) based agroforestry system. *Journal of Plant Development Sciences* **11** (4): 189-199.

Young A 1989. *Agroforestry for Soil Conservation*. International Centre for Research in Agroforestry (ICRAF), Nairobi, Kenya.

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