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Economics of *Senegalia catechu* based Agroforestry Systems of Samba and Kathua Districts in Jammu and Kashmir

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Abstract: The present study examined the economics of agroforestry systems involving *Senegalia catechu* (*khair*) and compares its performance with conventional cropping practices in the rainfed areas of Samba and Kathua districts of Jammu and Kashmir (J&K), India. A total of 100 *khair*-growing farmers were randomly selected from lists provided by the forest department, and data on production, management, and marketing were collected through personal interviews using a pre-tested questionnaire. For comparison, 30 farmers practicing conventional farming without trees were also surveyed. The analysis employed standard cost concepts to estimate costs and returns, and the Cobb–Douglas production function to assess resource-use efficiency. Results indicated that the predominant cropping pattern consisted of maize, paddy, and blackgram during the kharif season, and wheat, mustard, and *toria* (*Brassica campestris* var. toria) during the *rabi* season. The average cost of cultivation was 52,979.25 for maize, ₹58,795.21 for paddy, ₹46,367.06 for wheat, ₹41,232.21 for blackgram, and ₹44,787.77 for mustard, with corresponding benefit–cost (B:C) ratios of 1:1.32, 1:1.90, 1:1.07, 1:1.97, 1:2.64, and 1:2.13, respectively. Comparative analysis revealed that although yields were marginally higher under sole cropping, agroforestry systems generated substantially greater net returns, with an overall B:C ratio of 1:6.14 compared to 1:1.88 in non-agroforestry systems. The Cobb–Douglas regression further showed that the cost of *S. catechu* trees and the quantity of DAP (Diammonium Phosphate) fertilizer were highly significant determinants of gross profit, with the model explaining 78% of the variation in returns . These findings demonstrate that *S. catechu*-based agroforestry is more profitable and sustainable than conventional cropping alone, providing both short-term agricultural benefits and long-term income from trees in rainfed regions of J&K.

Keywords: Economics, Resource use efficiency, *Senegalia catechu*, *Khair*, Agroforestry

Agroforestry refers to a diverse set of land-use systems and technologies in which woody perennials such as trees, shrubs, palms, and bamboos are intentionally integrated with agricultural crops and/or livestock, either spatially or temporally (FAO 2015). It is increasingly recognized for its multiple ecological, economic, and livelihood benefits. Beyond providing timber, fuelwood, medicines, tannins, dyes, and fodder, agroforestry contributes to improved soil fertility, reduced erosion, and enhanced long-term sustainability of farming systems. Commonly adopted tree species in agroforestry systems include *Populus* (poplar), *Senegalia*, *Pinus* (pine), *Eucalyptus*, *Santalum* (sandalwood), and *Terminalia* species (Luna et al., 2009b, 2011).

Among these, *Senegalia catechu* (L.f.) P.J.H. Hurter & Mabb., previously known as *Acacia catechu* Willd. (*khair*), holds a special place due to its multiple uses. It is a deciduous tree that yields catechu, tannins, dye, firewood, and nectar for bees (Orwa et al., 2009). The heartwood, bark, and extract are extensively used in traditional medicine due to the presence of natural compounds such as Catechin and epicatechin (Peng et al., 2015), while the extract also serves in dyeing, leather tanning, preservation of fishing nets, and viscosity regulation in oil drilling (Kumari et al., 2022). Studies have highlighted its pharmacological (anti-ulcer) properties (Khare et al., 2018), antioxidant (Verma and Pandey 2014), nutritional, anti-fungal (Ahmed 2020), anti-microbial and UV-protection (Samant et al., 2020), and anti-diabetic (Pandey et al., 2020). Its medicinal relevance also includes applications in dermatology, sore throat, asthma, and constipation (Rout et al., 2021). From an agronomic and ecological perspective, Kabir et al.,. (2016) observed that *S. catechu* performs well in rainfed and unirrigated areas, especially in small landholdings where density tends to be higher. Research on growth regulators (Thakur et al., 2018) has further demonstrated its potential for vegetative propagation, while studies on related Acacia species highlight sustainable plantation management practices (Huong et al., 2020) and financial viability under taungya systems (Nigussie et al., 2020). Cochard et al. (2021) also documented farmer-driven expansion of Acacia plantations in Vietnam, emphasizing its economic role in land-use change and rural livelihoods. Also, the carbon storage potential of *S. catechu* can be utilized for harnessing the intangible benefits (Mahajan et al., 2023)

In India, the significance of *S. catechu* has also been shaped by policy interventions. The Indian Forest Act, 1927 (Section 51A) empowered states to regulate forest produce, including *S. catechu*. In Jammu and Kashmir, this authority led to the formulation of The Jammu and Kashmir Non-Forest Land Khair Trees (*Acacia catechu*) Management Plan Rules, 2016 (SRO 111 of 2016). These rules permit private cultivation, regulated felling, conversion, and transportation of *khair*, as well as the establishment of *katha* manufacturing units, subject to inspection and licensing. This policy shift has opened new avenues for farmers to cultivate *S. catechu* on private lands. Farmers in the lower Himalayan region, in particular, continue to retain khair trees within traditional agroforestry systems, which serve as a sustainable and dependable source of income (Thakur et al., 2005, Thakur et al., 2008, Luna et al., 2009a).

Despite its diverse applications and supportive policy framework, limited systematic research has been conducted on the economic evaluation of Senegalia catechu-based agroforestry compared to traditional cropping systems in Jammu and Kashmir. Consequently, the present study was undertaken to assess the economics and profitability of *S. catechu* in the rainfed areas of Samba and Kathua districts, in comparison with alternative cropping systems without trees. Additionally, the study examines resource-use efficiency through the Cobb–Douglas production function, providing insights into the economic viability of *S. catechu*-based agroforestry systems.

MATERIAL AND METHODS

The present study was conducted in the Union Territory of Jammu and Kashmir to assess the economics of agroforestry systems involving *S. catechu*, compared to alternative cropping systems without trees. Kathua and Samba districts were purposively selected for data collection, as they represent rainfed conditions where *S. catechu*-based agroforestry is commonly practiced. A comprehensive questionnaire was designed to capture information on production, management, and marketing aspects of *S. catechu*. The schedule was developed in line with the study objectives and pre-tested with a small group of farmers to ensure clarity, reliability, and relevance. Necessary modifications were incorporated based on the feedback from pre-testing, making the instrument practical and effective for field conditions.

Primary data for the study were collected through personal interviews with the respondent farmers. Face-to-face interactions ensured accuracy of responses and enabled the collection of detailed information on costs incurred, outputs obtained, and marketing channels utilized. To obtain a representative sample, a list of *S. catechu*-growing farmers was obtained from the Forest Department of Jammu and Kashmir, from which 100 farmers were randomly selected for the survey. These respondents provided comprehensive data on plantation management, input use, harvesting, and income generation from S. catechu. For comparative analysis, an additional group of 30 farmers from neighboring areas, not practicing *S. catechu* cultivation, was also surveyed. These farmers followed conventional cropping systems without trees, and information was collected on their crop inputs, yields, costs, and incomes. This comparative group served as a benchmark to analyze the relative profitability of S. catechu-based agroforestry versus traditional crop-based systems.

The cropping patterns followed by farmers in the study area were documented to understand seasonal cultivation practices. During the *kharif* season, maize, paddy, and blackgram were commonly grown, while wheat, mustard, and *toria* predominated in the *rabi* season. This information provided insights into how the integration of *Senegalia catechu* influenced crop selection and farming practices across seasons. To assess the cost of cultivation and returns, the cost concepts recommended by the Commission for Agricultural Costs and Prices (CACP) were applied. These included: Cost A_1 (paid-out costs such as hired labour, bullock and machinery charges, seeds, fertilizers, irrigation, and repairs); Cost A_2 (Cost A_1 plus rent paid for leased-in land); Cost B_1 (Cost A_2 plus interest on fixed capital); Cost B_2 (Cost B_1 plus rental value of owned land); Cost C_1 (Cost B_1 plus imputed value of family labour); Cost C_2 (Cost B_2 plus imputed value of family labour); and Cost C_3 (Cost C_2 plus 10% managerial cost). Incomes were evaluated in terms of Gross Income (total value of output) and Net Income (Gross Income minus Cost C_3).

The profit efficiency was estimated using “Cobb-Douglas” or “Translog” functional specifications as per the suitability of data. The Cobb-Douglas functional form employed in the presented study is presented as equation 'I'.

$$Y_i = f(X_i; \beta)e^{V_i - U_i} \text{ ---------------- I}$$

where

Y_i = Profit of the i[th] farmer

X_i = (1 × K) vector of input quantities used by i[th] farmer

β = (K × 1) vector of parameters to be estimated

V_i = random variations due to factors outside farmer's control, it is an independently and identically distributed random error component (statistical noise), and usually assumed to follow the standard normal distribution with zero mean and constant variance σ_v^2.

U_i = error due to inefficiency i.e. profit inefficiency (within the control of farmer)

The explicit forms of Cobb Douglas model is expressed in equation as:

$$\ln Y = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + (V_i - U_i) \text{-------- II}$$

The profit inefficiency effects model using the various socio-economic variables is given as equation III.

$$U_i = \delta_0 + \delta_1 \ln(\text{Cost of } Senegaliacatechu \text{ trees}) + \delta_2 \ln(\text{urea applied}) + \delta_3 \ln(\text{seed used}) + \delta_4 \ln(\text{Labour}) + \delta_5 \ln(\text{MOP}) + \delta_6 \ln(\text{DAP}) + \delta_7 \ln(\text{Age}) + \delta_8 \ln(\text{Farming experience}) \quad \text{---------------- III}$$

Profitability analysis: Profitability analysis of agroforestry system was assessed using the following concepts:

Net Present Value

Where

$$\sum_{t=1}^{n} \frac{\mathbf{R_t}}{(\mathbf{1} + i)^{\mathbf{t}}}$$

R_t= Net cash inflow-outflows during a single period t

i = Discount rate or return that could be earned in alternative investments

t = Number of time periods

Internal rate of return

$$0=NPV= \sum_{t=1}^{n} \frac{C_t}{(1+IRR)^t} - C_0$$

Where

C_t = Net cash inflow during the period t

C_0 = Total initial investment costs

IRR = The internal rate of return

t = Number of time periods

Cropping system resource use efficiency: The marginal physical product (MPP) of inputs was obtained by taking derivatives of production function. The estimated production function underlying crop production was used to assess the efficiency of factor proportions.

The Marginal value of product (MVP) was computed by multiplying the coefficients of the given resource with the ratio of the geometric means of the output to the geometric mean of given resource.

$$\text{MVP } (X_i) = b_i \frac{\text{Geometric Mean } \overline{Y}}{\text{Geometric Mean } \overline{X}_i}$$

Where

MVP = Marginal Value of Product

bi = Corresponding elasticity of

Xi (G.M.) = G.M. of i^{th} resource

Y (G.M.) = Computed value of Y at G.M. levels of resources

The MVP helps in assessing the efficiency of resource use in production economics as given below:

- MVP > 1: Indicates underutilization of resources (more of the resource can be profitably used)
- MVP < 1: Indicates overutilization of resources (excess use is reducing efficiency)
- MVP = 1: Indicates optimal utilization of resources (resources are being used most efficiently)

RESULTS AND DISCUSSION

Concentration of *Senegalia catechu:* The spatial distribution of *S. catechu* plantations in the Jammu region exhibited considerable variation across villages. The blue-shaded areas on Figure 1 represent zones of low concentration (0.1-7 ha), indicating scattered plantations, often maintained as boundary trees or in small patches within farmlands. Yellow-shaded areas (7.1-25 ha) denote medium concentration zones, where farmers have adopted *S. catechu* plantations on a relatively larger scale, integrating them with seasonal crops under an agroforestry model. Red-shaded zones, representing high concentration areas (above 25 ha), highlight clusters where *S. catechu* cultivation has become a dominant land-use practice and serves as a significant source of income. Green boundaries depict village limits, helping to demarcate the spread of *S. catechu* across the study area.

This distribution pattern indicated that adoption of *S. catechu*-based agroforestry is uneven, concentrated in pockets where soil, rainfall, and farmer preferences are favorable. High-concentration zones, in particular, suggest the emergence of localized production hubs, which could facilitate collective marketing, establishment of katha-processing units, and enhanced bargaining power for farmers. Conversely, the prevalence of low-concentration areas reflects that many farmers are still experimenting with *S. catechu* or remain reliant on conventional crops. These findings underscore the importance of policy support, extension services, and market linkages to promote wider adoption of *S. catechu* plantations in the region.

Cropping pattern: The farmers predominantly cultivate a mix of cereals, pulses, and oilseeds across the kharif and rabi seasons (Table 1). During the *kharif* season, maize emerged as the major crop, grown by 79 farmers over 42.20 ha, reflecting its importance as both a staple food and fodder

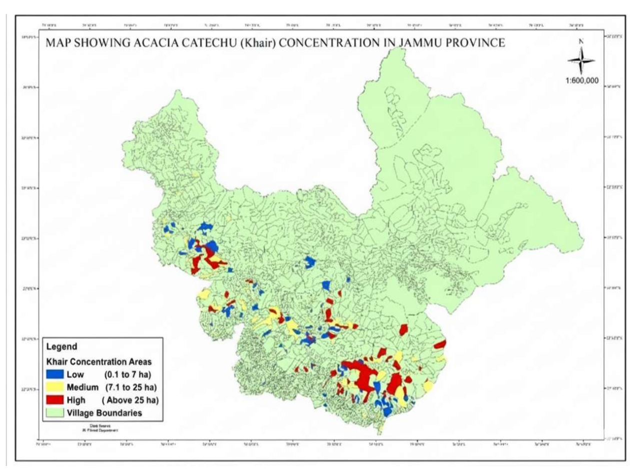

Fig. 1. Concentration of *S. catechu* in Jammu region

under rainfed conditions. Paddy was the second most prominent crop, cultivated by 63 farmers on 29.20 ha, primarily in areas with relatively better water availability. In contrast, blackgram was grown by only 4 farmers on 2.00 ha, highlighting its marginal role in the regional cropping system. In the *rabi* season, wheat dominated, with 89 farmers cultivating it on 57.60 ha, underscoring its significance as the primary winter staple. Oilseeds also featured in the rotation, with mustard grown by 25 farmers on 9.35 ha and *toria* by 11 farmers on 2.30 ha, indicating that farmers diversify their cropping system with short-duration oilseed crops for both subsistence and market purposes.

Overall, cereal crops, particularly maize and wheat, form the backbone of the farming system in the sampled districts, while pulses and oilseeds occupy relatively smaller areas. This pattern reflects farmers' preference for food security through cereals, supplemented by cash income from mustard and, to a lesser extent, blackgram and toria. The relatively low area under pulses and oilseeds also points to potential opportunities for crop diversification and nutritional security interventions. Furthermore, when integrated with *Senegalia catechu* plantations, this cropping pattern provides a balanced mix of food, cash, and tree-based products, enhancing both farm income and overall resilience.

Economics of *kharif* crops: The cost structure, returns, and profitability vary across crops, with labour emerging as the most significant cost component in all cases (Table 2). For maize, the cost of cultivation was estimated at ₹52,979.25/ha, with human labour, including both hired and family labour accounting for the largest share (₹11,672/ha), followed by seed expenses (₹4,171.47/ha). This underscores that maize production in the study area is highly labor-intensive and requires a relatively high seed rate. The gross return from maize was ₹70,081.53/ha, resulting in a net return of ₹17,102.28/ha and a benefit–cost (B:C) ratio of 1:1.32. Rana et al. (2018) also highlighted the labor-intensive nature of maize cultivation under rainfed conditions.

For paddy, the cost of cultivation was slightly higher at ₹58,795.21/ha. Labour remained the dominant input, with farmers spending ₹27,604.81/ha on human labour-nearly half of the total cost. Herbicide application was the second-largest expense, averaging ₹4,864.52/ha, reflecting the crop's high requirement for weed management. Gross returns were estimated at ₹112,125.31/ha, significantly augmented by by-product returns of ₹32,429.46/ha from straw. This resulted in a net return of ₹53,329.96/ha and a benefit–cost (B:C) ratio of 1:1.90, indicating that paddy cultivation under the agroforestry system is highly remunerative. These findings are consistent with Srinivasan (2012), where paddy is among the most labor-intensive crops, often requiring twice the labour input compared to other cereals.

In blackgram, the cost of cultivation was estimated at ₹41,232.21/ha. As with other crops, labour constituted the largest share of expenditure (₹14,700.00/ha), followed by herbicide costs (₹650.00/ha). The gross return was ₹81,585.00/ha, yielding a net return of ₹40,352.79/ha and a benefit–cost (B:C) ratio of 1:1.97-the highest among the *kharif* crops studied. The blackgram, despite being cultivated over a relatively smaller area, is a highly profitable crop under S. catechu-based agroforestry systems. Mohiuddin et al.

Table 1. Cropping pattern of *S. catechu* growing farmers in Jammu region

Season/Crops	Total area (ha)	No. of farmers
Kharif		
Maize	42.20	79
Paddy	29.20	63
Blackgram	2.00	04
Rabi		
Wheat	57.60	89
Mustard	9.35	25
Toria	2.30	11

Table 2. Economic return of *Kharif* crops under Agroforestry system involving *S. catechu* trees

Particulars	Maize	Paddy	Blackgram
Seed (₹)	4171.47	3183.06	405.00
Manure (₹)	2680.77	2012.90	450.00
Urea (₹)	3326.92	529.41	62.50
DAP (₹)	289.62	1017.20	0.00
MOP (₹)	596.92	264.59	160.00
Herbicide (₹)	381.54	4864.51	650.00
Hired Labour (₹)	3460.00	8467.74	4550.00
Family Labour (₹)	8212.00	19137.07	10150.00
Interest on working capital (₹)	521.75	711.87	219.71
Depreciation (₹)	11671.15	1915.32	7350.00
Rental Value (₹)	15000.00	15000.00	15000.00
Interest on fixed capital (₹)	2667.11	1691.53	2235.00
Total cost (₹)	52979.25	58795.21	41232.21
Yield of main product (quintal)	36.78	27.58	12.95
Price of main product ((₹/q)	1870	2889.62	6300.00
Returns from main product (₹)	68778.60	79695.80	81585.00
Returns from by-product (₹)	1302.93	32429.46	0.00
Gross return (₹/ha)	70081.53	112125.31	81585.00
Net return (₹/ha)	17102.28	53329.96	40352.79
Cost-benefit ratio	1:1.32	1:1.90	1:1.97

(2018) also reported that blackgram is labor-intensive but capable of generating substantial net returns, based on their study in the Sherpur and Jamalpur districts of Bangladesh. Comparative analysis indicates that paddy and blackgram outperformed maize in terms of profitability under *S. catechu*-based agroforestry systems. While maize continues to serve as an important subsistence crop in rainfed conditions, farmers in the study area achieved higher economic gains from paddy and blackgram, particularly when accounting for by-product returns in paddy and favorable market prices for blackgram. These results suggest that integrating *S. catechu* plantations with high-value or input-efficient crops can enhance overall farm income, improve labour utilization, and increase resource-use efficiency.

Economics of *Rabi* crops: The economic returns of *Rabi* crops under the *S. catechu*-based agroforestry system indicated that wheat cultivation incurred a cost of ₹46,367.06/ha, with labour as the dominant input (₹17,657.30/ha) followed by seed (₹4,940.53/ha), reflecting its highly labor-intensive nature (Table 3). The crop generated a gross return of ₹51,367.44/ha and a net return of ₹5,000.38/ha, resulting in a modest benefit–cost (B:C) ratio of 1:1.07. These findings are consistent with Kharel et al. (2021), who similarly reported wheat as a labor-intensive crop with relatively low profitability. Mustard exhibited stronger economic performance, with a cost of cultivation of ₹44,787.77/ha, dominated by labour expenditure (₹13,550.80/ha) followed by DAP fertilizer (₹2,267.38/ha). The gross return from mustard was ₹118,581.87/ha, yielding a net return of ₹73,794.10/ha and a B:C ratio of 1:2.64, indicating its high economic viability under the agroforestry system.

Sonvanee and Pathak (2016) also identified mustard as a profitable crop with favorable input–output ratios. Toria, despite having the highest cultivation cost (₹60,002.85/ha), demonstrated considerable profitability. Labour remained the largest cost component (₹19,478.20/ha), followed by DAP fertilizer (₹5,269.56/ha). The crop generated a gross return of ₹128,106.65/ha and a net return of ₹68,103.80/ha, resulting in a benefit-cost (B:C) ratio of 1:2.13. Thakuria et al., (2025) also reported B:C ratio of 2.07 for toria. Overall, the results indicate that while wheat continues to serve as a staple crop, oilseeds such as mustard and toria offer substantially higher returns under S. catechu-based agroforestry, making them more suitable for enhancing farm income and improving resource-use efficiency in the study area.

Economics of *S. catechu* agroforestry and non-agroforestry interventions: The crop yields were slightly higher under the non-agroforestry system-for example, maize (30.20 q/ha vs. 28.58 q/ha), paddy (28.64 q/ha vs. 27.58 q/ha), wheat (20.60 q/ha vs. 18.39 q/ha), and mustard (24.15 q/ha vs. 23.31 q/ha) (Table 4). This modest reduction in yield under agroforestry is expected due to tree–crop competition for light, moisture, and nutrients. However, when net returns and benefit–cost (B:C) ratios were compared, the agroforestry system clearly outperformed sole cropping. Although the net return from mustard was slightly lower under agroforestry (₹73,794.10/ha) compared to conventional cultivation (₹80,477.10/ha), the inclusion of *S. catechu* significantly enhanced overall farm income, contributing ₹48,63,485 and achieving a very high B:C ratio of 1:32. As a result, the average B:C ratio of farms with agroforestry reached 1:6.14, compared to only 1:1.88 in the conventional system. These findings establish agroforestry as a more profitable and sustainable land-use strategy, despite marginal reductions in annual crop yields. Shode and Amanuel (2016) also demonstrated that tree-based agroforestry systems provide substantially higher net benefits than monocropping, primarily due to the complementary role of trees in enhancing farm income and long-term productivity.

S. catechu is financially viable when harvested at 22 years of age, with a positive net present value (NPV) of ₹9,18,956.40 at an 8% discount rate, ₹5,41,450.97 at 10%,

Table 3. Economic returns of *Rabi* crops under *S. catechu* based agroforestry systems

Particulars	Wheat	Mustard	Toria
Seed (Rs.)	4940.53	1124.92	4317.39
Manure (Rs.)	247.35	545.45	86.95
Urea (Rs.)	709.43	599.67	1108.69
DAP (Rs.)	821.12	2267.38	5269.56
MOP(Rs.)	265.16	1874.33	2652.17
Herbicide (Rs.)	2624.71	761.49	560.86
Hired labour (Rs.)	5517.41	3219.25	6086.95
Family labour (Rs.)	12139.88	10331.55	13391.30
Interest on working capital	529.39	363.73	702.89
Depreciation (Rs.)	1883.70	6545.45	8478.26
Rental Value (Rs.)	15000.00	15000.00	15000.00
Interest on fixed capital	1688.37	2154.54	2347.82
Total cost	46367.06	44787.77	60002.85
Yield of main product	18.39	23.31	26.54
Price of main product/q	1975.00	4650.00	4650.00
Returns from main product	36320.25	108391.50	123411.00
Returns from by-product	15047.19	10190.37	4695.65
Gross return/ha	51367.44	118581.87	128106.65
Net return/ha	5000.38	73794.10	68103.80
Cost-benefit ratio	1:1.07	1:2.64	1:2.13

and ₹2,96,702.52 at 12% (Table 5). The internal rate of return (IRR) for this rotation age was estimated at 13%, exceeding the assumed discount rates and confirming profitability. However, extending the harvest age beyond 22 years reduced economic viability, as reflected by negative NPVs at higher discount rates and a sharp decline in IRR (8% at 32 years, 5% at 42 years, and 2% at 52 years). This attributable to increased opportunity costs and diminishing incremental returns over time, highlighting the importance of timely harvesting for maximizing profitability in *S. catechu*-based agroforestry systems. Pitigala and Gunatilake (2002) also reported that species such as mahogany, teak, jackfruit, and eucalyptus yielded positive NPVs at moderate discount rates, but values turned negative at higher rates, underscoring the significance of selecting an appropriate economic rotation for forestry species.

The estimates of the Cobb–Douglas regression model) provide insights into the factors influencing gross profit under the *S. catechu*-based agroforestry system in Samba and Kathua districts (Table 6). The coefficient of determination indicate that 78% of the variation in gross profit was explained by the selected explanatory variables, thus reflecting a good fit of the model. The cost of *S. catechu* (0.30*), quantity of seed (0.18**), labour (0.33**), and DAP (0.23*) had positive and statistically significant effects on gross profit. This implies that a 1% increase in these inputs would increase gross profit by 0.30, 0.18, 0.33, and 0.23%, respectively. These findings highlight the critical role of both tree and crop inputs, particularly labour and fertilizers, in enhancing profitability under agroforestry systems.

The urea (-0.05) exhibited a negative, though statistically non-significant, relationship with gross profit, suggesting that excessive or imbalanced application may not contribute positively to returns. Similarly, MOP (0.008), age of respondents (0.03), and farming experience (0.05) had positive but non-significant coefficients, indicating that while these factors tend to enhance gross profit, their impact was not strong in this study. Marginal Value Product (MVP) analysis further revealed that resources such as the cost of *S. catechu* (₹3.28), seed (₹299.59), labour (₹838.83), and DAP (₹31,924.70) were underutilized, suggesting potential for better allocation to improve returns. Phuge et al., (2020) also

Table 6. Estimates of Cobb Douglas regression model

Dependent variable: Gross profit (₹)

Variables	Regression coefficients	Standard error	MVP
Constant	2.849*	0.419	-
Cost of *S. catechu* (₹)	0.30*	0.09	3.28
Quantity of urea (q)	-0.05	0.93	-5999.81
Quantity of seed (₹)	0.18**	0.07	299.59
Quantity of labour (q)	0.33**	0.13	838.83
Quantity of MOP (q)	0.008	0.04	2847.02
Quantity of DAP (q)	0.23*	0.48	31924.70
Age of respondent (year)	0.03	0.17	168.79
Farming experience (year)	0.05	0.12	441.85

Coefficient of determination (R^2) = 0.78
*, **Significant at 1 % and 5% level of significance

Table 4. Comparative economics of agroforestry with non-agroforestry system

Crops	With agroforestry intervention			Without agroforestry intervention		
	Yield (q/ha)	Net return (₹/ha)	B.C ratio	Yield (q/ha)	Net return (₹/ha)	B.C ratio
Maize	28.58	17102.28	1:1.32	30.20	18443.13	1:1.34
Paddy	27.58	53329.96	1:1.90	28.64	55569.91	1:1.95
Wheat	18.39	5000.38	1:1.07	20.60	7005.16	1:1.14
Blackgram	12.95	40352.79	1:1.97	13.42	43572.50	1:1.99
Mustard	23.31	73794.10	1:2.64	24.15	80477.1	1:2.68
Toria	26.54	68103.80	1:2.13	27.10	76455.00	1:2.22
Senegalia catechu	1000	4863485	1:32	-	-	-
Total	-	5121168.31	1:6.14	-	281522.80	1:1.88

Table 5. Feasibility analysis of *S. catechu* under agroforestry systems

Particulars	Age of trees: 22 years	Age of trees: 32 years	Age of trees: 42 years	Age of trees: 52 years
NPV@8%	₹ 9,18,956.40	₹ 3,16,296.19	₹ -3,35,663.60	₹ -5,35,371.70
NPV@10%	₹ 5,41,450.97	₹ 1,02,637.05	₹ -3,53,899.57	₹ -4,57,493.20
NPV@12%	₹ 2,96,702.52	₹ -5,277.03	₹ -3,30,187.69	₹ -3,87,370.45
IRR	13%	8%	5%	2%

reported that human labour, fertilizer, and irrigation had significant positive effects on farm income. The study highlights that efficient management of S. catechu, labour, and fertilizer inputs plays a critical role in enhancing the profitability of agroforestry systems.

CONCLUSION

The highest concentration of commercially exploitable *Senegalia catechu* was located in Kathua district, followed by Samba district in the Jammu region of J&K. The farmers adopting *S. catechu*-based agroforestry systems achieved a substantially higher benefit–cost under sole cropping, highlighting agroforestry as a more profitable and sustainable land-use practice. The gross profit was positively influenced by the costs of *S. catechu* seed, labour, MOP, DAP, as well as farmer age and experience/These findings underscore the importance of balanced input use and efficient management for maximizing profitability under agroforestry. The optimum marketable age of *S. catechu* is 22 years, corresponding to an average tree diameter of 30 cm; beyond this age, the Net Present Value (NPV) becomes negative, rendering delayed harvesting economically unviable for farmers. The study concludes that *S. catechu*-based agroforestry not only enhances farm-level income and resource use efficiency but also provides long-term sustainability in rainfed areas of Jammu and Kashmir. It offers a viable model for integrating trees with crops to secure both economic and ecological benefits.

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