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Evaluation of Agroforestry Systems under Cauvery water basin of Tumkur District, Karnataka, India

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ABSTRACT

The study was conducted to evaluate the agroforestry systems under Cauvery water basin of Tumkur district Karnataka state, during the year 2018-19 with the major objective to identify and evaluate existing different agroforestry systems and to assess the tree diversity in Cauvery water basin of Tumkur district which comprising of five taluks viz., Tumkur, Gubbi, Turuvekere, Kunigal and Tiptur and three agro-climatic zones namely Central Dry Zone, Eastern Dry Zone and Southern Dry Zone with the average annual rainfall ranges from 600 to 900 mm with a coefficient of variance over 30-40% and mean elevation ranges from 678-860 m MSL. Bund and boundary planting, Horti-silviculture were the major traditional agroforestry systems practiced by the farmers. The productivity of crop with respect to grain and straw yields of finger millet under neem and teak based different agroforestry systems were documented lower compared to control. The cost-benefit ratio under agroforestry systems reported to be higher in association with other field crops, further Horti-silviculture system recorded higher cost benefit ratio compare to other agroforestry systems. Higher carbon sequestration potential was observed in agroforestry systems than the conventional agriculture. The number of trees was positively correlated with farm holding size and type of agroforestry systems followed by the farmers. Shannon's diversity index was higher with the large farmers. Nineteen tree species belonging to twelve plant families with 68.42 % of trees being indigenous. Tectona grandis was the most dominant tree species followed by Grevillea robusta, Azadirachta indica and Cocos nucifera. The farmers are following agroforestry systems based on their preferences such as economic benefit, multipurpose utility and cultural preference of the locality based.
Keywords: Agro-climatic zones; Cauvery water basin; Shannon's diversity index.

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INTRODUCTION

Agriculture is a major economic activity and primary source of livelihood for about 58 percent of India's population. At present thousands of hectares under forest land and agriculture land is degraded and loss of biodiversity occurred in the name of modern agriculture and development without any sustainable management. In addition to this, the concentration of carbon dioxide (CO_2) and other Green House Gases (GHG's) in the atmosphere has considerably increased over the last century and is set to rise further. The larger proportion of this is a result of the burning of fossil fuels and the conversion of tropical forests to agricultural land. To overcome this huge burden in the future over our existing ecosystem and population, it is more important to take some alternative steps to meet the demand of the population and to reduce the threat on ecosystem and biodiversity (IPCC 2001). Hence the concept of multiple uses of land with multipurpose tree species has become massively important in these days and in future for this resolution agroforestry is a major one which plays dynamic, ecologically based, natural resources management system [13] through the integration of trees on farms and in the agricultural landscape, diversifies and sustains production for an increased social, economic and environmental benefit for land users at all levels. Agroforestry plays a crucial role in the Indian economy by way of tangible and intangible benefits. In fact, agroforestry has a high potential for simultaneously satisfying three important objectives viz., protecting and stabilizing the ecosystems; producing a high level of output of economic goods; and increasing the source of income and basic materials to rural population [5] Agroforestry is mainly based on the on-farm and off -farm tree production in support of sustainable land-use and natural resource management. While the aboveground and belowground diversity provides more stability and flexibility for the system at the site level [15] [10]. Alternative land use systems are playing a major role in sustaining the resource base and increasing overall productivity in the rainfed areas that too in arid and semi-arid regions in particular. Agroforestry land use increases livelihood security and reduces susceptibility to climate and environmental change. There is plenty of evidence to show that the increase in overall biomass productivity, soil fertility improvement, soil moisture and soil conservation, nutrient cycling, microclimate improvement, reclamation of problematic soils and carbon sequestration potential of an agroforestry system is generally greater than that of an annual production system [6]. The change in the frequency of extreme events, leading to accelerated rates of degradation of soil and water resources, thereby reducing soil productive capacity and increasing sedimentation in water bodies and drainage systems. Finding low-cost methods to sequesting carbon is now emerging as a major issue in the context of global climate change. [25] Sequestering carbon through tree-based systems is now being considered as an attractive economic opportunity for carbon trading. In India, where a majority of the population is dependent on agriculture, tree-based systems provide a long-term strategy to increase the amount of carbon while still allowing growing food crops. Projections of ICRAF that the carbon market may exceed US$1 trillion by 2025 suggest that significant funds could potentially be available to finance sustainable rural development and adaptation to climate change [17] [11]. The prominent role of forestry and agroforestry systems in carbon sequestration has increased global interest to stabilize greenhouse gas emissions. It has been reported that 630 million hectares area would be available for agroforestry, which has the potential to sequester 586 Mt C per year by 2040 [27]. The science of agroforestry system focuses on four factors competition, complexity, sustainability, and profitability and there should be a balance among all these factors to get fruitful returns. Agroforestry is the only one best alternative to cope up with these situations and the indigenous and traditional knowledge of agroforestry practices is very essential to explore and document for its betterment [23]. It has been realized that agroforestry is the only alternative to meet the target of increasing forest cover to 33 per cent from the present level of less than 25 per cent. Thus a major role for agroforestry is also emerging in the domain of environmental services. [9] stated that a total of 53.32 Mha, representing about 17.57 per cent of the total reported geographical area of India, could potentially be under agroforestry in the near future, thus making agroforestry a major land use activity, after agriculture and forestry and Karnataka is the most suitable zone in Southern india for practicing of tree based farming systems especially in southern dry zone of Karnataka that too named as dry district i.e., Tumkur which falls in the eastern dry agro-climatic zone which is categorized by arid and semi-arid region comprises of five taluks and three agro-climatic zones namely Central Dry Zone, Eastern Dry Zone, and Southern Dry Zone. The average annual rainfall ranges from 600 to 900 mm with an average rainfall of 750 mm with a coefficient of variance over 30% - 40% and mean elevation ranges from 678-860 m MSL. The major type of soils occurring in the districts are red loamy soil, red sandy soil and mixed red and black soils. Under the background information collected on the geographical condition of the study area, it is, therefore, an approach to understand the importance of agroforestry systems in adaptability and sustainability concerning multidimensional functions in the ecological conditions which emphasis of the present study with the following objective like Identification, Evaluation of different agroforestry systems existing in Cauvery water basin of Tumkur district and to assess the tree diversity.

MATERIAL AND METHODS

The study was carried out in five taluks that comes under the Cauvery water basin of the Tumkur district of Karnataka state India situated in South-eastern part of the geographical region of the southern part of Karnataka. It spreads between 13.0228° to 13.3109° Northern Latitude and 76.9391° to 77.0205° Eastern longitude. The Cauvery water basin comprises of five taluks are Tumkur, Gubbi, Kunigal, Turuvekere, and Tiptur. The sampling technique was used to select the sample by considering taluk as a unit and in each taluk three hoblis were identified based on agro-ecological situations and for each agro-ecological situation three villages were identified and in each village three farmers were randomly selected among the agroforestry practicing farmers based on their land holding such as small (< 2 ha), medium (2 – 4 ha) and large farmer (> 4 ha). The total sample size was 135 farmers, comprising 27 farmers from each taluk and for which information was obtained from the respondents through a personnel interview method adopting structured question Watson es and visiting physically to their fields for identification of existing agroforestry systems, utilization pattern, perception on the adoption of agroforestry systems and the interest of the farmer's preference on the tree species for further integration to farmland, assessment of productivity and carbon sequestration potential of agroforestry system for bund, boundary, scattered planting, and horti-silviculture, biomass and grain yield of finger millet under agroforestry system and control area through interaction with the farmers were also calculated using below formule.

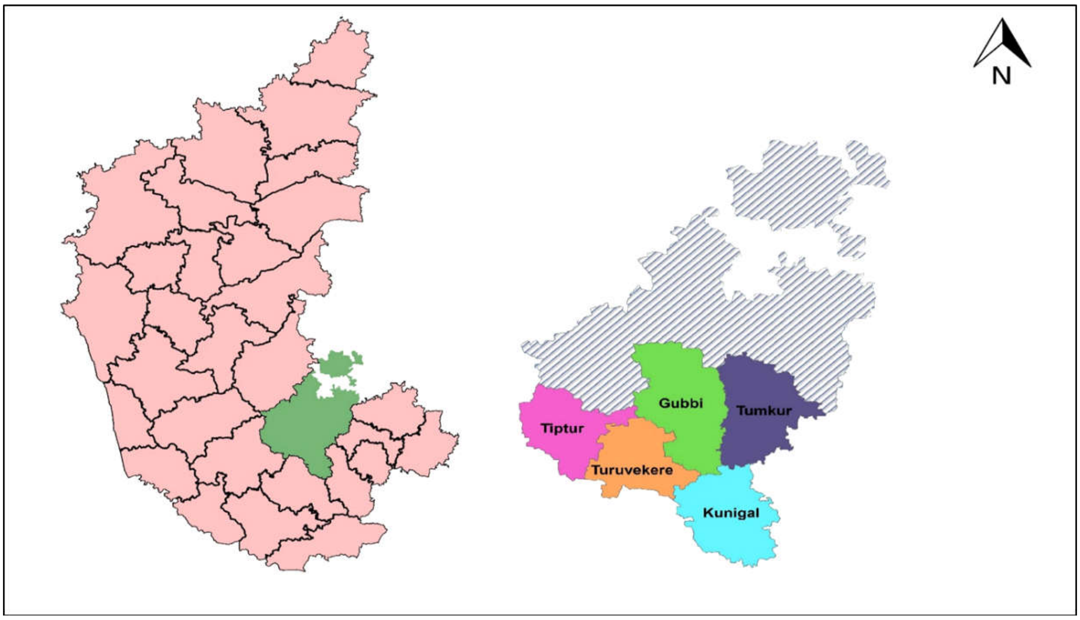
Biomass in terms of carbon (C kg ha^{-1}) = Yield or biomass X 0.45 (default value)

Tree productivity, Tree height [3] , Tree girth, Volume using a formula V = X h, Computation of above ground biomass [2] of tree in terms of carbon equivalent (C kg ha^{-1}) by multiplying the total dry biomass with default value *i.e.* 0.50 Carbon Estimation [18]. using Carbon Storage = Biomass x 0.45 (default value), Annual increment m^3 ha^{-1} is calculated by average volume of tree by average age of tree, Fruit yield if so in existing agroforestry, Economic analysis of agroforestry systems i.e., Cost of cultivation, Gross return, Net return Species richness, tree density [24] using the formulae, Shannon diversity index (H') [20] , Simpson index [21]. The data was analysed with descriptive statistics and one way ANOVA at a significance level of 0.05 using SPSS (Statistical Package for Social Science).

Relative density = ………(1)

Relative frequency = ……..(2)

and



Study area of Cauvery water basin of Tumkur district, Karnataka.

RESULTS AND DISCUSSION

The different types of agroforestry systems practiced by the different categories of farmers in different Agro-climatic zones are presented in (fig:1) and expressed in the percentage of respondents following the agroforestry system. It was found that there are five prominent agroforestry systems mainly followed in Cauvery water basin of Tumkur district. In addition to this it was also noticed that based on the structure and component of tree species grown in the field, some of the farmers following different combinations of agroforestry systems are expressed in respective combinations. Among different agroforestry systems, it was recorded that the majority of the farmers practicing bund planting (28.14 %) followed by bund + boundary planting (23.70 %) and boundary planting (22.22 %). Considering the different categories farmers the small farmers following bund planting (45%) and scattered planting (11.67 %). Boundary planting (34 %) and bund + boundary planting (30 %) are found to be followed by medium farmers in the majority. Further, it was revealed that Horti-silviculture system (24 %) is majorly followed by the large farmers. And while considering the major agroforestry systems fallowed taluka wise was the bund planting and boundary planting in Turuvekere and Kunigal (37.04 %) Tiptur (33.33 %) found to be major taluk following boundary planting system. Further, it was noticed that bund + boundary planting (59.25%) was followed in Tumkur taluk and Kunigal accounted for practicing Horti-silviculture system (11.11 %) as major agroforestry system among the taluks. When we studied according to agro-climatic zones of Karnataka such as Central dry zone (Tiptur), Eastern dry zone (Tumkur and Gubbi) and Southern dry zone (Kunigal and Turuvekere) we come to now that bund planting (37.04 %) is the major agroforestry system followed in the southern dry zone, boundary planting in the central dry zone, bund + boundary (33.33%) planting in Eastern dry and Scattered planting, block planting, and horti-silviculture agroforestry systems were followed in the minor area in the agro-climatic zone as compared to bund and boundary planting agroforestry systems. The results obtained by the study was indicating bund plating and boundary planting as the major agroforestry systems followed by farmers in their farm rather than the inclusion of tree species as scattered planting or practicing block planting and horti-silviculture and the findings are in line with [8] [26].

Growth and tree biomass of neem and teak

The neem tree was recorded significantly higher girth and height in bund planting (75.08 cm) and boundary planting (7.30 m) However, overall biomass and volume did not differ significantly [22] stated the same result and gave the explanation that the bund has maximum amount of nutrient accumulation and water retention capacity. While in teak girth of trees differed significantly whereas the height, volume and biomass did not differ significantly (Table:1).

Productivity of crop in Neem and teak based different agroforestry systems.

The productivity of finger millet in Neem and teak based different agroforestry systems in comparison with control (Table: 2) is found that the grain yield and straw yield of finger millet significantly higher in control i.e., without trees compared to other agroforestry systems [14]. The lower crop yield and biomass was found in different agroforestry systems compared to control condition due to the reduction in growth performance of field crops under the line of trees in the farm through shading effect, moisture condition, competition for nutrients and root extension in the crop field. This could be avoided by taking appropriate pruning management and other practices.

Above ground biomass and Carbon Sequestration

Significantly higher above ground biomass and carbon stock was recorded in boundary planting followed by bund planting & scattered planting, whereas lower above carbon stock was recorded with control without perennial tree component. Which specifies that the aboveground biomass and carbon stock was higher in agroforestry systems compared to a control condition where crop land was devoid of trees [7]. Boundary planting recorded the higher carbon stock which could be considered due to higher tree density. Similarly in teak based different agroforestry system horti-silviculture was recorded the higher carbon stock followed by boundary planting and bund planting , where lower carbon stock was recorded in control land with field crop (Table:3). This proposes that the carbon sequestration potential is much higher in agroforestry systems compared to the agriculture crops alone [12]. The higher carbon stock was recorded in horti-silviculture system due to the presence of more density of fruit and forest tree species and proper management of trees in the system.

Economic analysis of Agroforestry Systems

The cost-benefit analysis of Neem based different agroforestry systems was higher in pure crop stand having cost-benefit ratio of 2.02 with a net return of Rs. 30,899.75 ha^{-1} yr^{-1} followed by scattered planting (1.88, Rs. 27,267.25 ha^{-1} yr^{-1}), bund planting (1.86, Rs. 26,635.75 ha^{-1} yr^{-1} respectively) and boundary planting (1.80, Rs. 24,438.50 ha^{-1} yr^{-1}). The results were not having much difference among control and agroforestry. Similarly in teak based agroforestry systems higher returns per rupee expenditure and net returns were recorded in horti-silviculture system (3.99, Rs. 15,8270 ha^{-1} yr^{-1} respectively) followed by boundary planting (3.03, 63,033.50 Rs. ha^{-1} yr^{-1} respectively), bund planting (2.71, Rs. 53,484.50 ha^{-1} yr^{-1}) and control (2.02, Rs. 30,899.75 ha^{-1} yr^{-1}).The results (Table :4) obtained indicated that the net returns and B:C ratio were higher in horti-silviculture system since the integration of trees with horticultural crops provide higher economic value for products and act as the major source of income [4] [20].

Species richness, tree density, diversity and categories of farmers

Under agroforestry system assessed, it was recorded 19 tree species belonging to 12 botanical families. Among these families, Fabaceae family contributed seven species followed by two species by Meliaceae and remaining one species each. Further, the study indicated that out of the total species 68.42% were of indigenous ones. The study also recorded one threatened species namely *Santalum album* which is listed in IUCN red data book. These findings indicated that majority of the tree species retained on the farm are local, multipurpose tree species that are useful to the farming community and which grow naturally on the farm land. The results are in line with the Vodouhe et al. (2011) who reported 21 species of 14 plant families in traditional agroforestry systems in Benin (West Africa). Further, they also reported that 85 per cent of the total 21 tree species were indigenous to the area. The higher number of tree species was recorded with the small farmers (18) followed by large farmers (15) and a medium farmers (14). However, significant differences were observed with respect to the tree density among the different categories of farmers (Figure: 2) where the higher number of trees per hectare was recorded with large farmers (88.80) followed by the medium farmers (49.14) and small farmers (28.23). Whereas it was found that there were no significant difference among Simpson and Shannon diversity indices (Figure: 3) under different categories of farmers. However, numerically higher Shannon diversity index was noticed in the large farmers (0.75) followed by the medium farmers (0.64) and small farmers (0.56). The results

(Table :5) revealed that the mean number of trees per hectare in large farmer category was significantly higher, indicating that land holding size influences the tree density of the farm. Probably, as the large land holding of the farmer has opportunity to accommodate more number of trees compared to the small farmer where landholding becomes a limiting factor [19] to integrate more number of trees, where field crops are more important for their economic livelihood.

Species richness, tree density and diversity in agro-climatic zones.

The study revealed (Table: 6) that there was no significant difference in tree density and diversity indices among the taluks. However, higher mean number of trees per hectare recorded in Kunigal taluk followed by Gubbi and lowest recorded in Turuvekere taluk. Shannon diversity index was found higher in Kunigal taluk followed by Turuvekere taluk. Besides the mean number of trees and diversity indices did not show any differences among the different agro-climatic zones of the study area. Still, the southern dry zone accounted for a relatively higher Shannon diversity index compared to other agro-climatic zones [16] [1]

CONCLUSION

The present study titled "Evaluation of agroforestry systems under Cauvery water basin of Tumkur District" came out with the following findings in accordance with practical significance was, bund planting and boundary planting were the major agroforestry systems practiced by the farmers in the Cauvery water basin of Tumkur and in which the number of trees in the farm positively correlated with the land holding of the farmers and the agroforestry system practiced by the farmers.

Table 1: Growth performance of Neem and Teak trees in different agroforestry systems.

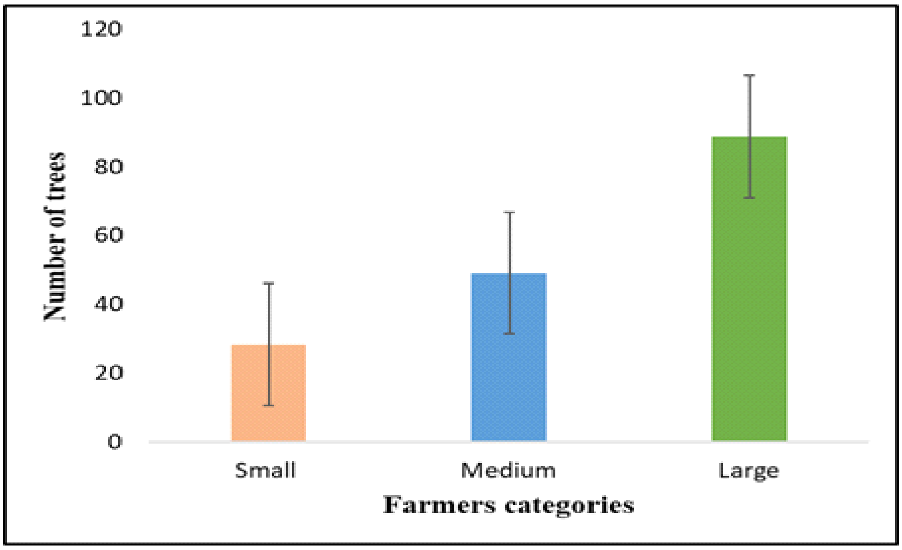
S N.	Agroforestry systems	Girth(cm)		Height (m)		Volume (m3)		Biomass (kg / tree)	
		Neem	Teak	Neem	Teak	Neem	Teak	Neem	Teak
1	Bund planting	75.08[a] (±5.17)	71.80[a] (±15.81)	7.01[a] (±0.73)	8.18 (±0.93)	0.319 (±0.07)	0.36 (±0.19)	220.35 (±50.39)	200.30 (±105.45)
2	Boundary planting	68.90[c] (±8.81)	64.80[b] (±13.57)	7.30[b] (±0.65)	8.31 (±0.91)	0.282 (±0.08)	0.29 (±0.14)	194.74 (±57.28)	164.03 (±79.9)
3	Scattered planting	74.82[b] (±7.46)	61.10[c] (±10.33)	6.72[c] (±0.71)	8.82 (±1.11)	0.305 (±0.08)	0.30 (±0.13)	210.84 (±55.92)	165.50 (±71.75)
	P- value	**<0.05**	**<0.05**	**<0.05**	0.107[NS]	**0.332[NS]**	0.334[NS]	**0.332[NS]**	0.334[NS]

Table 2: Productivity of finger millet in neem and Teak based different agroforestry systems.

Sl. No.	Agroforestry systems	Crop (Finger millet)			
		Grain yield (kg ha^{-1})		**Straw yield (kg ha^{-1})**	
		Neem	Teak	Neem	Teak
1	Bund planting	2071.50[b] (±83.94)	2034.75cb (±70.56)	3987.50[b] (±165.20)	4087.50b (±94.65)
2	Boundary planting	1959.25[cb] (±121.55)	2136.25b (±69.94)	3757.50[c] (±187.68)	3645.00c (±264.13)
3	Scattered planting	2121.50[abc] (±100.35)	-	4175.00[ab] (±170.78)	-
4	Control	2268.00[a] (±80.53)	2268.00a (±80.53)	4500.00[a] (±316.23)	4500.00a (±316.23)
	P – Value	**<0.05**	<0.05	**<0.05**	<0.05

Table 3: Above ground biomass and carbon stock in Neem, Teak and Mango based agroforestry systems.

Sl. No.	Agroforestry systems	Mean biomass (kg tree^{-1})			Mean no. of trees ha^{-1}			Total above ground biomass (t ha^{-1})							Total carbon stock Neem based AF (t ha^{-1})	Total carbon stock Teak + mango based AF (t ha^{-1})
								Neem			Teak + Mango					
		Neem	Teak	Mango	Neem	Teak	Mango	Tree	Crop	Total	Teak	Crop	Mango	Total		
1	Bund planting	220.35	200.30	-	20.50	32.53	-	4.51	6.05	10.56	6.56	6.12	-	12.68	4.75	5.71
2	Boundary planting	194.74	164.03	-	29.86	58.62	-	5.82	5.71	11.53	9.62	5.78	-	15.40	5.18	6.93
3	Scattered planting	210.84	165.50	91.81	12.35	67.29	75	2.64	6.29	08.93	11.14	-	6.89	18.03	4.01	8.11
4	Control	-	-	-	-	-	-	-	6.77	06.77	-	6.77	-	06.77	3.04	3.04



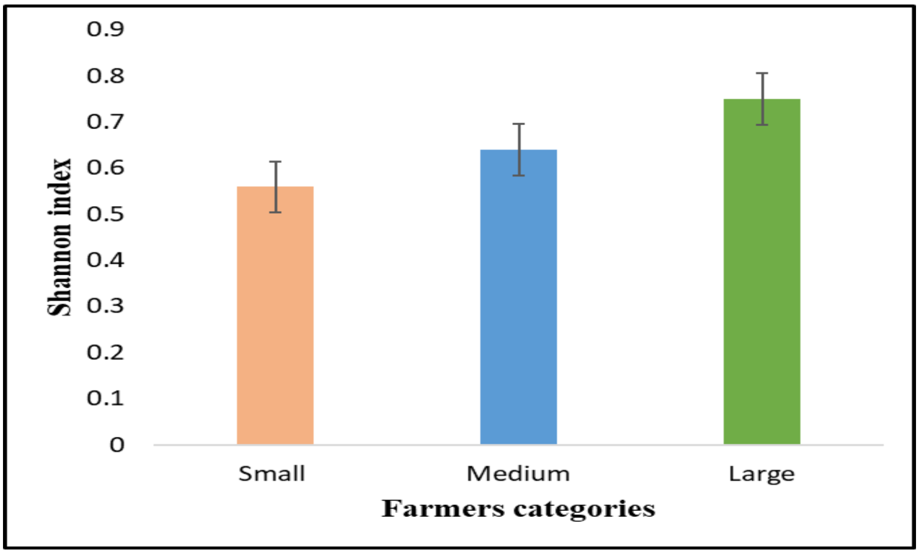


Fig:3 Shannon's index for no. of trees with farm holding size in Cauvery water basin

Table 4: Cost benefit analysis of neem and teak based agroforestry systems.

S. N.	Cost/Benefits	Rs. ha^{-1} yr^{-1}				Rs. ha^{-1} yr^{-1}			
		Neem				Teak			
		Bund planting	Boundary planting	Scattered planting	Control (without trees)	Bund planting	Boundary planting	Scattered planting	Control (without trees)
	Cost								
1	Land preparation	2800	2800	2800	2800	2800	2800	4200	2800
2	Seeds and sowing	6150	6150	6150	6150	6150	6150	-	6150
3	Intercultivation	1200	1200	1200	1200	1200	1200	2400	1200
	Fertilizers								
4	FYM	4000	4000	4000	4000	4000	4000	6000	4000
5	Chemical fertilizers	2309.25	2500	2345	2470	2309.25	2500	7550	2470
6	Agrochemicals	1800	1330.25	1800	1330.25	1800	1330.25	2280	1330.25
7	Human labor	8050	8050	8050	7700	8400	8400	17550	7700
8	Harvesting and threshing	4650	4650	4650	4650	4650	4650	13000	4650
	Total cost	**30959.25**	**30680.25**	**30995.25**	**30300.25**	**31309.25**	**31030.25**	**52980**	**30300.25**
9	**Returns**								
a	Crop output	55775	52738.75	57212.5	61200	57493.75	54513.75	164000	61200
b	Tree biomass	1820	2380	1050	-	27300	39550	47250	-
	Gross return	**57595**	**55118.75**	**58262.50**	**61200**	**84793.75**	**94063.75**	**211250**	**61200**
	Net return	**26635.75**	**24438.50**	**27267.25**	**30899.75**	**53484.50**	**63033.50**	**158270**	**30899.75**
	B:C ratio	**1.86**	**1.80**	**1.88**	**2.02**	**2.71**	**3.03**	**3.99**	**2.02**

Table 5: Species richness, tree density and diversity in different categories of farmer land holding and Agroforestry systems under Cauvery water basin of Tumkur district.

Particulars	Species richness (Total number)	Tree density (ha-1)	Simpson index	Shannon index
Categories of farmer				
Large farmer (n=25)	15	88.80[a]	0.47	0.75
Medium farmer (n=50)	14	49.14[b]	0.41	0.64
Small farmer (n=60)	18	28.23[c]	0.35	0.56
P – Value		<0.05	0.187[NS]	0.206[NS]
Average (n=135)	16	47.24 (±36.57)	0.39 (±0.23)	0.62 (±0.41)

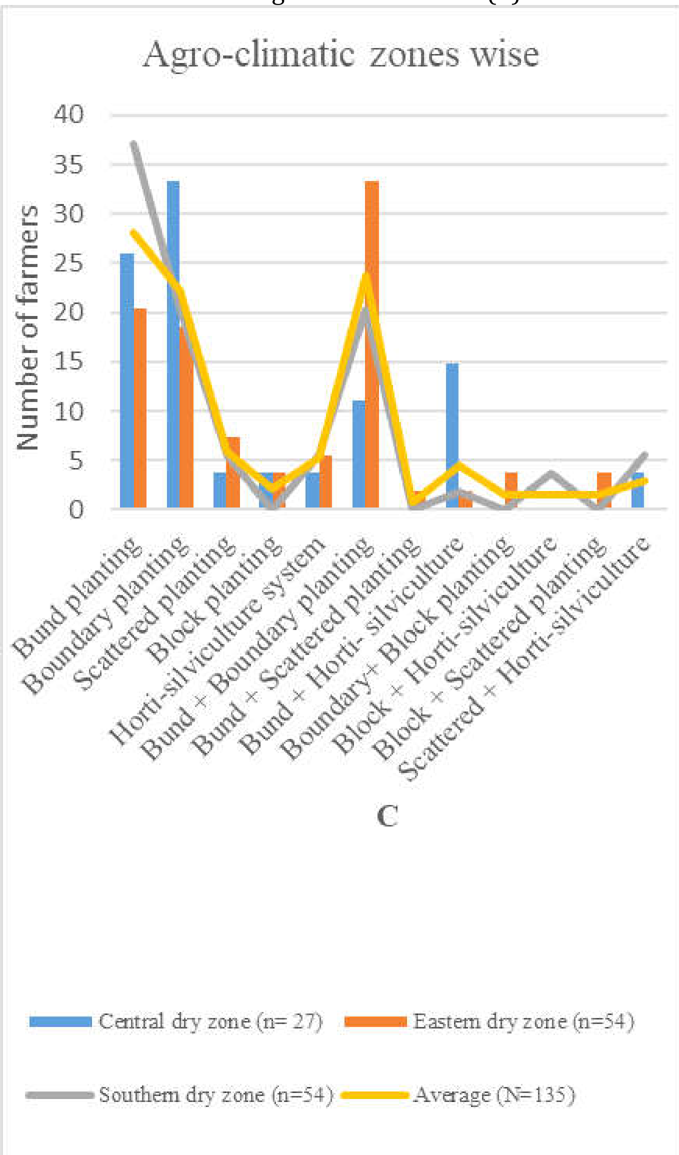
Particulars	Species richness (Total number)	Tree density (ha^{-1})	Simpson index	Shannon index
Agroforestry systems				
Bund planting (n=38)	13	28.84^{ifh}	0.29^{efghi}	0.48^{fh}
Boundary planting (n=30)	11	40.63^{hf}	0.36^{cgh}	0.58^{dh}
Scattered planting (n=8)	03	10.62^{khij}	0.28^{fghij}	0.50^{e}
Horti-silviculture(n=7)	06	95.71^{cb}	0.50^{a}	0.80^{af}
Block planting(n=3)	02	80.00^{eb}	0.25^{ghij}	0.41^{gh}
Bund + Boundary planting (n=32)	08	46.78^{gf}	0.50^{a}	0.79^{a}
Bund + Scattered planting (n=1)	03	17.00^{jhi}	0.55^{ad}	0.92^{ae}
Bund + Horti- silviculture (n=6)	08	54.83^{fe}	0.42^{af}	0.72^{bc}
Boundary + Block planting (n=2)	08	167.00^{a}	0.57^{ac}	1.09^{a}
Block + Horti-silviculture (n=2)	03	155.00^{a}	0.39^{bg}	0.82^{ae}
Block + Scattered planting (n=2)	04	80.00^{db}	0.35^{dghi}	0.53^{e}
Scattered + Horti-silviculture (n=4)	10	101 .00^{b}	0.60^{a}	1.06^{a}
P - Value		<0.05	<0.05	<0.05
Average (n=135)	7.25	73.11 (±31.34)	0.42 (±0.16)	0.72 (±0.25)

Table 6: Species richness, tree density and diversity in different taluks and in different agro-climatic zones.

Particulars / **Taluks**	**Species richness (Total number)**	**Tree density (ha^{-1})**	**Simpson index**	**Shannon index**
Tumkur (n=27)	09	41.67	0.34	0.49
Gubbi (n=27)	14	51.07	0.37	0.58
Turuvekere (n=27)	10	39.59	0.42	0.68
Kunigal (n=27)	13	59.66	0.47	0.74
Tiptur (n=27)	10	44.22	0.35	0.57
P – Value		**0.677^{NS}**	**0.210^{NS}**	**0.122^{NS}**
Average (n=135)	**11.20**	**47.24 (±30.24)**	**0.39 (±0.22)**	**0.61 (±0.40)**

Particulars / **Agro-climatic zone**	**Species richness (Total number)**	**Tree density (ha^{-1})**	**Simpson index**	**Shannon index**
Eastern dry zone (n=54)	14	46.37	0.35	0.53
Southern dry zone (n=54)	13	49.62	0.44	0.71
Central dry zone (n=27)	10	44.22	0.35	0.57
P – Value		**0.962^{NS}**	**0.238^{NS}**	**0.229^{NS}**
Average (n=135)	**12.33**	**46.73 (±29.66)**	**0.38 (±0.25)**	**0.60 (±0.41)**

Fig 1: Agroforestry systems followed by different categories of farmers (A) in different taluks (B) and in different agro-climatic zones (C).



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