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IMPACT OF AGROFORESTRY SYSTEMS: A REVIEW

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Abstract– Agroforestry is a collective name of all agricultural processes related to the scientific management of land that increases overall production under different manners. The security of our natural resources is decreasing every day, these processes will increase the pressure on natural forests and agriculture. We are staying on the stage where we have to take a hard decision to conserve our natural resources and their sustainability. In this context, agroforestry makes sure a scientific solution to all these problems which provide a vast series of good public services. Under this review paper, we discussed various environmental services and conclude that the incorporation of native tree species on farmland can diversifis the farm income and promote maximum use of land. While, Nutrient pumping is one of the best intangible environmental services of the agroforestry system in which productivity of land can be utilized sharply, at the same time agroforestry boosts the soil health in the course of decomposition of raw materials. Biodiversity and Carbon sequestration in agroforestry systems is typically higher than in conventional agricultural systems. Two or more interacting plant species in a given area create a more complex habitat that can support a wider variety of fauna. Tree cover accounts for more than 75% of the global carbon pool. Agroforestry can significantly contribute to climate change mitigation along with adaptation benefits. Adoption of agroforestry drove carbon storage and increased livelihoods simultaneously among small-scale farmers. Agroforestry has a wide range of systems and practices, with their selection and use-dependent on ecological, biophysical, and social factors. The main focus of agroforestry is to meet the needs of rural people in developing countries in a sustainable manner. Its growth and implementation have been closely linked with social and community forestry programs in developing countries.

INTRODUCTION

Agroforestry is viewed as a sustainable alternative to monoculture systems because of its ability to provide multiple ecosystem services (Kuyah *et al.*, 2016). Now a day's India faces crises of fuel, food and fodder. Increasing population made this situation more critical, the last decade has seen an increase in scientific investigation and data that substantiate some of these claims. To reduce this effect researcher suggest a unique land use system known as agroforestry. The integration of trees, agricultural crops, and/or animals into an agroforestry system has the potential to enhance soil fertility, reduce erosion, improve water quality, enhance biodiversity, increase aesthetics, and sequester carbon (Garrett and McGraw 2000).

Incorporation of native species in agroforestry systems often depends on the indigenous knowledge of local landowners and communities. Agroforestry practices also provide improved wildlife habitat by increasing structural and compositional plant diversity on the landscape (Jose 2009). Agroforestry can be a good step to check deforestation and erosion in the hills. Agroforestry encompasses a wide variety of practices, including crop-fallow rotations, complex agroforests, simple agroforests, silvipastoral systems, and urban agroforestry (Steppler and Nair, 1987). According to Raj *et al.*, (2014) agroforestry has the potential to alter the microclimate under the tree canopy. It plays a major role in enhancement of overall farm productivity, soil fertility through addition of litter and organic matter, climate change mitigation through carbon sequestration, phytoremediation, watershed protection and biodiversity conservation.

According to Dhyani *et al.* (2013) in India the current area under agroforestry is estimated at 25.32 Mha, or 8.2% of total geographical area of the country. This includes 20.0 Mha in cultivated lands

(7.0 Mha in irrigated and 13.0 Mha in rainfed areas) and 5.32 Mha in other areas such as shifting cultivation (2.28 Mha), home gardens and rehabilitation of problem soils (2.93 Mha). Now a day's farmers use planting trees along with crops improves soil fertility, control and prevents soil erosion, controls waterlogging, checks acidification and eutrophication of streams and rivers, increase local biodiversity, decrease pressure on natural forests for fuel and provide fodder for livestock. The main objective of this research paper is to expose the environmental and economic benefits of agroforestry which helps the socio-economic development of the people in harmony with the conservation of ecological balance.

Agro-forestry can play a major role in the protecting environment and forest Khurana and Khosala (1993). People have little choice in the selection of plants and whatever grows naturally is accepted. The farmers have integrated crops, trees, and animals in their farming and land management systems reasonably for solving the problem of acute shortages of fuelwood, fodder and other forest produce Bhatt (2002).

Agroforestry systems impacts on soil

Agroforestry is a combination of agricultural technology and forest in order to complete, variety, productivity, health, and sustainability of land Shamekhi, (2007). Agroforestry systems are believed to increase, or at least maintain, the organic-matter levels in the soil (Young *et al.,* 1986). The soil microbial biomass has important functions in the soil, including nutrient cycling and the degradation of pollutants like pesticides; urban and industrial waste, etc. (Araújo and Monteiro, 2006). Organic level in the soil is positively connected with the number of microbial activity, which helps to decompose dead organic materials on-farm floor. According to Powlson *et al.,* (1987), the main function of microorganisms is to mediate soil processes and high rates of turnover, which is a sensitive indicator of changes in the soil organic matter. Quite a lot of authors have stated that soil microbial biomass and microbial assortment are greater in the AFS due to the ameliorative effects of trees and organic matter inputs and the differences in litter value and quantity and root exudates (Sorensen and Sessitsch 2007).

Agroforestry promotes more efficient cycling of nutrients than traditional agriculture systems. It is also more sustainable and better for the environment. However, the amount of nutrient addition through litter decomposition varies from species to species Hasanuzzaman and Mahmood (2014). The amount of nutrient addition to a particular ecosystem was found to vary with the species Benton and Jones (1998), and other climatic conditions Semwal *et al.,* (2003). Wardle (2002) reported that the dominant species control many community and ecosystem processes. Leaf litter inputs to the ground floor serve as an important mechanism by which trees regulate ecosystem functions including nutrient and energy cycling, tree regeneration, and the maintenance of biological diversity and served valuable environment for adjoining agricultural crop. Amighi *et al.,* (2013) evaluate the effects of the agroforestry system on the soil characteristics in Aq qala area. Organic matter, total N, electrical conductivity, pH and moisture content in area that has agroforestry system had significant increase against evident area (Table 1).

The withdrawal of nutrients from decomposed leaves and other plant parts proceeding to abscission allows a plant to use the same unit of nutrient to build several leaves or other plant parts successively through the soil nutrient cycling process. For support of this statement Hulugalle and Ndi (1994) demonstrated that hedgerows of *Senna* (*Senna spectabilis*) and *Flemingia* (*Flemingia congesta*) significantly improved soil properties in a newly cleared Ultisol (Typic Kandiudult) in southern

Table 1. Statistical distribution of physical and chemical characteristics of soil samples at three locations and depths.

Site	Sampling depth (C M)	OC (%)	OM (%)	N (%)	Lime (%)	EC ($dS.m^{-1}$)	pH	Saturated moisture
Under trees	0-25	1.73[a]	2.98[a]	0.17[a]	09.06[a]	2.41[a]	7.72[a]	46.64[a]
	25-50	0.88[b]	1.52[b]	0.08[b]	21.06[b]	4.45[b]	8.03[b]	38.73[b]
Between trees	0-25	1.01[a]	1.74[a]	0.10[a]	20.12[a]	2.88[a]	7.92[a]	40.22[a]
	25-50	0.57[b]	0.99[b]	0.05[b]	20.25[b]	4.41[b]	8.1[b]	35.37[b]
Control	0-25	0.49[a]	0.84[a]	0.05[b]	22.34[a]	2.98[a]	8.22[a]	37.84[a]
	25-50	0.35[a]	0.60[a]	0.03[a]	23.30[b]	3.73[b]	8.42[a]	34.07[b]

Amighi *et al.,* (2013) (Different letters indicated the meaningful difference)

Cameroon. The procedure which helps to increase the addition of nutrients into the soil can increase the productivity automatically. Various researchers also conclude that productivity depends on efficient nutrient cycling mechanisms that ensure rapid turnover of litter nutrients (Vendrami *et al.*, 2012).

Agroforestry promote the formers to divert their aim of cultivation from high production to sustainable cultivation. Soils managed in sustainable and conventional farming systems with organic practices have shown high levels of organic matter (SOM) and total nitrogen (Reganold, 1988). Many researchers introduced improved fallow as a sustainable option to replenish soil fertility within the shortest possible time (Kwesiga *et al.*, 1999).

Improved fallow involves planting of fast growing plant species that are usually nitrogen-fixing tree, shrubs and herbaceous cover crops while other researcher focus on multipurpose agroforestry systems which helps to increase soil fertility. Table 2 reveals some example of agroforestry systems which helps to enhance the soil fertility. These

Table 2. Regional examples of soil-fertility enhancement in multifunctional agroforestry systems in India.

Region	References	Challenge	Changes observed due to agroforestry
Himalayas (Kurukshetra) 69	Kaur *et al.,*(2002)	Improvement of sodic soils	Increase in microbial biomass, tree biomass and soil carbon; enhanced nitrogen availability
Himalayas19	Maikhuri *et al.,* (2000)	Restoration of abandoned agricultural sites	Biomass accumulation (3.9 t ha^{-1} in agroforests compared to 1.1 t ha^{-1} in degraded forests); improvement in soil physico-chemical characteristics; carbon sequestration
Western Himalayas70	Narain *et al., (*1997)	Reducing soil and water loss in agroecosystems in steep slopes	Contour tree-rows (hedgerows), reduced run-off and soil loss by 40 and 48% respectively (in comparison to 347 mm run-off, 39 Mg ha^{-1} soil loss per year under 1000 mm rainfall conditions)
Sikkim Himalaya71,72	Sharma *et al.,*(1996)[a] Sharma *et al.,*(1996)[b]	Enhancing litter production and soil nutrient dynamics	Nitrogen-fixing trees increase N and P cycling through increased production of litter and influence greater release of N and P; nitrogen-fixing species help in maintenance of soil organic matter, with higher N mineralization rates in agroforestry systems
Indo-Gangetic Plains (UP) 73	Singh (1998)	Biomass production and nutrient dynamics in nutrient-deficient and toxic soils	Biomass production (49 t ha^{-1}/decade)
Himalayas (Meghalaya) 74	Dhyani *et al.,*(1998)	Enhancing tree survival and crop yield	Crop yield did not decrease in proximity to *Albizzia* trees
Western India (Karnal) 75	Kaur *et al.,*(2000)	Improvement of soil fertility of moderately alkaline soils	Microbial biomass C which was low in rice–berseem crop (96.14 gg^{-1} soil) increased in soils under tree plantation (109.12 gg^{-1} soil); soil carbon increased by 11–52% due to integration of trees and crops
Western India (Rajasthan)76	Gupta *et al.,*(1998)	Compatibility of trees and crops	Density of 417 trees per ha was found ideal for cropping with pulses
Central India (Raipur)77	Puri and Swamy (2001)	Biomass production in N and P-stressed soils	*Azadirachta indica* trees were found to produce biomass in depleted soils
Central India78	Pandey *et al.,*(2000)	Soil improvement	Decline in proportion of soil sand particles; increase in soil organic C, N, P and mineral N
Southern India (Kerala)80	Kumar *et al.,* (2001)	Growing commercial crops and trees	Ginger in interspaces of *Ailanthus triphysa* (2500 trees ha^{-1}) helps in getting better rhizome development of the former compared to solo cropping

systems are scientifically approved by many researchers.

Agroforestry systems impact on productivity

India has reached very close to a situation where renewability of most of the natural resources has succumbed to the magnitude of overexploitation (Chakraborty *et al.,* 2009). Agroforestry show the viable option for food security and climate resilience for present and future prospective. Agroforestry is a sustainable and multiple land utilization system in which trees incorporates with crops and/or livestock on same unit of land at a time Kumar and Thakur (2017). Generally, agroforestry always provides a platform where one component interacts with other components continuously. So, various interactions take place between the tree and herbaceous plants (crops and pasture), which are referred to as the tree-crop interface.

According to Nair (1993) interaction is the effect of one component of a system on the performance of another component and/or the overall system. Tree/crop interactions can occur aboveground, for example through interception of radiant energy and rainfall by foliage and moderation of temperatures by canopies (Luedeling *et al.,* 2016) or belowground, e.g., in resource use like nutrient, water, space competition, or complementarities (Rao *et al.,* 1998). Study about interaction help to understand how to system goes and utilize resources through caring and shearing benefits between each others, this act maintain the sustainability of system. Nair (1993) described the interaction between two components under the agroforestry system and revealed that Interactions can be positive, neutral, or negative. Figure 1 shows schematically the relationships between two agroforestry components according to the type of interactions between them. When the interaction is positive, there is complementarity between the components, while there is competition if the interaction is negative.

An increasing population can produce unexpected pressure on fodder production. A significant proportion of livestock population (66%) is also in the rainfed areas Mathukia (2016). In the current situation our forest cannot fulfill the domestic requirement of animals. So that in this condition agroforestry play a vital role to maintain the demand and supply of fuel food and fodder simultaneously agroforestry can reduce the pressure on natural forest. The central agroforestry research institute calculates the future domestic demand for various commodities and agroforestry contributions to fulfill these requirements under the vision of 2050 (Table 3).

In different agroforestry systems multipurpose trees and shrubs often contribute a significant amount of leaf fodder in all regions during the lean period through lopping/pruning of trees, popularly known as a top feed.

The leaf fodder yield depends on species, initial age, lopping intensity, and interval as well as agroclimatic conditions. Modern agroforestry systems (e.g., alley-cropping of crops and short-rotation trees) have been recognized as multifunctional systems that can reduce nitrate leaching, increase carbon sequestration, and increase pollination services (Kay *et al.*, 2018), maintaining agricultural productivity (Pardon *et al.,* 2018; Swieter *et al.,* 2018) and food safety of small-grain cereals such as wheat (*Triticum aestivum*) and barley (*Hordeum vulgare*) Beule *et al.,* (2019b). Many researchers reveal that the tree which is used in agroforestry adds organic matter to fields, can improve the physical and chemical properties of soil, it results in an improvement in availability moisture as well as increase productivity of the land. According to Bertin *et al.,* (2003) trees add organic matter to the soil system in various manners, whether in the form of roots or litterfall or as root exudates in the rhizosphere.. The agroforestry systems reduced 20% N loss through 1 to 10% reduction in soil erosion (Udawatta *et al.,* 2002). In addition, SOM improves soil physical and chemical properties important for plant productivity through increasing aeration, cation exchange capacity and water holding capacity while reducing erosion (Woomer *et al.,* 1994; Carter, 1996). Mokgolodi *et al.,* (2011) prove that *Faidherbia albida's* provides positive impacts on the productivity of the crop under its crowns. Agroforestry also helps to positively control moisture content in soil both above and below ground seepage of water. Sahu *et al.,* (2015) reported that the tree has the potential not only to arrest fast depletion of the groundwater table but also to have a capacity to reverse the trend quickly.

Agroforestry, be able to improve the soil fertility

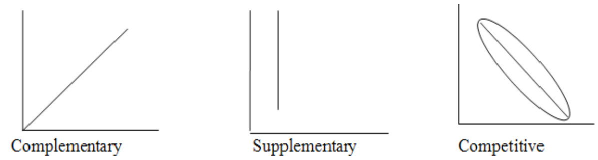

Fig. 1. Nature of common types of biological interactions in agroforestry systems

by adding organic manures through litter fall, degradation of tree branches, twigs and woody components. Tree components are basis of essential macro, micro nutrients and also play significant role in nutrient recycling Table 4.

Agroforestry could improve water use efficiency through reducing the uncreative components of the water balance, such as run-off, soil evaporation and drainage disturbance (Bayala and Wallace, 2015). There is a number of trees in agroforestry systems capture water resources that would not be put to productive use in the absence of trees, mainly from deep soil layers beyond the reach of annual crops. Crop roots in drier surface soil may benefit from hydraulic lift of water by trees from wetter soil at depth (Burgess *et al.*, 1998), either at night when transpiration is low (Hultine *et al.*, 2003) and/or during the day along water potential gradients driven by variation in soil salinity (Hao *et al.*, 2009).

Agroforestry impact on environment

The transition from agriculture to agroforestry significantly increased soil organic carbon an average of 34 percent, according to Michael Jacobson, professor of forest resources, whose research group in the College of Agricultural Studies conducted the study. The conversion from pasture/grassland to agroforestry produced soil organic carbon increases of about 10 percent, on average (Penn State News, 2018). In the changing scenario of global warming, agroforestry can be credited to thousand of expectations in recent years.

According to Nair (2011), the benefits of AFS: water quality enhancement, carbon sequestration, and soil improvement. These benefits are based on the perceived ability of (i) vegetative buffer strips

Table 3. Total Domestic demand for various commodities and Agroforestry Contribution in 2050 (CAFRI 2015)

Items	2010-2011	Projected for 2025	Projected for 2050	Contribution from AFS in 2050
Food grains (millions t)	218.20	320.00	457.1	41.14*
Fruits (millions t)	71.20	106.00	305.3	47.74*
Fodder (millions t)	1061.00	1170.00	1545	154.50
Fuel wood (millions t)	308.00	479.00	629	308.00
Timber (millions t)	120.00	171.00	347	295.00
Biodiesel (millions t) required for 20 % blending of diesel	12.94	22.21	37.92	30.34
Area (millions ha) required for TBOS	12.32	15.86	21.67	17.34
Agroforestry (millions ha)	25.32		53.32	

*Food-grains/fruits production from systematic agroforestry systems viz. agri-silviculture/ agri horticulture only considered.

Table 4. Tree species highly boost up the nutrient status of soil

S. N.	S.N Plant species	Nutrient contents (Kg ha^{-1}) N	P	K	Remark	Reference
1	*Prosopis juliflora*	231	7	333	Whole tree	Tewari *et al.*, (2014) Dagar *et al.*, (2014)
2	*Prosopis cineraria*	221	11	479	Whole tree	Tewari *et al.*, (2014) Dagar *et al.*, (2014)
3	*Gliricidia sepium*	21	2.5	18	1 tone leaf ha^{-1}	Rao *et al.*, (2011)
4	*Albizia stipulata*	458	39	437	20 years old plantation	UHF (2010)
5	*Dalbergia sissoo*	459	32	409	20 years old plantation	UHF (2010)
6	*Terminalia arjuna*	275	28	388	20 years old plantation	UHF (2010)
7	*Sesbania aculeata*	1.5	0.3	2.0	Percentage nutrient content of green foliage	Khadka & Chand (1987)
8	*Pongamia pinnata*	3.69	2.41	2.42	Percentage nutrient content of green foliage	Patnaik, (1987)
9	*Madhuca indica*	1.66	0.50	2	Percentage nutrient content of green foliage	Patnaik, (1987)

Source of data Kumar and Thakur (2017)

(VBS) to reduce surface transport of agrochemical pollutants, (ii) large volumes of aboveground and belowground biomass of trees to store high amounts of C deeper in the soil profile, and (iii) trees to enhance soil productivity through biological nitrogen fixation, efficient nutrient cycling, and deep capture of nutrients. Agroforestry can reduce the temperature of microclimate and increase the micronutrient in the field. Sileshi, (2016) revealed that 'Albida effect' is one of the best examples in this context; which shows that lower temperatures under the canopy of *Faidherbia albida* could play an important role to increase provides water and nutrient availability for adjoining crops. Through together with trees in agricultural production systems, agroforestry can, arguably, increase the amount of carbon stored in lands devoted to agriculture, while still allowing for the growing of food crops (Kursten, 2000).

Tans (2010) revealed that the atmospheric concentrations of carbon dioxide (CO_2) rose from 280 to 369 ppm, and increased between the years 1850 and 2000, further to 388 ppm by August 2010, a 5.1% rise over the last 10 years. The environmental benefit of agroforestry is it helps to decline carbon content in the atmosphere by a well-known process of carbon sequestration. The plant absorbs this C and convert it there biomass. Mangalassery *et al.*, (2014) confirm that silvipastoral systems can better sequester carbon in soil and biomass and help to improve soil conditions. Among various land-use systems under study, maximum carbon was sequestered by silvipastoral system relating *Acacia* + *C. ciliaris* (6.82 Mg C ha^{-1}) followed by *Acacia* + *C. setegerus* (6.15 Mg C ha^{-1}) compared to 6.02 Mg C ha^{-1} sequestered by *Acacia* planted monoculture. The silvipastoral system involving *Neem* + *C. ciliaris* and *Neem* + *C. setegerus* registered a total carbon stock of 4.91 and 4.87 Mg C ha^{-1} respectively, against sole cropping of *Neem* that recorded 3.64 Mg C ha^{-1}. Similarly, Palm *et al.*, (2004) prove that tree component in agroforestry sequester aboveground and belowground carbon and thus contribute to the mitigation of climate change, in the long run.

Montagnini and Nair (2004) reported that the average carbon storage by agroforestry practices has been estimated as 9, 21, 50, and 63 Mg C ha^{-1} in semiarid, subhumid, humid, and temperate regions. For smallholder agroforestry systems in the tropics, potential C sequestration rates range from 1.5 to 3.5 Mg C ha^{-1} yr^{-1}. Agroforestry can also have an indirect effect on C sequestration when it helps decrease pressure on natural forests, which are the largest sink of terrestrial C. Kim (2016) studied the carbon sequestration and net emissions of CH_4 and N_2O under different agroforestry systems and resulted that the agroforestry stands sequestered 7.2 ± 2.8 ^{o}C ha^{-1} y^{-1} (70% in biomass and 30% in soil). Soils under agroforestry oxidized 1.6 kg CH_4 ha^{-1} y^{-1} and emitted 7.7 kg N_2O ha^{-1} y^{-1}. Agroforestry was estimated to mitigate 27 ± 14 ^{o} CO_2 equivalent ha^{-1} y^{-1}.

Another good environmental facility which is provided by agroforestry is purification running water. In riparian buffer is multispecies row's of tree and grasses planted in stripe sloppy areas which help to reduce contamination in running water and provide sufficient time to infiltrate the running water. Sarah *et al.*, (2008) revealed that the plants

Table 5. Criteria important to different stakeholders

Stakeholders	International community		Agriculturists	National policy-makers		Smallholders
Criteria	Global environmental quality		Plot level production sustainability	Social profitability	Employment	Production incentives
Measured by	Carbon sequestration: time averaged (Mg/ha)	Biodiversity: plant species perstandard plot	Rating	Returns to land at social prices (Rp 1 000/ha)	Labour input (days/ha/ year)	Returns to labour at private prices (Rp/day)
Natural forest	254	120	1	0	0	0
Rubber agroforest	116	90	0.5	73	111	4000
Rubber agroforest with clonal planting material	103	60	0.5	234-3622	150	3900–6900
Upland rice/bushfallow	74	45	0.5	53-180	15-25	2700-3300
Continuous cassava degrading to Imperatas pp.	**39**	**15**	**0**	**315-603**	**98-104**	**3895-4515**

Note: 1 Rupiah (Rp) = US$0.00012 (2000). *Source:* Adapted from Tomich *et al.*, (2001).

have been used for water treatment from ancient times and there is evidence to suggest that communities in the developing world have used the tree-based systems as one strategy for purifying running as well as drinking water.

Most economic analyses of agroforestry focus on benefits to farmers, yet many groups of stakeholders are interested in changes of land use. Tomich *et al.* (2001) used a matrix to assess how various land-use practices performed across different criteria important to six groups in Sumatra: the international community, hunter-gatherers, small-scale farmers, large-scale estates, absentee farmers and policy-makers (Table 5) and explain the various environmental benefits. Data shoes in table 5, smallholders can get maximum benefit from agroforestry system.

Agroforestry impact on biodiversity conservation

Agroforestry systems have potential to support as high as 50-80 per cent of biodiversity of comparable natural system (Noble and Dirzo, 1997) including a wide range of species, from soil micro insects to mammals and have diversified and intensified agro-ecosystems to keep and improve biodiversity. Biodiversity provides enormous direct economic benefits, an array of indirect essential services through natural ecosystems, and plays a prominent role in modulating ecosystem function and stability. Out of this agroforestry conserve microfauna which provided that stability in the ecosystem. McNeely and Schroth (2006) proposed that the widening focus from the traditional tree-based land use practice to a more advanced landscape-scale agroforestry (AF) approach creates a stronger link between agroforestry and biodiversity conservation. Likewise, home gardens are ecologically sustainable and diversify the livelihood of the local community; they are considered as excellent tools for biodiversity conservation (Linger, 2014).

Klie (2018) investigated the potential of agroforests for serving as habitat for the golden-headed lion tamarin (*Leontopithecus chrysomelas*), the maned sloth (*Bradypus torquatus*) and the golden-bellied capuchin (*Sapajus xanthosternos*) in Brazil´s north-eastern Atlantic Forest biome. Observations concluded under the variety of factors *viz.* a higher income generation (89%), the diversification of the production system (86%), and an increase in the land's quality and productivity (86%).

Source of data Klie (2018)

Results (Fig. 2) revealed that the maned sloth was the most common "emblematic species" found in the analyzed farms. According to the results of the questionnaire, the maned sloths occurred in 23% of the agroforest systems, compared to 7% for the Golden headed-lion tamarin and 5% for the Golden-bellied capuchin. Similarly, multipurpose trees that are found fewer numbers in the natural forest can be conserved through agroforestry practices. Murdiyarso *et al.,* (2002) compared the number of plant species found in different types of land use in the Jambi area of central Sumatra. They found that continuously cultivated cassava had 15 species per 1.5-hectare plot, oil palm plantations had 25 species per plot, and rubber agroforests had 90 species per plot, while primary forests had 120 species per plot.

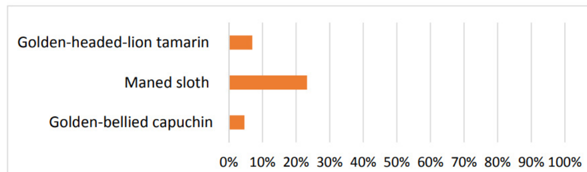

Fig. 2. Potential of agroforests for serving as habitat:

Haichar *et al.*, (2008) reported that, soil microbial community structure and function are shaped by resource availability, which in turn is controlled, among other factors, by the quantity and quality of plant litter input as well as root exudation and decay. Radhakrishnan and Varadharajan (2016) studied eight soil samples in different agroforestry systems at Tamil Nadu and found a maximum (64%) *bacterial* population, *actinomycetes* (23%) and *fungi* (13%) in different samples screened. Results revealed that the total *bacterial* count had a positive correlation with soil organic carbon (C), moisture content, pH, nitrogen (N), and micronutrients such as Iron (Fe), copper (Cu), and zinc (Zn). Similarly, the total *actinomycete* count also showed positive correlations with bulk density, moisture content, pH, C, N, phosphorus (P), potassium (K), calcium (Ca), copper (Cu), magnesium (Mg), manganese (Mn), and zinc (Zn). It was also observed that the soil organic matter, vegetation, and soil nutrients altered the microbial community under agroforestry systems. Doddabasawa and Pampangouda (2018) found higher microbial density in teak-based agroforestry, followed by silvi-horti, boundary plantation, and bund plantation while it was again the lowest in the crop-based farming system.

Out of this agroforestry provides a number of intangible benefits such as employment, reduction pressure on natural forests, conservation of endangered species. Additionally, agroforestry can be used as adaptation strategies for climate change. On the basis of the above benefits, we can articulate that agroforestry can be a means to increase crop yield without compromising the provision of regulating/maintenance ecosystem services. It was proved that agroforestry was effective at enhancing the ecosystem services studied in most situations.

CONCLUSION

The agroforestry is always providing good results in all forms of cultivation. Out of this, there is a vital need to broaden the knowledge base of the subject of agroforestry to provide a more substantive basis for effective teaching and training programs. Researchers need to focus on a typical university system and prepare an easy guideline which indicates how interdisciplinary research teams can be brought together to work on agroforestry projects. To understand and evaluate the existing agroforestry systems and to develop action plans for their improvement, it is necessary to classify them according to some common criteria. The prevalence of agroforestry systems in India advises opportunity worth consideration not only for carbon sequestration but also for livelihoods improvement, biodiversity conservation, soil fertility enhancement, and poverty reduction.

We have to focus on farm agroforestry technology demonstrations under both rainfed and irrigated conditions. Significant among the demonstrations are agrihorticulture (both under alley and boundary system), bio-fence practices, and on-site demonstrations of multipurpose tree. The government needs to arrange a systematic "Diagnostic survey and appraisal of existing farming system and agroforestry practices and farmers' preference" to find out the gap based on the requirements of the farmers and to design future experiments based on its findings. It will help in the collection, screening, and selection of trees and shrubs for agroforestry and developing sustainable agroforestry systems and their management. Policymakers will have to design and development of bio-economic models for sensitizing investment and influencing policies for agroforestry development. An expert person needs to be appointed to study market demands, industry requirements, and the species suitability and livelihood needs of people.

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