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Agroforestry: An Effective Potential Tool for Ensuring Quality Life for the Indian Farmers: A Review

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ABSTRACT

Millennium Development Goals (MDGs) and the succeeding Sustainable Development Goals (SDGs) have been at the heart of the global development agenda. Where half of the population is being employed in the agriculture sector in a rapidly growing demographics like India, the pressure is very tense on the natural resources in order to make harmony between economy and environment. Uplifting the majority of farming families from the poverty line (doubling farmer's income by 2022 is a time frame set up by NITI Aayog) and ensuring a quality of life in the line of globally standardised development goals has been reflected in governments' policies. The potential of tangible and intangible benefits referred to as an ecosystem service, delivered by agroforestry systems have been widely accepted all over the world. The need for a climate-resilient and sustainable system of land use for food security is the aim of the new world. The present review discusses the scope of agroforestry for food, environment and economic security that will be helpful for an all-round development of farmer's life in a rapidly developing country like India, which has a diversified agricultural scenario throughout the length and breadth of the country. We referred peer-reviewed research papers and government publications to come into a conclusion regarding the status of agroforestry as a potential tool in Indian agricultural scenario to ensure a quality of life to the farmers and further suggestions. The potentiality of taking traditional agroforestry practices to a new level through contract tree farming, financing through banking institutions, integrating agroforestry farmers with industries and a tree insurance approach may be a way forward in the country to augment's farm income and adaption of suitable agroforestry practices as compatible to agro-climatic zones.

Key words: Agroforestry, Climate resiliency, SDG, Sustainability, Tree-based systems.

Combating hunger, poverty, disease, illiteracy, environmental degradation and discrimination against women is the thematic area of focus of global development (World Bank, 2016). Ecosystem services are the many and varied benefits to humans provided by the natural environment and healthy ecosystems. Provisioning, regulating, cultural and supporting services were defined as four primary categories of ecosystem services in the Millennium Ecosystem Assessment, a significant UN-sponsored effort to study the impact of human activity on ecosystems and human well-being. Ecosystem system services are directly as well as indirectly correlated with the well-being of humans. Any negative impact on the ecosystem will ultimately lead to a negative impact on human life. In order to cope with the growing need for the survival of the population, that to satisfy the quality of living ultimately the natural environment is to be harvested starting from the basic need of food, fibre and shelter to things for easement of lifestyle. As the climate is an important factor of agricultural productivity and this product has a direct effect on human welfare so, any climate change-related happenings have too effect on crop productivity and associated human welfare. In various global forums, interest in this matter has motivated a substantial body of research on climate change and agriculture over the past decades and insisted research groups find out climate-resilient technologies to sustain agricultural productivity in those adversities. One of the best sustainable ways to regulate ecosystem services is by adopting "agroforestry models" that are environment-friendly and sustainable in the long run. Agroforestry systems are a preferred choice for adopting climate-resilient agriculture and livelihood enhancement in various climatic conditions since the tree species and other components are in synchronization with the environment. Research findings and synthesis around the world have torched out that agroforestry has the greatest potential for carbon sequestration of all the land uses under study (IPCC, 2000). Traditional agroforestry systems are well-known for their contributions to regulating, supporting, cultural and provisioning services. Agroforestry is appealing as a rural development solution because it minimizes trade-offs between economic and environmental benefits. It has moved from forest margins to peri-urban regions in various forms and practices. Adaption of organic cultural practice in

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agriculture is not only environmentally sustainable but also generates a good benefit-cost ratio as compared to inorganic practice and agroforestry is beyond organic farming as implementing these systems which mimic nature's functions. So, no doubt in this decade and century it is the prime time to harvest the potential of agroforestry for beneficial environmental and social effects. The concept of integrating trees into the agricultural landscape is an age-old practice and has been in practice by peoples in various combinations improving their livelihood status. It is only after the 1980s that agroforestry is conceptualized and studied in-depth leading to categorizing of agroforestry into different sets of criteria *viz*., structural, functional, socioeconomic and ecological basis (Nair, 1993). The most common one is the alley cropping which is involves cultivating field crops between rows of trees and researchers concluded that the system produces in an average 40% more product per given area than the sole cropping of crops involved (Dupraz *et al*., 2011). Hence, there is a need to aware practitioners of cultivation, the never-ending advantages of agroforestry in terms of environmental sustainability as well as a way of a better source of income generation (Fentahun and Hager, 2010). The true potential of extension education can be utilized in educating and propagating the advantages of agroforestry by all tools of extension education. The practical approach should be shown to the growers regarding the income generation potential of agroforestry system, how it is a sustainable management system that can bear them good results in long run and can assure them regarding their livelihood security (Bryden and Bollman, 2000). In this era of rising population and day by day increasing attitude of competitiveness, agroforestry system has emerged as a new solution that won't let anyone sleep hungry. The World Agroforestry Centre (ICRAF) which is dedicated for harnessing the benefits of trees in farm for people and the environment has identified that agroforestry practice can materially address the following aspects which are crucial for up lifting farmer's life quality (Garrity, 2004).

i. Help in eradicating hunger through pro-poor food production systems in agriculturally constraint land through agroforestry intervention.
ii. Lifting more people from the poverty line through tree cultivation systems that supplements farm income.
iii. Health and nutritional requirement of rural poor people is duly taken care of by agroforestry practice.
iv. Conservation of biodiversity through people's participation is the broad arena of taking care of ecosystem which ultimately can be achieved through agroforestry.
v. Protect watershed services through implementing agroforestry-based solutions that allow the poor to be compensated for providing these services.
vi. Tree cultivation is a credible way to better adapt to climate change and getting the benefits from the emerging carbon markets for the farmers.
vii. Strengthen human and institutional capacity in agroforestry R and D.

Considering the varied and proven benefits of agroforestry through the experiences from worldwide research, the present review synthesizes the dimensions of agroforestry to effectively integrate in farming practice in India for ensuring a quality of life to the farmers of the country. We searched for peer review research paper in Google Scholar web database, CAB Abstracts and Krishikosh digital respiratory using the key words combined - 'agroforestry', 'tree-based system', 'socio-economic benefits', 'financial benefits', 'sustainable development goals' and 'poverty elevation'. Only peer reviewd research paper based on Indian agricultural scenarios has been considered for our present study. We also refereed the cental government and state government reports of our concerns for the study.

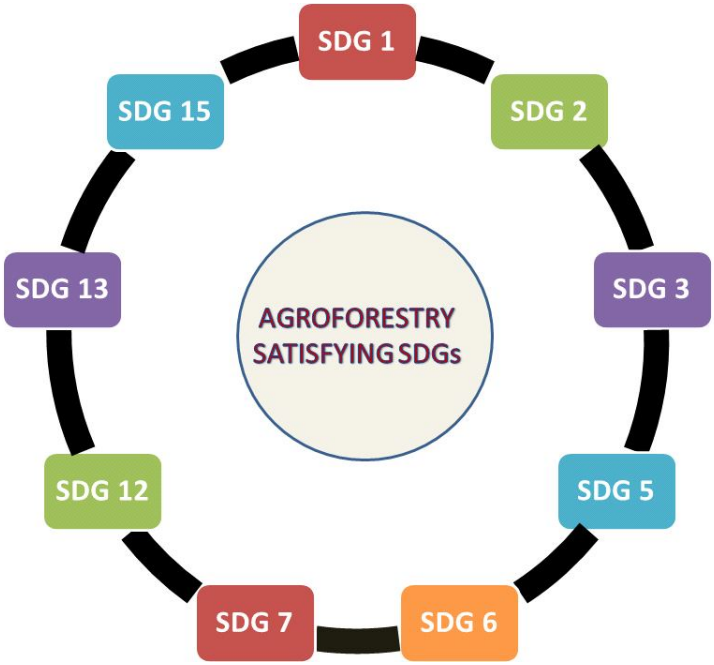
Agroforestry for achieving sustainable development goals (SDG) through enhanced food production and nutritional attainment

The mutual agreement among all UN Member States in 2015 leads to the formation of 2030 Agenda for Sustainable Development, which provides a shared roadmap for peace and prosperity for people and the planet today and in the future. Till then it serves as fundamentals for making our planet more suitable for human establishment. Agroforestry has paved the way for achieving these global goals and there are ample evidences that nine out of the 17 SDG can be achieved through it (Van Noordwijk, 2020). Agroforestry has the strongest impact on the following SDGs (Fig 1).

To fix the issues of food and nutritional security, a variety of interconnected agricultural approaches are needed, including advancements in staple crop productivity, genetic improvement of staples and the cultivation of a broader range of edible plants that provide fruits, nuts, vegetables and other foods for more varied diets (Frison *et al*., 2011). Food grain, fruit, vegetable, spices and livestock food products are all produced as output by different agroforestry system, which has more than two components where one is definitely a perennial woody component and have complementary effects with the chosen annual crops. Among the varied agroforestry systems that will play a crucial part in countries' food security are agri-silviculture, agri-horticulture, silvi-pastoral, agri-silvi-pastoral and other systems like aqua forestry and apiculture with tree species. The age-old practice of raising homegardens which is a distinctive agroforestry practice in the tropics serves the food, fodder, fuelwood and timber requirement of the small households. The year-round accessibility to a variety of foods in homegardens not only aids in feeding a growing population during the off seasons, but also food diversity is being ensured (Kumar and Nair, 2004). In a study, conducted by Shankar *et al*. (1998) it was found the families under the observation for the study, had a considerable boost in the year-round production and intake of fruits and vegetables rich in vitamin was more compared to control group who didn't had homegardens. Due to the intake of all important nutrients and vitamins available through the fruits and

vegetables produced in homegardens like vitamin A, iron and iodine, the vulnerability of children towards xeropthalmia was reduced. In home garden systems, the inputs used are generally organic and easily available in the system and hence there is no need of addition of chemical fertilizer and high quality of output is obtained. Thus, there are ample evidences that agroforestry has a broader dimension and to reach the nook and corner of deprived population serving to achieve the second SDG *i.e* zero hunger (Table 1).

Large percentages of the populations of developing countries including India depend upon agriculture for their livelihoods and agriculture is the human enterprise that is most likely to be affected by climate change. The expected impact of climate change on agricultural production and its correlation with food security has been studied at many global forums *e.g*. United Nations Framework Convention on Climate Change (UNFCCC). More than 800 million people are chronically malnourished around the world, with 1,100 million living in dire poverty as per the report by Food and Agriculture Organization (FAO, 1999). Farmers in the developing world already facing a number of sustainability challenges and climate change will add to this more. For instance, climate change will have an impact on pest and disease occurrence and virulence in ways that are now unknown. Temperature and humidity have a profound impact on disease and insect populations and changes could affect their distribution and virulence. Agroforestry is a pretty good example of a combination of innovative activities that are aimed to boost productivity while also helping to mitigate climate change. Therefore, traditional agroforestry practices are studied and screened out to standardise the best tree-crop combination (Kang, 2000; Islam, 2021; Kumar *et al*., 2023). For example, in the arid regions of Rajasthan, studies were initiated in late 1970s, to find the most promising agroforestry systems that would suit the arid climate and would be best to get compatible with the existing agroforestry systems in the state. Silvipasture systems having *Lasiurus sindicus*, for example, is an efficient biomass builder with an energy consumption efficiency of 1.4-2 per cent (Harsh *et al*., 1992). The agri-horticulture system of Ber (*Zizyphus maurituana*) intercropping resulted in generation Rs. 8000 of net profit ha^{-1}, in contrast to sole intercropping of mungbean that resulted in generation of Rs. 4800 net profit ha^{-1}. Intercropping of *Hardwickia binata* and *Cenchrus ciliaris* have been reported to have more carrying capacity *i.e*., 4.1 sheep ha^{-1} $year^{-1}$, in contrast to sole cropping of *Hardwickia.binata* plantation having 1.6 sheep ha^{-1} $year^{-1}$ and monocropping of *Cenchrus ciliaris* pasture having a carrying capacity 3.7 sheep ha^{-1} $year^{-1}$ (Roy and Tiwari, 2012). The yield of Ziziphus based cropping system has been reported higher than the monoculture of either trees or crops by many workers in the arid region of Rajasthan. Intercropping in ber orchards increased intercrop grain yields by 5-20% above sole planting and intercropping appears promising,



(SDG 1- No poverty; SDG 2- Zero hunger; SDG 3- Good health and well-being; SDG 5- Gender equality; SDG 6- Clean water and sanitation; SDG 7- Affordable and clean energy; SDG 12- Responsible consumption and production; SDG 13- Climate action; SDG 15- Life on land) [Source: Adopted and modified from Van Noordwijk (2020)].

Fig 1: Agroforestry and sustainable development goals.

especially during the juvenile stage of fruit plantation with various annual food crops and pasture (Singh *et al*., 2013; Bhandari *et al*., 2014). Horti-pastural system having ber as main crop along with *Cenchrus ciliaris* was proved to be one of most beneficial combination, the production of dry grass was found to be 1.55 t ha^{-1} $year^{-1}$ (Vashishtha and Prasad, 1997). Similarly, in an aonla-based cropping system, it has been revealed that a model consisting of aonla + ber, moth bean or fenugreek can be successfully integrated as a sustainable model for the residents' nutritional and income security (Awasthi *et al*., 2007). In this way, agroforestry can be a gimmick tool for achieving the SDG goal 1 and 12 *i.e*. No poverty and responsible consumption and production respectively. As, just a few food crops account for 90% of the food calories and are cultivated as annual monocrop in vast tracts which are at a high risk of pest and disease outbreaks (Altieri, 1999). These monocultures are highly dependent on external inputs in terms of fertilizers and pesticides and eventually contribute to the global carbon footprint (Davis *et al*., 2012). Crop diversification with tree-based land use in the case of agroforestry systems has been a time-tested tool to mitigate the concerns of climate change. This gives long-term sustainability of the land in a rapidly deteriorating environment (Amundson *et al*., 2015).

Agroforestry has the potential to improve human nutrition by increasing the production and availability of very nutritious fruits and leaves, as well as diversifying farmers' meals in general which will lead to good health and well-being of rural people, hence achieving the SDG 3. Once the food security objective is achieved then food diversification and food sovereignty come next for uplifting people's quality of life. The culturing of fruit trees in the farms has the potential to have a substantial impact on the nutritional quality of children. Indigenous trees like *Adonsonia digitata* (baobab) and *Uapaca kirkiana* (wild loquat) as well as exotic plants like *Moringa oleifera* (drumstick tree) and *Psidium guajaya* (guava) are being promoted by agroforestry research and development organizations throughout Africa (Holmgren *et al*., 1994; Franzel *et al*., 2002). Some of these goods have a remarkable nutritional profile. The leaves and fruits of the baobab tree, for example, are high in beta carotenes and vitamin C, whereas the leaves of the *Moringa oleifera* tree are high in vitamin C and beta-carotene, as well as protein, phosphate, lipids and calcium. According to a study conducted by the World Agroforestry Centre and Hanover University in Zimbabwe, many households consume big amounts of fruit and earn a significant amount of money from indigenous fruits as reported by Jordaan *et al*. (2007). Growing healthy fruit and other food crops in agroforestry has numerous linkages to improving the health and nutrition of rural impoverished people. Fruit plants are the most significant component of agri-horticulture systems, as they provide a wealth of nutrients, vitamins and vital alkaloids. It has the potential to play a significant role in child nutrition.

Table 1: Examples of traditional agroforestry practices harnessed for food requirement.

Agroforestry system	Category of AF system	Region, Country	Major food crops obtained	Source
Homegardens	Agrisilvopastoral	Kerala, India	Banana, papaya, mango, jackfruit, coconut, annona, guava, brinjal, ladies finger, cow pea, amaranthus.	Peyre (2006)
Dehesa system	Agrisilvipastoral/ silvipastoral	Iberian Peninsula, Spain	Wild pear, strawberry, olive, mushrooms.	Joffre *et al*. (1999)
Zebo	Soil conservation hedges/Integrated farming system	Nagaland, India	Cucumber, okra, brinjal, tomato, bitter gourd, *Dioscorea* spp.	Bhatt *and* Bujarbaruah (2005)
Streuobst	Plantation cropcombination	Temperate Europe	Apple, pear, palm, mazard cherry, almond, sweet chestnut.	Herzog (1998)
Walnut fruit forest	Alley cropping	Jalal-Abad Region, South Kyrgyzstan	Walnut, wild and domesticated apple and pear, plum, apricot, pistachio, hawthorn, mushrooms.	Cantarello *et al*. (2014)
Parkland traditional agroforestry system	Multipurpose trees on farmland	Benin, West Africa	Mango, cashew, African baobab, *Diospyros* spp., *Citrus* spp.	Fifanou *et al*. (2011)

This is especially relevant given the overexploitation of indigenous fruit tree species in local forests.

Correlation of health with agroforestry for an all-round development has been identified as a feasible tool in a disadvantaged area of Africa and Asia. It has the ability to improve health, but community health has an impact on agroforestry. Many diseases and ailments affect the poor in developing countries and dependence on natural medicinal plants for treatment is common (Rao *et al*., 2004). People's health and nutritional state have an impact on how they use trees and other natural resources, the amounts and types of resources they use in their farming activities and how attractive various agroforestry systems are to them. Households afflicted by chronic disease or death are more likely to rely on woodland resources for food and income. Due to their delayed payoffs and high management needs, such households are likely to minimize their usage of purchased farming inputs and become deterred from adopting agroforestry systems. Natural medicines are also gaining popularity in the developed countries creating new and expanded markets for these products thus creating opportunities to domesticate medicinal trees and promote their cultivation on farms. Collaborative research programmes between agroforestry and the medicinal science will be a critical area to assist more economic benefits to farmers.

Economics of agroforestry systems which is more profitable than traditional cropping for income augmentation of farmers

Agriculture in India is a subsistence activity that is primarily reliant on natural resources and irrigation. Forests are natural, with patches of artificial regeneration and they are under a lot of stress. As a result, persons who rely on agriculture and forests for a living are economically disadvantaged. Agricultural development is therefore in the top priority to boost the nation's economy and ensuring a quality life of mass. International, national and regional level institutions are engaged to develop more economically beneficial cultivation systems in the farm in varied agro-climatic zone. Integration of diversified components *e.g*. horticultural crops, fodder crops, animals, apiary and aquaculture in different spatial and temporal arrangement is to reduce crop failure related loss due to extremities. Agroforestry has been recognized for nearly half a century as a sustainable agricultural practice which mimic's nature function and climate resilience. This approach to find agroforestry as an economically sound practice in harmony with different challenging environments, research has been carried out to show its potential profitability (Dagar *et al*., 2014). The vast geographic area of India supports a varied agro-climatic zone and in each zone profitable agroforestry system are present (Table 2).

The economics of different agroforestry systems is a matter of great interest as it directly decides and can be suggested to farmers for practice. Bhatt and Mishra (2003) conducted research in North Eastern India to better understand the possibilities, costs and benefits of agrihorticulture systems. Agrihorticultural systems with *Psidium* spp. produced a net return 2.96 times greater than identical systems without trees, according to this study. Guava-based agroforestry systems received an average net monetary advantage of Rs. 20,610/ha while Assam lemon-based agroforestry systems received an average net monetary benefit of Rs. 13,787.60/ha. Jaba *et al*. (2015) investigated the sources of income of tribal and non-tribal communities in Tripura West district; their studies reveal that revenues from tree crops (through AF) were significant in indigenous areas, averaging Rs. 24,075 per year. A study of an eight-year-old agroforestry intervention in Palamau District, Jharkhand, found that the community relied primarily on rainfed farming and that agroforestry interventions have a good impact on animal husbandry (Dwivedi, 2001). Crop yield and yield features of crops including pearl millet, Brassica spp. and beans have been observed to be significantly increased in *Prosopis cineraria*-based agroforestry systems (Kaushik and Kumar, 2003; Roy *et al*., 2011; Singh and Bishnoi, 2013). Agroforestry has played a significant impact on the livelihood of organic farmers. It has been found that the organic farmers generate a higher B:C Ratio when compared to inorganically cultivating farmers. (Padhmavathy and Poyyamoli, 2013). Survey on the traditional agroforestry systems in Gharwal Himalaya region by Bijalwan *et al*. (2011) found that the systems are mainly agrisilviculture, agrihortisilviculture and agrihorticulture in this area which is supportive and sustainable to the families, with a monetary gain of 20.24 percent above sole cropping. Meena (2015) found from the study in hortipasture, a combination of *Cenchrus setigerus* and ber plants produced a maximum gross return of (Rs.1,04,429 ha^{-1}), net returns of (Rs.72,029 ha^{-1}) with a benefit: cost ratio of (2.21). *Cenchrus ciliaris* and *Cenchrus setigerus* fodder grasses were raised with neem, Acacia and subabul trees in a study conducted in the drought prone Kachchh district of Gujarat. Under this system both grass output and tree growth (In combination with neem) were found to be superior (Dayal *et al*., 2009). Economically sound farmer obviously heads toward a quality life with better opportunity of health, education and other amenities.

Participatory and Industrial approach for augmenting profitability and popularizing agroforestry among farming community

The multi-various benefits and services generated are recognised as a tool to improve the livelihood status of farmers. Commercial agroforestry gained momentum in the regions where it got support from industry and assured market facilities. A well-known and solid example of output from agroforestry which is demanded for industrial purpose and hence giving economic security is from the promising Poplar based agroforestry system of Northern plain states of India *e.g*. Punjab, Haryana and Western Uttar Pradesh.

Table 2: Agro-climatic zone wise representative agroforestry systems in India and the economic gain from tree components.

Agro climatic zone in India	Agroforestry models	Area of adoption	Major economic output from tree component
AER 1	Mulberry based silvopastural system	Jammu and Kashmir, Himachal Pradesh and hill districts of UP	Green tree fodder for silkworm rearing.
AER 2	*Melia azedarach* based agri-silvicultural system	Gujarat, Kathiawar Peninsula, Western areas of Madhya Pradesh, Rajasthan, Haryana, Punjab and dryland region of Andhra Pradesh, Telangana	Timber from bakin.
AER 3	*Melia dubia* based agri-silvicultural system	Karnataka Andhra Pradesh and Tamil Nadu	Short rotation (10-12 years) timber.
AER 4	Ailanthus based agrisilvicultural system	Gujarat, Rajasthan, Bihar, Orissa, Uttar Pradesh, Madhya Pradesh, Maharashtra, Karnataka and Tamil Nadu	Timber from tree, pulpwood for paper industry and green fodder from tree.
	Shisham based Agrisilvicultural and silvi-pastoral System	Bundelkhand region of Uttar Pradesh and Madhya Pradesh and other arid and semi-arid region of the country	Timber of Shisham, fodder requirement of livestock.
	Aonla based agri-horticultural system	Bundelkhand region of Uttar Pradesh and Madhya Pradesh	Fruit from aonla, requirement by pharmaceutical companies.
AER 5	Melia (*Melia azedarach*) based agroforestry system	Karnataka, Maharashtra	Multipurpose tree, small timber/ pole purpose.
AER 6	Teak based Agrisilvicultural System	Karnataka, Maharashtra	Valuable timber, fuel and biomass for composting.
	Sapota-Teak based agroforestry system for hill zone of Karnataka	Karnataka, Maharashtra zone of Karnataka	Superior quality timber from teak and fruit from sapota.
	Tamarind basedSilvi-horticultural System	Karnataka, Maharashtra	Fruit and fuelwood from tamarind.
AER 7	Terminalia basedAgri-silvicultural System	Telangana and Andhra Pradesh	Medicinal purpose of *Terminalia bellirica* seeds.
	Tamarind basedAgri-silvicultural System	Dryland districts of Telangana and Andhra Pradesh	Tamarind pods.
	Mango based Agrihorticultural System	Telangana and Andhra Pradesh	Mango fruit has high demand in market.
AER 8	Block plantation of sandal wood	Eastern ghat parts of Odisha Andhra Pradesh, Tamil Nadu	Heart wood for carving, wood and root for oil extraction, sap wood in agarbatti industry, Ayurveda.
	Coconut (*Cocos nucifera*) based horti-pastural system	Kerala, Tamil Nadu andhra Pradesh and Karnataka	Edible oil, tender one used for drinks, fibre from the outer husk produces value added products.
AER 9	Poplar based agri-silvicultural system	Punjab, Haryana, Himachal Pradesh, Uttar Pradesh	Demanding for plywood industries and other timber based products.
AER 10	Bamboo based agri-silvicultural system	Bundelkhand region of Uttar Pradesh and Madhya Pradesh, Maharashtra and other arid and semi-arid regions of the country	Fodder, small timber, fuelwood and provide the raw material to pulp and paper based industries.
AER 11	Gmelina and eucalyptusbased agri-silvi-horticultural system	Chhattisgarh, Madhya Pradesh and West Bengal	Finest quality timber of *Gmelina arborea* for furniture and wood carving. Pulpwood of Eucalyptus is used in paper industry and essential oil is used for pharmaceutical product manufacturing company.

Table 2: Continue...

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AER 12	Mango basedAgri-horticultural System	Odisha	Mango is a major fruit which earns a substantial amount of return.
AER 13	*Dalbergia sissoo* based agri-silvicultural system	Uttar Pradesh, Bihar and entire state of Odisha	Best demanded for furniture industry, leaves used for fodder purpose.
AER 14	Grewia based agri-silvicultural system	Jammu and Kashmir, Himachal Pradesh and Uttarakhand	Fuelwood, fibre and edible fruits, medicinal purpose.
AER 15	*Litsea glutinosa* basedAgri-silvicultural System	Assam, Arunachal Pradesh and Nagaland	High commercial value, used as a binding agent in incense-stick industry and is being considered as the binding agent in tabletformulations and as plasters for fractured limbs.
	Bambusa balcooa based agri-silvicultural system	Assam, Arunachal Pradesh, Nagaland and West Bengal	Bamboo poles for multiple utilities and young shoots are edible.
AER 16	Agar based AgroforestrySystem	Assam, Arunachal Pradesh andNagaland	Agar wood yields the highly aromatic oil upon distillation
AER 17	Alder based agri-silvihorticultural system	Tripura, Mizoram, Meghalaya, Sikkim, Arunachal Pradesh and Darjeeling and Jalpaiguri districts of West Bengal	Used for firewood and charcoal making.
AER 18	*Gliricidia sepium* and*Leucaena leucocephala* based silvi-pasture system	Tamil Nadu	Used for fuel-wood, animal feed, green manure, shade, poles and living fences.
	Acacia mangium based agri-silvicultural system	Odisha	Wood is used for construction, boat building, particle board, furniture and cabinet making.
AER 19	Bamboo based agrisilvicultural system	Konkan Region of Maharashtra	*Dendrocalamus stocksii* (Munro.) is used by rural people for handicraft making, fodder and fencing.
	Jackfruit and Acacia basedSilvi-horticultural System	Kerala	Jack is a fruit yielding tree, yields timber and leaves is used for fodder purpose. *Acacia auriculiformis* for timber purpose.
AER 20	Coconut based hortipastural system	Tropical regions in Kerala, Islands of Lakshadweep and Andaman and Nicobar and other states in Indiathat enjoy a rain fall >2000 mm	Coconut fruit yield edible oil, tender one used for drinks, fibre from the outer husk produces value added products.

[Sourced and modified from Handa (2019)].

Presently 30 million trees of poplar, producing 1,125 million m^3 industrial wood annually are standing in UP, Uttaranchal, Haryana, Punjab, Himachal Pradesh and Jammu and Kashmir in combination with agricultural crops in various spatial patterns. This is equivalent to 60,000 ha pure plantation of poplar (@ 500 trees/ha). It is estimated that around 25,000 ha equivalent plantation of poplar are now being established every year in association with a number of agricultural and horticultural crops under a rotation of 6-8 years. In order to cover this much of acreage, 10 million ETPs (entire transplants) are being raised, though the demand would be around 13 million per year during the current decade. This shall create much needed employment to 40 million people only in plantations activities (Chandra, 2001). Through the cooperative agroforestry movement, 26,060 ha wastelands have been planted with MPTS in 17 years and have generated employment for 5.10 million human days @ 196/ha, of which 41 per cent were the women beneficiaries (IFFDC).

The drawbacks associated with the traditional seed-based progenies to construct agroforestry plantations can be overcome through production of clone-based genetic stocks which can substantially boost the productivity in the field as it leads to increased rooting percentage, high quality rooting system, uniform growth in the field, less gestation period (approximately half), requirement of lesser area and no requirement of growth hormones. Studies conducted at TNAU, by Parthiban *et al.* (2011) that the use of clone-based genetic stocks has resulted in a large boost in productivity, which has risen from less than 10 m^3/ha/year to more than 25 m^3/ha/year. Thus the production of clonal planting stock for large scale agroforestry and industrial plantation can be taken as an opportunity as a new enterprise. Increased agroforestry area and accompanying value chain development activities such as nursery development, plantation development, construction of felling institutions and organized marketing organizations have resulted in long-term employment and income generation. It is estimated that such activities arising from the agroforestry production to consumption system have generated 220-300 man days of employment per hectare of plantation establishment and 21.9 million man days of employment for the 75,000 ha of additional land brought under agroforestry plantations. This provides enormous socioeconomic benefits not just to agroforestry farmers, but also to other Production to Consumption System (PCS) value chain participants (Parthiban *et al*., 2021).

Contract tree farming is a new arena which will certainly boost the agroforestry farmers' income with a legally binding operation through a quadripartite model, which must then be converted into tripartite and bipartite models over time to ensure the model's long-term viability. The formation of Society for Afforestation, Research and Allied Works (SARA) by a paper company named West Coast Paper Mills Limited for sustainable supply of raw material in Dandeli, Gujrat has successfully reclaimed the degraded land and generated employments in 2001. Getting inspiration from this captive plantation project through CFF (Contract for farming) by formation of SARA more than 50,000 acres of degraded land has been converted to plantation through farmer's participation and with the mutual contract with WCPM and SARA has eased for selling the pulpwood from these plantations. Setting up hi-tech clonal nursery for satisfying the need of quality planting material of 5-6 millions of clonal ramets through clonal propagation technology was also opened a new way to enhance productivity and generate employments for rural communities of the associated farmers (Sharma *et al*., 2014).

The endorsement of value chain-based industrial agroforestry has gotten a lot of attention from the wood-based industries, tree-growing farmers and other value chain players, resulting in increased area, productivity, industry participation, socio-economic advancement and a better carbon sequestration process. This is the advance arena where policy makers need to focus for boosting the farmer's income and extension work by research institutes can surely give a new horizon of agroforestry practice.

Socio-economic and Integrated rural development through agroforestry and breaking the migration cycle of rural people

Small-scale, marginalized farmers and landless labourers, who are typically resource-poor and endure malnutrition as a result of protracted food and nutritional insecurity, make up the majority of migratory districts and those classed as "prone to movement." It has been estimate that yearly wages of INR 60,000-70,000 (USD 822-960) at home could protect families from the negative effects of migration says the World migration report (Lee *et al*., 2015). The NRCAF (2007) calculated that better AF systems could provide 943 million person-days of employment annually from 25.4 million hectares. Domestication of fruit trees as well as other species produced in agroforestry systems provides a great opportunity for poor people in the tropics to enhance their nutritional and economic security (Leakey and Tchoundjeu, 2001). In the Sikkim Himalaya, wild edible plants are an essential part of traditional diets, with around 190 species consumed and nearly 47 species traded on the local market. Carbohydrate content in wild edible fruit species ranges from 32 to 88 per cent (Sundriyal and Sundriyal, 2001). Farmers can end the cycle of hunger by planting trees on their farms and providing sufficient meals to their family. These new farming operations have raised revenues and given food security for many poor farmers in drought-stricken Cameroon, the Democratic Republic of Congo and Nigeria, especially during the 'hungry season.' To increase milk output, an estimated 200,000 smallholder dairy producers in East Africa use fodder trees as a source of high-quality, nutritional feed (UNEP, 2008). Small and dispersed estates characterize Uttarakhand's hill agriculture. Crop yields are low due to a lack of irrigation in conventional agricultural practices. Agricultural production is insufficient to meet even

half of the region's needs. As a result, individuals migrate out of this area in pursuit of work and remittances from relocated family members are a vital source of income (Samra *et al*., 1999). The types of community capacities and livelihood sources had a big impact on community reactions. Many casual employees lost their jobs when factories closed, for example and were compelled to return to or transfer their immediate families to their rural parents and relatives. The rural-urban migration was reversed and urban-rural migration became the primary, although transient, method of transportation. In any case, such returns must provide for their families upon returning and gathering wild foods and hunting to cover their basic requirements is becoming increasingly common. Findings of the study from the semi-arid western part of India *i.e*., Banswara district in Rajasthan and Dahod district in Gujarat where wadi AF was introduced found that AF had numerous benefits to the people and particularly to the condition of women group in this site (Bose, 2015). The BAIF Development Research Foundation's Wadi initiative, which began in south Gujarat in the 1980s, has since expanded to many tribal parts of India. Wadi is an agri-horti-silvi model and a comprehensive programme for natural resource management with the adoption of sustainable farming practices the eventually uplifts the rural communities providing livelihood security. A study of AF implementation in the Attappady block of Kerala, in the Nilgiri biosphere Reserve, reported significant improvements in the socio-economics, food and livelihood security of the people involved in the watershed area (Kumar, 2006). Adaptation of diversified agroforestry system in the arid zone of India where many environmental and climatic adversity exist, the CAZRI has developed suitable agroforestry model where shelterbelt plantation, fruit tree combination, fodder grasses and animal rearing all integrated for higher income. The introduction of *Cenchrus ciliaris* with Ber (6m×6m) orchard was very profitable where grass production was 1.55 t ha^{-1} $year^{-1}$ and the fruit, leaf fodder and fuel wood production from ber was 2.77, 1.87, 2.64 t ha^{-1} $year^{-1}$, respectively (Meena *et al*., 2019). *Melia azedarach* is reported to be a promising and suitable multipurpose tree species for improving livelihood to farmers of eastern Plateau and Hill region of India which is traditionally rice mono-cropping zone. The fast growing nature and short rotation period of 10 years the farmers can easily get a market price of 600-800 from sale of 6-8 year old tree (Sarkar *et al*., 2017).

Covid-19, had instant impacts or issues on the agro-ecosystems followed by disastrous consequences. The major agro-ecological sectors affected are agriculture, forestry, fishery, wildlife and water resources. In agriculture sector, decreasing labour supply was observed that led to poor productivity of agriculture, farming input supplies became limited that led to a total loss or decreased production and thus alleviating poverty (Khanna, 2020). Less disease and pest resistant crops were used due to non-availability of the good products and lockdown effect that led to non-movement of the people and thus inhibiting the transfer of products from and to nearby areas and thus the productivity is hampered to poor agriculture growth and effect of insecurity of food (Kumar *et al*., 2023; Gupta *et al*., 2021). In the forestry sector, the encroachment and illegal felling of high timber value species were done in order to fetch good amount of money to sustain the family needs that led to degradation in forest and thus generation of low ecosystem services (https://india.mongabay.com/2020/05/covid-19-lockdown-dents-the-economy-of-indias-forest-dwellers/). The pandemic has taught a great lesson that permanent and sustainable enterprise like agroforestry can be adopted by our small and marginal farmers for satisfying their basic needs and earning a more from tree derived products. It is the high time to take the lesson from this pandemic and establish resilience enterprises which will give a security to the rural people in terms of livelihood.

Way forward for securing financial risk to agroforestry farmers: Tree insurance for financial protection in case of adversity

Tree insurance has been introduced in order to help the farmers to safeguard their farm income and investments from natural calamities and fluctuating market prices. To get protection against a single hazard, single peril coverage and against multiple hazards, multiple peril coverage is provided. Taking into account, the grieve impact of nature on agricultural output since India's most part experiencing a tropical climate, a multi-peril insurance scheme has been launched. Presently, three insurance companies are taking this responsibility *i.e*. Oriental Insurance Bank, United India Insurance and Agriculture Insurance Company and the jeopardies covered, amount of premium and sum guaranteed differs from bank to bank.

Following are the several tree insurance policies of India (www.aicofindia.com; www.irdai.gov.in; Uthappa *et al*., 2015).

I. Agroforestry plantation insurance-

- This policy is offered by United India Insurance, Chennai. This is an annual policy.
- The sum assured is the input cost and a premium of 1.25% of the input cost is given.
- Species covered: C*asuarina, Eucalyptus, Ailanthus, Gmelina, Leucaena* and *Dalbergia sissoo*, *Melia dubia*.

II. Pulpwood tree insurance-

- This policy is offered by Agriculture insurance company of India. This is an annual policy.
- The sum assured is the equivalent to input cost and extended upto 125%-150% of input cost. The premium provided depends on species, risks, geographical location *etc.*
- Species covered: Poplar, Eucalyptus, Subabul and Casuarina.

III. Bio-fuel tree/plant insurance-

- This policy is offered by Agriculture insurance company of India. This is an annual policy.
- The sum assured is the equivalent to input cost and extended upto 125%-150% of input cost. The premium provided depends on species, risks, geographical location *etc*.

• Species covered: Jatropha, Karanja, Neem, Mahua, Callophyllum and Simarouba.

IV. Plantation/horticulture insurance-

• This policy is offered by The Oriental Insurance Company Limited. This is an annual policy.
• On the basis of cost of cultivation, the sum is being insured. The premium provided is 1.25% of insured sum.
• Species covered: Rubber, Eucalyptus, Poplar, Teak, Arecanut, coconut, citrus, chikoo, pomegranate.

V. Rubber plantation insurance-

• This policy is offered by Agriculture insurance company of India. The sum assured is on the basis of input cost and yield deduction. The premium provided depends on cost of input and stage of crop.
• Species covered: Rubber.

CONCLUSION

Agriculture has a historic challenge to feed a world population of 9 billion people by 2050 while avoiding negative environmental and social consequences. This century is the crucial to find a long-term sustainable agricultural system simultaneously conserving our environment for next generation, ensuring the basic needs of people and a financially satisfactory way of life to the farmers. Agroforestry research and development has paved the way for a potentially stable enterprise that can be a major boost to people's engaged in agriculture sector. Through crop diversification, intentional combination of multiple utility tree species and rearing of livestock is the key to food and nutritional security and agroforestry satisfies all these aim from farm. Due to the sustainable nature of agroforestry the food products obtained are substantially devoid from the residual effect of chemical pesticide which is an additional blessing for the consumer. Long-term sustainability of the land is achieved through agroforestry practice hence the soil remains productive for plants growing in perpetuity so economics for food production stay less. It has the ability to meet the demand of a small household to a larger mass giving a handsome income to farmers in our country. Uplifting of the socio-economic status of tribals throughout the length and breadth of the country is in the policy of several government agencies and agroforestry can be that transformative solution achieving this. Research and development to enhance the overall productivity of already existing traditional agroforestry through technical and policy level approach from top to bottom will boost the on-farm income from the multivariate components in these systems. The multiple benefits from agroforestry practice needed to be harvested to their full potential. It is no doubt that government policies and incentives have a huge impact on farmer's preference for adoption of agroforestry and allied systems. Institutional financing to agroforestry farmers through Nationalized banks, Regional rural banks, Co-operative banks with partnership of NABARD (National Bank for Agriculture and Rural Development) in line of agricultural farm credit (Kisan credit card, agriculture term loan) will be encouraging to farmers to practice agroforestry in a large scale. The economics of different profitable agroforestry systems are now clearly visible to scientific worlds and the future of agroforestry as a nation-building tool through people's participation lies on adapting agroforestry by the farmers. Also agroforestry based activities like production of quality planting materials, plantation activities, value addition of products based upon requirements and profitability can produce employment generation to rural people. Commercial agroforestry in this context plays a vital role in order to take agroforestry enterprises to an intense economic approach for assure profitability through involvement of industries and farmers. When farm income will be more stabilised, less risk prone to climatic factors it will discourage small and marginal farming family to migrate for livelihood search. Ultimately when our farmer's will be economically sound from there enterprises and from the experience and results where agroforestry has been testified to meet all the above discussed criteria for life quality enhancement. It is the golden hour to harness the opportunity for transforming a vast section of Indian farmer's quality of life.

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REFERENCES

Altieri, M.A. (1999). The ecological role of biodiversity in agroecosystems. Agric. Ecosyst. Environ. 74: 19-31.

Amundson, R., Berhe, A.A., Hopmans, J.W., Olson, C., Sztein, A.E. and Sparks, D.L. (2015). Soil and human security in the 21st century. Sci. 348(6235): 1261071. doi: 10.1126/science.1261071.

Awasthi, O.P., Saroj, P.L., Singh I.S. And More T.A. (2007). Fruit Based Diversified Cropping System For Arid Regions, CIAH Tech Bull, No 25, CIAH, Bikaner, Pp. 18.

Bhandari, D.C., Meghwal, P.R. and Lodha, S. (2014). Horticulture Based Production Systems in Indian Arid Regions. In: Sustainable Horticultural Systems [(eds.) Nandwani, D.]. Springer International Publishing, Switzerland. pp. 19-49.

Bhatt, B.P., Bujarbaruah, K.M. (2005). Intensive integrated farming system: A sustainable approach of landuse in eastern Himalayas. Technical Bulletin No. 46. ICAR Research Complex for NEH region, Umiam, pp. 43.

Bhatt, B.P. and Misra, L.K. (2003). Production potential and cost-benefit analysis of agrihorticulture agroforestry systems in Northeast India. J. Sustain. Agric. 22(2): 99-108.

Bijalwan, A., Mohan Sharma, C. and Kediyal, V.K. (2011). Socioeconomic status and livelihood support through traditional agroforestry systems in hill and mountain agro-ecosystems of Garhwal Himalaya, India. Indian For. 137(12): 1423-1431.

Bryden, J. and Bollman, R. (2000). Rural employment in industrialised countries. Agric. Econ. 22(2): 85-197.

Bose, P. (2015). India's drylands agroforestry: a ten-year analysis of gender and social diversity, tenure and climate variability. Int. For. Rev. 17(4): 85-98.

Cantarello, E., Lovegrove, A., Orozumbekov, A., Birch, J., Brouwers, N. and Newton, A.C. (2014). Human impacts on forest biodiversity in protected walnut-fruit forests in Kyrgyzstan. Journal of Sustainable Forestry. 33(5): 454-481.

Chandra, J.P., Chauhan, S.K., Sharma, R., Garg, R.K., Singh, K. and Saralch, H.S. (2011). Development of poplar based agroforestry system. Indian J. Ecol. 38(3): 1-14.

Dagar, J.C., Pandey C.B. and Chaturvedi C.S. (2014). Agroforestry: A Way Forward for Sustaining Fragile Coastal and Island Agro-Ecosystems. In: Agroforestry Systems in India: Livelihood Security and Ecosystem Services [(eds.) Dagar, J.C., Singh, A.K., Arunachalam, A.], Springer, New Delhi, pp. 185-232.

Davis, A.S., Hill, J.D., Chase, C.A., Johanns, A.M. and Liebman, M. (2012). Increasing cropping system diversity balances productivity, profitability and environmental health. Plos One. 7(10): e47149. doi: https://doi.org/10.1371/journal.pone.0047149.

Dayal, D., Shamsudheen, M. and Ram, B. (2009). Alternative farming systems suitable for Kachchh region of Gujarat. Regional Research Station, Central Arid Zone Research Institute, Kukma-Bhuj, Gujarat, pp. 22.

Dupraz, C., Talbot, G., Marrou, H., Wery, J., Roux, S. and Liagre, F. (2011). To Mix or Not to Mix: Evidences for the Unexpected High Productivity of New Complex Agrivoltaic and Agroforestry Systems. In: (5th World Congress of Conservation Agriculture Incorporating 3rd Farming Systems Design Conference). Brisbane, Austria, September, 2011. pp. 203-204.

Dwivedi, M.K. (2001). Apiculture in Bihar and Jharkhand-A study of costs and margins. Agricultural Marketing, Government of India, New Delhi. 44(1): 12-14.

FAO, (1999). The state of food insecurity in the world. Food and Agriculture Organization of the United Nations, Rome, Italy, pp. 35.

Fentahun, M. and Hager, H. (2010). Integration of indigenous wild woody perennial edible fruit bearing species in the agricultural landscapes of Amhara region, Ethiopia. Agrofor. Syst. 78(1): 79-95.

Fifanou, V.G., Ousmane, C., Gauthier, B. and Brice, S. (2011). Traditional agroforestry systems and biodiversity conservation in Benin (West Africa). Agrofor. Syst. 82(1): 1-13.

Franzel, S., Cooper P., Denning, G. and Eade, D. (2002). Development and Agroforestry: Scaling Up the Impacts of Research. Oxfam, GB, ICRAF.

Frison, E.A., Cherfas, J. and Hodgkin, T. (2011). Agricultural biodiversity is essential for a sustainable improvement in food and nutrition security. Sustain. 3(1): 238-253.

Garrity, D.P. (2004). Agroforestry and the achievement of the millennium development goals. Agrofor. Syst. 61(1): 5-17.

Gupta, A., Zhu, H., Doan, M.K., Michuda, A. and Majumder, B. (2021). Economic impacts of the Covid-19 lockdown in a remittance dependent region. Am. J. Agric. Econ. 103(2): 466-485.

Handa, A.K., Dev, I., Rizvi, R.H., Kumar, N., Ram, A., Kumar, D., Kumar, A., Bhaskar, S., Dhyani, S.K. and Rizvi, J. (2019). Successful agroforestry models for different agro-ecological regions in India. Central Agroforestry Research Institute (CAFRI), Jhansi and World Agroforestry (South Asia), New Delhi.

Harsh, L.N., Tewari, J.C., Burman, U. and Sharma, S.K. (1992). Agroforestry in arid regions. Indian Farming. 42(3): 32-37.

Herzog, F. (1998). Streuobst: A traditional agroforestry system as a model for agroforestry development in temperate Europe. Agrofor. Syst. 42(1): 61-80.

Holmgren, P., Masakha, E.J. and Sjöholm, H. (1994). Not all African land is being degraded: A recent survey of trees on farms in Kenya reveals rapidly increasing forest resources. Ambio. 23(7): 390-395.

IPCC, (2000). Land Use, Land-use Change and Forestry. Cambridge University Press, Cambridge, UK, A Special Report of the IPCC. pp 375,

Islam, K.K., Saifullah, M. and Hyakumura, K. (2021). Does traditional agroforestry a sustainable production system in Bangladesh? An analysis of socioeconomic and ecological perspectives. Conserv. 1(1): 21-35.

Jaba D., Taran, M. and Deb, S. (2015). Contribution of women in agroforestry practices of West Tripura, North-East India. Octa J. Environ. Res. 3(4): 343-351.

Joffre, R., Rambal, S. and Ratte, J.P. (1999). The dehesa system of southern Spain and Portugal as a natural ecosystem mimic. Agrofor. Syst. 45(1): 57-79.

Jordaan, D., Akinnifesi, F.K., Ham, C. and Ajayi, O.C. (2007). The feasibility of small-scale indigenous fruit processing enterprises in southern Africa. Indigenous fruit trees in the tropics: Domestication, utilization and commercialization. World Agroforestry Centre, Nairobi. pp. 273-287.

Kang, B.T. and Akinnifesi, F.K. (2000). May. Agroforestry as alternative land use production systems for the tropics. In Natural Resources Forum Oxford, UK: Blackwell Publishing Ltd. 24(2): 137-151.

Kaushik, N. and Kumar, V. (2003). Khejri (*Prosopis cineraria*)-based agroforestry system for arid Haryana, India. J. Arid Environ. 55(3): 433-440.

Khanna, A. (2020). Impact of migration of labour force due to global Covid-19 pandemic with reference to India. J. Health Manag. 22(2): 181-191.

Kumar, B.M. and Nair, P.R. (2004). The enigma of tropical homegardens. Agrofor. Syst. 61(1): 135-152.

Kumar, B.M. (2006). Land use in Kerala: Changing scenarios and shifting paradigms. J. Trop. Agric. 43: 1-12.

Kumar, P., Uthappa, A.R., Chavan, S.B., Chichaghare, A.R., Debta, H., Bhat, S. and Dagar, J.C. (2023). Achieving Biodiversity Conservation, Livelihood Security and Sustainable Development Goals Through Agroforestry in Coastal and Island Regions of India and Southeast Asia. In: Agroforestry for Sustainable Intensification of Agriculture in Asia and Africa Singapore: Springer Nature Singapore. (pp. 429-486).

Leakey, R.R. and Tchoundjeu, Z. (2001). Diversification of tree crops: Domestication of companion crops for poverty reduction and environmental services. Exp. Agric. 37(3): 279-296.

Lee, J.J. and Guadagno, L. (2015). World Migration Report 2015-Migrants and Cities: New Partnerships to Manage Mobility.

Meena, L.R. (2015). Productivity and economics of ber (*Ziziphus mauritiana*) based hortipasture system as influenced by integrated nutrient management under rainfed condition of Rajasthan. Forage Res. 41(3): 176-182.

Meena, L.R., Kumar, D., Meena, L.K. and Singh, S.P. (2019). Productivity and economics of ber (*Ziziphus mauritiana*) based horti-pasture system as influenced by integrated nutrient management under rainfed condition of Rajasthan. The Indian Journal of Agricultural Sciences. 89(2): 322-326.

Nair, P.K.R. (1993). An introduction to agroforestry. Springer Dordrecht.

NRCAF, (2007). NRCAF Perspective Plan Vision 2025. National Research Centre for Agroforestry, Jhansi, pp 46.

Parthiban, K.T., Seenivasan, R., Vennila, S., Anbu, P.V., Kumar, P., Saravanan, V., Kanna, S.U., Rajendran, P., Subbulakshmi, V. and Durairasu, P. (2011). Designing and augmenting pulpwood supply chain through contract tree farming. Indian J. Ecol. 38: 41-47.

Parthiban, K.T., Fernandaz, C.C., Sudhagar, R.J., Sekar, I., Kanna, S.U., Rajendran, P., Devanand, P.S., Vennila, S. and Kumar, N.K. (2021). Industrial agroforestry-A sustainable value chain innovation through a consortium approach. Sustain. 13(13): 7126. doi: https://doi.org/10.3390/su13137126.

Padmavathy, A. and Poyyamoli, G. (2013). Role of agro-forestry on organic and conventional farmers' livelihood in Bahour, Puducherry-India. Int. J. Agric. Sci. 2(12): 400-409.

Peyre, A., Guidal, A., Wiersum, K.F. and Bongers, F.J.J.M. (2006). Dynamics of homegarden structure and function in Kerala, India. Agrofor. Syst. 66: 101-115.

Rao, M.R., Palada, M.C. and Becker, B.N. (2004). Medicinal and Aromatic Plants in Agroforestry Systems. In: New Vistas in Agroforestry [(eds.) Nair, P.K.R., Rao, M.R., Buck, L.E.)], Springer, Dordrecht.

Roy, M.M., Tewari, J.C. and Ram, M. (2011). Agroforestry for climate change adaptations and livelihood improvement in Indian hot arid regions. Int. J. Agric. Crop. Sci. 3(2): 43-54.

Roy, M.M. and Tiwari, J.C. (2012). Agroforestry for climate resilient agriculture and livelihood in arid region of India. Indian J. Agrofor. 14(1): 49-59.

Samra, J.S., Dhyani, B.L. and Sharma, A.R. (1999). Problems and prospects of natural resource management in Indian Himalayas-a base paper. Problems and prospects of natural resource management in Indian Himalayas-a base paper. Hill and Mountain Agro-Ecosystem Directorate, NATP.

Sarkar, P.K., Das, B. and Bhatt, B.P. (2017). Bakain (*Melia azedarach* L.): A Promising Agroforestry Species for Improving Livelihood to Farmers of Eastern Plateau and Hill Region of India. ICAR, New Delhi, India.

Sharma, S.K. and Chopra, R.K. (2014). Agroforestry initiatives for capacity building and social security through captive plantations on degraded lands of farmers in State Karnataka, India. J. Agric. Sci. Technol. 4: 816-822.

Shankar, A.V., Gittelsohn, J., Pradhan, E.K., Dhungel, C. and West, J.K.P. (1998). Home gardening and access to animals in households with xerophthalmic children in rural Nepal. Food Nutr. Bull. 19(1): 34-41.

Singh, J. and Bishnoi, M. (2013). Performance of bean crops under Khejri (*Prosopis cineraria*) canopy in agroforestry systems of arid zone. Int. J. Agric. Sci. Res. 2(12): 318-321.

Sundriyal, M. and Sundriyal, D.C. (2001). Wild edible plants of the Sikkim Himalaya: Nutritive values of selected species. Econ. Bot. 55(3): 377-390.

UNEP (United Nations Environment Programme), (2008). Indigenous Knowledge in Disaster Management frica. UNEP. Compiled and edited by Peter Mwaura.

Uthappa, A.R., Chavan, S. and Handa, A.K. (2015). Tree Insurance: A New Initiative in India. Krishi Sewa.

Vashishtha, B.B. and Prasad, R.N. (1997). Horti-silvi-pasture systems for arid zone. Silvi-pastoral System in Arid and Semiarid Ecosystems. pp. 277-284.

Van Noordwijk, M. (2020). Agroforestry as Nexus of Sustainable Development Goals. In: IOP Conference Series: Earth and Environmental Science, Volume 449, The 3rd International Conference in Agroforestry (ICAF) Adopting Modern Agroforestry Toward Smart Social Forestry Program, IOP Publishing Ltd.

World Bank, (2016). Poverty and Shared Prosperity 2016: Taking on Inequality. The World Bank.