



POTENTIAL OF HORTICULTURE CROPS AND TREES IN AGROFORESTRY SYSTEMS IN INDIA

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Research Article

Received: **18.07.2022**

Accepted: **26.07.2022**

Published: **16.08.2022**

ABSTRACT

Agroforestry is a branch of science of a combined farming system of trees, crops, and animals on the same unit of land. Horticulture / tree-based agroforestry has been proven as an important tool for crop diversification. Tree and vegetable combination is new horticulture-based alley cropping system which maintains higher output and also boosts the economic status of the farmers, improves farmers livelihood on a sustainable basis, and provide employment throughout year. The horticulture-based alley cropping systems (agroforestry) combine perennial woody crops and non-woody crops, the vegetables are managed spatially to achieve both economic and environmental benefits of the farming system. The selection of crops is depending upon various factors like agro-climatic and edaphic conditions, crop root system, and water and nutrient requirement pattern and above-ground growth habits. There are several agroforestry systems based on fruit trees is practiced in whole part of the country according to local conditions. Fruit tree-based agroforestry system has significant roles in the livelihood improvement and it provides several ways to the income generation of household and supplementary food for smallholder farmers. These systems not only provide fruits but also fulfil the timber, food, fuel, and fodder requirement. Besides, they also generate employment, provide nutritional security, reduce greenhouse gas emissions, improvement on soil health and provide sustainable economic improvement of farmers.

Keywords: Agroforestry, Agri-horticulture, Alley Cropping, Greenhouse, Livelihood, Monoculture.

INTRODUCTION

Agroforestry and Horticulture are emerging thrust areas of agriculture sector in post green revolution period for food, wood, shelter, nutritional and environmental security (Bijalwan et al. 2015). In India, Trees and forests are an integral part of society and centre of aesthetic value. Foresters and agriculturists, who have conventionally worked within rather inflexible disciplinary boundaries concentrated on monoculture production of their preferred commodities of crops, animals, and overlooked trees for such mutual production systems. Agroforestry is indeed a very old practice. Farmers of the tropical area have a long tradition of growing food crops, trees, and animals together as well as manipulating multiple ranges of production from natural

wood lots. Agroforestry is capable for the conservation of natural resources through various systems under different agroclimatic zones (Dhyani *et al.*, 2009). In temperate agroforestry systems, cereals, pulses and vegetable crops are intercropped with fruits, fodder and fuel wood yielding trees (Malik *et al.*, 2010). By the end of the 19th century, establishing forest or agricultural plantations had become an important objective for practicing agroforestry. Agroforestry is also playing the most important role in maintenance of the the resource base and increasing overall productivity in the rainfed areas in general and the arid and semi-arid regions in particular. A common hypothesis is strongly implied to the agroforestry systems that integration of trees with annual crop increases the overall productivity of system. However,

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some studies have shown reduction in crop yield when grown with the tree plantation (Malik *et al.*, 2010). In the wasteland have much more scope for introducing fruit trees as horti pasture system for monetary gain and higher forage production. An area of 14 M. ha of rainfed lands can be also develops for the use of horti pasture system (Dhyani *et al.*, 2009). Agroforestry has a huge potential for simultaneously fulfilling three important objectives viz., protecting and stabilizing the ecosystems; producing a high level of output of economic goods; and improving income and basic materials to the rural population (Dhyani *et al.*, 2018). Agroforestry systems are now a days promising as management practices to carbon sequestration by increasing aboveground and soil C stocks to mitigate greenhouse gas emissions. In tropical home gardens of Kerala, average aboveground standing stocks of C ranged from 16 to 36 Mg ha⁻¹, where small home gardens often have higher C stocks on unit area basis compared to large- and medium-sized. In soils,

within 1 m profile, soil C content ranged from 101.5 to 127.4 Mg ha⁻¹. Smaller sized home gardens (0.4 ha) (108.2 Mg ha⁻¹) 34. The apple-based cropping systems in which the cereal–cereal combination is integrated is useful as a strategy for mitigating the atmospheric CO₂ (Dhyani *et al.*, 2016). There are a number of tree crop combinations, which in turn reveal the differences in the climates and soil fertility of various regions in the country.

❖ **Agroforestry systems:**

A. There are 4 or 5 basic sets of components which are found in all agroforestry system. Structurally, the system can be grouped as:

1. Agri-silviculture system
2. Silvi-pastoral system
3. Agri-Silvipastoral system
4. Other or specialized systems.

Table 1: The following common agroforestry systems are being practiced on basis of nature in different agro-ecological regions in India (Dhyani *et al.*, 2018):

1.	Agri-silviculture (trees + crops)
2.	Boundary plantation (tree on boundary + crops)
3.	Block plantation (block of tree+ block of crops)
4.	Energy plantation (trees + crops during initial years)
5.	Alley cropping (hedges + crops)
6.	Agri-horticulture (fruit trees + crops)
7.	Agri-Silvi-horticulture (trees + fruit trees + crops)
8.	Agri-Silvi-pasture (trees + crops + pasture or animals)
9.	Silvi-olericulture (tree + vegetables)
10.	Horti-Pasture (fruit trees + pasture or animals)
11.	Horti-olericulture (fruit tree + vegetables)
12.	Silvi-pasture (trees + pasture/animals)
13.	Forage Forestry (forage trees + pasture)
14.	Shelter-belts (trees + crops)
15.	Wind-breaks (trees + crops)
16.	Live Fence (shrubs and under- trees on boundary)
17.	Horti-Apiculture (fruit trees + honeybee)
18.	Silvi or Horti-sericulture (trees or fruit trees + sericulture)
19.	Aqua-Forestry (trees + fishes)
20.	Homestead or Home Garden (multiple combinations of trees, fruit trees, vegetable etc).

1. FRUIT- TREE BASED AGROFORESTRY SYSTEMS:

Agri-horticulture:

The accurate assessment of area under different agroforestry systems is quite difficult. The area under agroforestry in country is estimated at 25.32 M. ha, or 8.2% of total geographical area of the country (Dhyani *et al.*, 2013). The Agri-horticulture system is one of the agroforestry systems that integrate the cultivation of arable crops and fruit trees. Because of higher economic value, Agri-horti system has the first position in the farming system research and development. The estimated area of agri-horticulture in india is 4.65 M. ha, while home garden is 2.42 M. ha (Dagar *et al.* 2014). In this system fruit species like *Embilica Officinalis*, *Psidium Guajava* and *Ziziphus mauritiana* are planted in fields and agricultural crops are grown between rows of tree species. The adoption rate of the agri-horticulture system is more when compared to other systems on account of risk distribution. Horticulture based production systems are now considered to be the most ideal strategy to provide food, nutrition, and income security to the people (Reddy *et al.*, 2018). The importance of horticulture in improving the productivity of the land, generating employment, improving economic conditions of the farmers and entrepreneurs, enhancing exports and above all, providing nutritional security. Handa *et al.* (2016) found in kinnow based horti-agriculture system is very profitable and provide an average gross income of Rs. 50,000 to Rs. 1,00,000 per acre. The fruit trees take a long time to bear fruits and are generally spaced widely. Till they grow and cover the entire land, farmers raise cereals, pulses, vegetables, tubers, medicinal and aromatic plants, and fodder in the interspaces. Papaya and dwarf varieties of banana are also inter cropped depending on the edaphic conditions. There is number of fruit-based agroforestry systems have been developed in all the region of the country. The higher net return from agri-horticulture system than the sole cropping system recorded by Malik *et al.* (2010).

Agri-horti-silvi system:

In this system, horticultural crops, silvicultural plantations, and fodder crops are being grown together on the same unit of land. Drought hardy fruit crops can survive and provide income to the farmers even under severe drought (Kumar *et al.*, 2019). Silvicultural plantations would check the drift of sand, provide forage, fuel, and timber and would help in creating suitable micro-climatic conditions. Some study reveals that the annual production of woody biomass in cardamom-based agroforestry ranges between 4.5 to 5.5 t/ha which is more than five times the fuel wood requirement for curing (Handa *et al.* 2016) indicating the profitability of the system. In this system fruit species like aonla, guava and ber are planted in association with Casuarina and Eucalyptus hybrids separately. Agricultural crops are grown between rows of tree species.

Horti-pastoral system:

It is a traditional farming system mainly adopted in dry areas. Grasses are grown in the fruit orchard for rearing cattle in this system. This model is also adopted as an alternative land-use system in northern regions of India. Farmers of these areas mostly like to grow fruit trees like *Psidium Guajava*, *Mangifera Indica*, *citrus*, *pomegranate*, *Embilica Officinalis*, etc. and rear small cattle that graze on pastures. Hybrid varieties of fruit trees are being grown and farmers earn money from selling fruits, milk, and other different products. In the horti-pastoral system, fruit trees usually form the first tier whereas grasses are grown as ground tier crop. Kumar *et al.* (2019) studied that the benefit cost ration of hortipastoral system over 10 year was 1.85 for pure pasture and 3.70 with the system along with the higher production of pasture in intercropping with the system.

2. Horticulture species for Agri-horticulture system:

Horticulture covers all the practices of fruit, vegetables, flowers, etc. Vegetable crops recommended, in alley cropping, are short durational and shade-loving crops with high

efficiency of photosynthesis and biological fixation (Singh *et al.*, 2018). A large number of varieties have been identified and developed for commercial cultivation. There are various vegetables crops is rich in various region and suitable for their cultivation practices such as *Momordica*, *Cucumis*, *Trichosanthes*, *Luffa*, *Coccinia*, *Solanum*, *Capsicum*, *Vigna*, *Lablab*, *Pisum*, *Colocasia*, *Amorphallus*, *Dioscoria*, *Abulmoschus*, *Basella*, *Beta*, *Corriandum*, *Trachyspermum*, *Rumex*, *Nigella*, *Lepidum*, *Foeniculum*, *Euryale*, *Trapa*, *Bamboosa*, *Curcuma Longa*, *Zingiver*, *Chenopodium* etc.

The production of horticultural trees as intercrops was found to be more effective for improvement in soil fertility and productivity (Verma *et al.*, 2017). For agri-horti system these are some important fruit tree species are used in various region: *Emblica officinalis*, *Mangifera indica*, *Tamarindus indica*, *Artocarpus heterophyllus*, *Psidium guajava*, *Musa spp*, *Carica papaya*, *Syzygium cuminii*, *Aegle marmelos* etc. Among the vegetable crops *Solanum melongena*, *Lagnaeria siceraria*, *Luffa acutangula*, *Luffa cylindrica*, *Citrullus lanatus*, *Citrullus*

lanatus var. fistulosus, *Cucumis melo var. utillismus*, *Cucumis melo var. momardica*, *Cucumis callosus*, *Moringa oleifera*, *Cymopsis tetragloba* and *Vigna unguiculata* are suitable for horticultural based farming systems (Kumar *et al.* 2012). Hasan *et al.* (2020) conducted an experiment to determine the economic evaluation of lemon based agroforestry system and compared with the sole cropping system and found high rate of net return with good benefit cost ration in agroforestry system. Agri-horti system comprising of *Ziziphus*+mung bean provides fruit, fuel wood and round the year employment even in below average rainfall years. Pomegranate has been found compatible with pearl millet, mung bean, isabgol, sorghum. Floriculture is another important area where skilled manpower is needs even for management of flori farms and all the high value crops like carnation, gladiolus, anthurium, rose, and all these are managed under protected cultivation unit. Horticulture and horticulture-based cropping pattern give best land utilization options and provides benefits to the farmers in various area of the country (Kumar *et al.* 2012).

Table 2: Estimated area under different agroforestry systems in India. (Dagar *et al.* 2014).

Category	Area (million ha)	Remark
Agroforestry in irrigated areas		
Agri-silviculture	2.63	Industrial use
Agri-horticulture	2.79	Fruit orchards/fruit tree based cropping systems
Tree on field boundary or bunds	1.58	Social forestry, live fences, etc.
Sub-total (A)	7.00	
Agroforestry in rainfed areas		
Agri-silviculture	2.40	Scattered trees on fields, bunds, boundaries
Agri-horticulture	1.86	Fruit orchards/fruit tree based cropping systems
Tree on field boundary or bunds	0.74	Social forestry, deliberate live fences, etc.
Silvo-pastoral	5.58	Trees on grazing/range lands
Sub-total (B)	10.58	
Other land use		
Home garden	2.42	Mostly in coastal areas and N-E states

Shifting cultivation	2.27	Mostly in NEH States, Orissa, Andhra Pradesh
Afforestation of problem Soils	2.12	Plantations on salty soils, mine areas, etc.
Tree on Common land	0.92	On Panchayat lands, along roads, railways, etc.
Sub-total ©	7.73	
Total Agroforestry area(A+B+C)	25.31	
Agroforestry as % of total reporting Geographical Area	8.28	

Significance of fruit tree-based agroforestry system:

Carbon sequestration: Different agroforestry systems sequester carbon both above and below the ground by enhancing soil carbon and root biomass and by storing it in standing biomass. Agroforestry has higher potentials for carbon sequestration and its mitigation due to multiple plant species in both belowground in the form of addition of soil carbon and root biomass and aboveground as carbon stored in plant biomass (Murthy *et al.* 2013). Dhyani *et al.* (2009) found that agroforestry systems have a greater capacity to store carbon than monocropping, with carbon sequestration in monocultures of trees and food crops being respectively 40% and 84% less than that of agri-silviculture. The incorporation of leaf litter and addition of decomposed roots to upper surface of soil is mainly responsible for the greater accumulation of soil organic carbon (Khaki *et al.* 2016). Samra and Singh (2000) studied in 5 years old agri silvi culture system, there was a 0.39 to 0.52% increase in soil organic carbon status of surface soil under *Acacia nilotica* + *Sacchram munja* and a 0.44 to 0.55% increase under *Acacia nilotica* + *Eulaliopsis binata*. Jha *et al.* (2001) revealed that up to 30 cm of soil depth, agroforestry could store roughly 83.6 tC/ha, 26% more carbon than farming in the Haryana plains. The cultivation of fruit tree with agriculture crops and timber tree can enhanced the amount of carbon sequestration. The capacity of carbon storage differs from region to region and depend upon tree growth and nature of tree species which is involved in system (Tanwar *et al.* 2019). Several studied shows that fruit tree-based agroforestry system have great potential to carbon sequestration.

Beneficial for soil: Agroforestry is the best scientific method for Eco restoration of damaged areas and sustainable resource management (Tripathi *et al.* 2009).

Fruit-tree based agroforestry system has primary objective is to conserve soil and enhance the productivity of soil by adding organic matter from litter fall and crop residues. The leaf litter from agroforestry practices helps to forms humas after decomposition and enhance soil properties and reduce soil erosion and by thus loss of nutrients also (Murthy *et al.* 2013). There is various agroforestry system such as agri-horticulture, horti-pastoral, agri-pastoral and silvipasture etc has been found very much potential for management and restoration of soil fertility (Prasad *et al.* 2019). There is various agroforestry system that play a significant role in enhancement of Soil organic carbon, nitrogen fixation and improvement of soil productivity by addition of leaf litter and decomposition (Bhatt *et al.* 2006).

Conservation of Biodiversity: Due to higher extraction of natural resources biodiversity has been affected very badly and has major challenge is for preservation and sustainable production. Fruit tree-based agroforestry system play important role for biodiversity conservation by providing all kind of life supports like shelter, food, favourable habitat, etc (Prasad *et al.* 2019).

Improvement of income and livelihood: Horticulture based agroforestry system provides fruit, fuelwood, timber, fodder for livestock, green manure by which farmers can increase their income and improve socio-economic status. Many underutilized fruit species play an important role for income generation of small, marginal and landless farmers (Kumar *et al.* 2019). Handa *et al.* (2016) reported that A horti-agricultural system based on kinnow is very economical. A Kinnow plantation typically yields an average gross revenue of Rs.50,000 to Rs.1,00,000/acre (Rs.125000-250000/ha) after 6-7 years, depending on tree density and management. Kumar and

Nair (2006) studied that the application of agroforestry system in the Attappady block of Kerala's Nilgiri Biosphere Reserve found that the socioeconomic, food, and livelihood security of individuals affected had significantly improved. In other study Bhatt and Mishra (2003) when compared to farmlands without trees, the guava and lemon-based agri-horticultural systems in the northeast Indian state of Meghalaya and Assam yield better net returns. The average net financial advantage of guava-based agroforestry systems was Rs. 20,610/ha, while the average net financial benefit of lemon-based agroforestry systems was Rs. 13,787.60/ha respectively.

Agroforestry system for employment: A significant rise in the number of small-scale enterprises dealing with wood and wood-based products has been brought on by an increase in the supply of wood (Handa et al. 2016). Bamboo based agroforestry system has a great

potential to provide employment both in the industrial sector and in rural areas. It has the potential to employ and pay a sizable number of people, particularly women who can work flexible hours close to their homes (Shashank et al.2018). The impact on livelihoods, including the creation of income and employment, is one of agroforestry's key economic benefits (Handa et al. 2016). Handa et al. (2016) and NRCAF (2007) reported that the 25.4 Mha of agroforestry has the potential to increase employment by up to 943-million-person days each year. Numerous business corporations, limited companies, such as ITC, WIMCO, West Coast Paper Mills Ltd., Hindustan Paper Mills Ltd., and financial institutions, such as IFFCO, have entered the market on a large scale and have started agroforestry activities in cooperation with farmers after realising the potential of agroforestry (Dhyani et al. 2009).

Table 3: Employment generation potential through agroforestry systems.

Agroforestry system	Area (million ha)	Additional employment generation/ha/yr (Person days)	Total employment/yr (million person days)
Silviculture	1.8	30	53.3
Agrisilviculture (Irr.)	2.3	40	91.3
Agrisilviculture (RF)	1.3	30	38.0
Agrihorticulture (Irr.)	1.5	50	76.1
Agrihorticulture (RF)	0.5	40	20.3
Silvipasture	5.6	30	167.4
TBOs	12.4	40	497.1
Total	25.4		943.4

Source: NRCAF (2007)

Table 4: Agroforestry systems developed by ICFRE for different agro-climatic regions.

S.No.	ACZ	Area under	Tree species	Agricultural crop	Agroforestry system
1.	Trans-Himalaya Region	Ladakh, Lahaul-Spiti, Kinnaur, Pangi tehsil of Chamba from Himanchal Pradesh.	<i>Malus Domestica</i> , <i>Salix</i> Spp. and <i>poplar</i> Spp. etc.	<i>Triticum Aestivum</i> , <i>Hordeum Vulgare</i> , <i>Buck Triticum Aestivum</i> , <i>Amarantbs</i> , <i>Solanum Tuberosum</i> , <i>Pisum Sativum</i> etc. <i>Prunus</i> , Spp.	Agri-horticulture, Silviculture, Horti-medical, based agroforestry system.
2.	Western Himalayan Region and Indo-Gangetic Plain	Jammu, Kashmir, Himachal Pradesh, Uttarakhand, Uttar Pradesh, Haryana and Punjab	<i>Melia</i> , <i>Prunus</i> , <i>Embilica Officinalis</i> , <i>Eucalyptus</i> , <i>Poplar</i> , <i>Morus alba</i> , <i>Alnus</i> , etc.	<i>Oryza Sativa</i> , <i>Triticum Aestivum</i> , <i>Cardemon</i> , <i>Pisum Sativum</i> , <i>Brassica</i> , <i>Coffee</i> , etc.	Agri-silvi-medical Agri-silviculture Agri-horticulture system

3.	Eastern Himalayan Region	Arunachal Pradesh, Assam, Sikkim, Meghalaya, Nagaland, Manipur, Mizoram, Tripura, and Darjeeling district of West Bengal	<i>Gmelina, Cadamba, Pinus, Coconut, Malus Domestica, Mangifera Indica, Eucalyptus, Psidium Guajava</i> , etc.	King chilli Arecanut, <i>Curcuma Longa longa, Vigna Unguiculata, Oryza Sativa, Zea Mays</i> , etc.	Agri-silviculture, Spice-horticulture system, Agri-silviculture, Horti-agriculture, Agri-horti-silviculture system.
4.	Gangetic Plain Regions	Uttar Pradesh, Bihar and West Bengal	Eucalyptus, Albizia lebbbeck, Psidium Guajava, D. Sissoo, Poplar, Papaya, Neem, Embilica Officinalis, Litchi, Mangifera Indica, etc.	<i>Curcuma Longa, Ginger, sesamum, Colocasia, Elephant foot yam, Triticum Aestivum, Zea Mays, sesamum, Sorghum, Banana</i> , etc.	Agri-silviculture, silvi-horticulture, Agri-horticultural System.
5.	Plateaus	Maharashtra, U.P., Orissa, West Bengal MP, Rajasthan, Andhra Pradesh, Karnataka, Tamil Nadu	Tectona Grandis, Embilica Officinalis, Dalbergia, Flemingia, Tamarindus indica, Sapota, Babul, etc.	<i>Bamboo, Bach, Psidium Guajava, Curcuma Longa, Sesamum, Triticum Aestivum, Vigna mungo, Vigna Radiata, Oryza Sativa, Gossypium</i> , etc,	Silvi-medicinal, silvi-agriculture, agri-medicinal, Agri-lac culture, Agri-horticulture system.
6.	Western Dry Region	Rajasthan, West of the Aravalli's, Gujarat and Dadar-Nagar Haveli.	Embilica Officinalis Prosopis Zizyphus Sesbania etc.	Hordeum Vulgare, Vigna Unguiculata, Cenchrus Cilliaris, etc.	Agri-silviculture, Agri-horticulture, and Silvi-horticulture system, TBOs
7.	Coastal Plains and Ghats	area of Coromandal and northern Circar coasts of Andhra Pradesh and Orissa, Malabar and Konkan coastal plains and Sahyadris	<i>Casuarina, Alianthus, Moringa, Tectona grandis, Acacia mangium, Cocos</i> , etc.	<i>Zea Mays, Moong, cajanus cajan, Vigna species, Pepper</i> , etc.	Agri-silviculture, agri-silvi-horticulture system, agri-silviculture system, and Silvi-horticulture system.

CONCLUSION

Agroforestry is both economically and ecologically more complex form of land management than pure agriculture or forestry system. Horticulture tree-based agroforestry system is an important tool for food and wood production and environment protection. Agri-horticulture, Horti-olericulture, Silvi-olericulture, Horti-pasture, Horti-Silviculture, Horti-Entomoforestry, and Horti-Pisciculture are some recommended for farmers which are beneficial for farmers as well as climatic change mitigation. Legume tree offers advantages to the horticultural crops, and mitigates challenges mainly related to the growing population, climate changes, and loss of biodiversity. Diversifying nature of Agri-horticulture system allows farmers to make the best use of their land by maximizing the crop yields as well as diversify income and reduces the loss of farmers. Agroforestry has various direct impact on foods that can be gathered, and fodders for livestock's, income generation for

rural people, and provide many directly and indirectly environmental services. Farmers can get employment through out the year which helps in improvement of their livelihoods.

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