

Agroforestry

in the context of improved production and climate change in Himalaya

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In the national food security and environmental security, the role of agroforestry is imperative, besides in achieving land degradation neutrality. Agroforestry is the incorporation of woody perennials and annual agricultural crops and/or animals on the same piece of land for sustained and improved production. The indirect benefits are more as compared to direct benefits from agroforestry land management. The agroforestry supports the very existence of human, as there is a saying that “woody perennial improve water availability; water will help food availability and food availability will help human existence”. It gives us food, fuel, fodder, shade and timber, and improves the fertility of land as well as increase water availability, prevents soil erosion and help in maintaining environmental balance.

Keywords: Agroforestry, Climate change, National agroforestry policy (2014)

TO meet the needs of the growing population conflict between forest and agricultural land has increased. Therefore, it is necessary to produce both agricultural and forestry products on the same piece of land to meet the increasing demand for different products. Agroforestry is not only a large and low cost opportunity to mitigate climate change, but also provides other services to the community. Tree converts atmospheric carbon dioxide (CO₂) into carbon molecules through photosynthesis in leaves, which is responsible for the growth of tree. One kilogram of dry wood contains ~0.5 kg carbon. According to IPCC (2003), tropical wet forest have carbon in above ground biomass of 65-430 t ha⁻¹ and 44-130 t ha⁻¹ in soil.

Tree provides leaves as manure for agriculture and provides food and fodder for human and animal. It helps in self-catering, reduce the risk, and provide appropriate environmental crops and the market for products. The agroforestry is a blessing especially to the small and marginal farmers that provides various benefits and windfall profits due to different harvest timings of produce. The greatest significance of

agroforestry is that the farmer's family can adopt it as a good activity without changing their business and trees are very cooperative in the agroforestry. In agroforestry, we should choose trees with a short life cycle and fast growing in nature. Our country's diversified climate, different agricultural conditions and abundant wasteland in villages has to be considered while implementing various systems of agroforestry. Various agroforestry practices can be used to get benefits based on need, climate of the place and utility.

Provision of agro-forestry-based industries in the National Agroforestry Policy (2014), will give a major boost to agroforestry. The policy envisages that agroforestry enhances farm productivity, generate employment and provides opportunities to rural households for livelihood especially to smallholder. The promotion of agroforestry as per policy will help in meeting the rising demand of timber food, fuel, fruit, etc., natural resource conservation, increase forest cover and strive the change in climate. The increasing population and urbanization have impact on forests loss, increased soil erosion and atmospheric pollution. Therefore, at present, the agro-

forestry tree planted portion will not only prevent soil erosion but also increase productivity and maintain environmental balance.

Various forms of agroforestry practices

Agroforestry systems can be classified in various forms according to composition and local needs as given below:

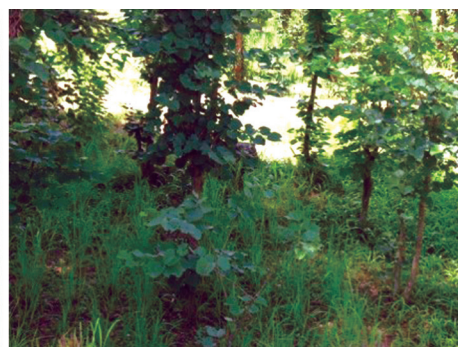
- **Agrisilviculture:** Production of agricultural crops in between the rows of forest trees.
- **Agrihorticulture:** Production of agricultural crops in between the rows of fruit trees.
- **Agrihortisilviculture:** Production of agricultural crops in between the rows of fruit bearing trees as well as fodder trees planted on farm bunds.
- **Silvihorticulture:** Shade-loving horticultural crops are grown with fodder trees.
- **Silvimedical:** With fodder trees, the shade-loving medicinal plants are grown.
- **Silvipastoral:** In this method, fodder crops are grown with forest trees to ensure fodder requirement of the animals.
- **Hortipastoral:** In the interspaces of the fruit trees and grasses are cultivated.



Fig. 1. (a) Silvihorticulture
(Fodder trees + Turmeric)



(b) Agrihorticulture
(Pecan + Agricultural crops)



(c) Silvipastoral
(Fodder trees + Improved grasses)

- **Aquaforestry:** In this multipurpose trees are planted along the pond boundary. This type of plantation on the banks of the pond leads to soil stabilization of pond bund and helps in fulfilling feed requirement of fish from falling leaves, flowers and fruits in water.
- **Homegarden:** The farmer plants fruit and forest trees in nearby lands, to meet their daily needs and also protect the animals from the sun and rain, etc.

Importance of agroforestry

Agroforestry has the ability to increase productivity, keeping the balance of nutrients as well as have the ability to protect nature. It plays two main roles, one is production and other protection services. In fact, agroforestry is a collective name of land-use systems and technologies in which the woody perennial, tree, shrubs etc., are deliberately planted on the same piece of land management with agricultural crops and livestock in some form of sequence and space. Agroforestry not only increases the production of food, forage, fuel, fruits, vegetables, wood but also increases income and in addition generate employment as well as farmers can improve their economic situation. Agroforestry systems trees play important role in sustaining agriculture as well as in protecting the environment. Plantation helps in salinity reduction, improvement in soil fertility, soil erosion control, swamp (waterlogging) control, catchment eutrophication reduction, expected to decrease in acidity, increase local biodiversity and decrease the greenhouse gas effects. Increase in the number of trees under agroforestry would also reduce noise

pollution because the tree can bring down the noise level to around 90%. Agroforestry is capable of removing Sulphur-dioxide (SO_2) @ 0.39% per ha per year and ~9.8 tonnes soil particles per ha are absorbed.

Trees suitable for agroforestry

Pecan nut (*Carya illinoensis*), hill lemon (*Citrus limon*), pear (*Pyrus communis*), plum (*Prunus domestica*), peach (*Prunus persica*) and apricot (*Prunus armeniaca*) fruit-trees are very useful for agroforestry. Fruit trees whose leaves fall off in winter have a special significance in agroforestry. Shade-loving such as colocasia (*Colocasia esculenta*), turmeric (*Curcuma longa*) and ginger (*Zingiber officinale*) can be grown under the shade of trees. Fodder trees such as *Grewia optiva* (Bhimal), *Quercus leucotrichophora* (oak), *Bauhinia variegata* (Kachnar), *Morus alba* (Shahtut), *Melia azedarach* (Bitain) and *Celtis australis* (Kharik) are also very useful for agroforestry plantation.

Crops which can be grown with trees

Grain and pulses: Wheat (*Triticum aestivum*), peas (*Pisum sativum*), maize (*Zea mays*), soybean (*Glycine max*), finger millet (*Eleusine coracana*), lentil (*Lens culinaris*) etc.

Vegetables: Brinjal (*Solanum melongena*), cabbage (*Brassica oleracea* var. *capitata*), carrot (*Daucus carota*), okra (*Abelmoschus esculentus*), potato (*Solanum tuberosum*), peas (*Pisum sativum*), radish (*Raphanus sativus*), tomato (*Solanum lycopersicum*) etc.

Spices: Coriander (*Coriandrum sativum*), pepper (*Piper nigrum*), ginger (*Zingiber officinale*), turmeric (*Curcuma longa*) etc.

Medicinal plants: Basil (*Ocimum basilicum*), periwinkle (*Catharanthus*

roseus), withania (*Withania somnifera*), Safed Musli (*Chlorophytum borivilianum*), satavari (*Asparagus racemosus*), brahmi (*Bacopa monnieri*) etc.

Grasses: *Digitaria decumbens*, *Cynodon plectostachyus*, *Panicum coloratum*, *Panicum repens*, *Setaria kazungula*, *Pennisetum purpureum*, *Lolium perenne*, *Festuca arundinacea* etc.

Ways to increase carbon storage

Carbon sequestration can be enhanced by adopting plantations through agroforestry. Loss of carbon storage can be prevented by reducing felling of forests, blocking or reducing emissions from agricultural activities and by reduced use of energy, oil and fertilizer. It is the biggest practical alternative, low-cost as well as associated ecological advantages, compatibility to reduce poverty, role of the social dimension / expansion are the key to global climate change mitigation and adaptation. Carbon storage in agroforestry remains in aboveground biomass (wood biomass), leaf group (foliage), shrub, vine, herb, dead biomass (dead wood, litter) and below ground biomass (roots), soil organic carbon etc. The World's vegetation carbon sequestration ability in major agroforestry systems is listed in Table 1.

The experiments were conducted at Vivekananda Parvatiya Krishi Anusandhan sansthan, Almora on high-density plantation of oak (*Quercus leucotrichophora*) for proper management of tree canopy with four lopping techniques. The lopping techniques includes: pollarding at 1 and 2 meters (backwards cutting of the tree trunk so that the dense

Table 1. Carbon sequestration potential in vegetation of World's major agroforestry systems

Agroforestry/ land use systems	Age	Average vegetation C (Mg ha ⁻¹ yr ⁻¹)
Fodder bank, Segu, Mali,South Africa, Sahel	7.5	0.29
Live fense, Segu, Mali,South Africa, Sahel	8.0	0.59
Tree based intercropping, Canada	13.0	0.83
Park lands, Segu, Mali,South Africa, Sahel	35.0	1.09
Agrisilviculture, Chhatisgarh, Central India	5.0	1.26
Silvopasture, South Oreogaon, USA	11.0	1.11
Silvopastoralism, Kurukshetra, India	6.0	1.37
Silvopastoralism, Kerala, India	5.0	6.55
Cocoa agroforestry, Makoe, Cameroon	26.0	5.85
Cocoa agroforestry, Durialban, Costa Rica	10.0	11.08
Shaded coffee, South-West Congo	13.0	6.31
Agroforestry woodlots, Partorico	4.0	12.04
13. Agroforestry woodlots, Kerala, India	8.8	6.53
Home and farm garden	23.2	4.29
Indonesian homegarden, Sumatra	13.4	8.00
Mixed species stand, Puerto Rico	4.0	15.21

Source: Nair *et al.* (2009)

Table 2. Effect of different cutting management on carbon stock, carbon sequestration and biomass carbon dioxide

Treatment	Carbon stock (Mg ha ⁻¹)	C sequestration (Mg ha ⁻¹ yr ⁻¹)	Biomass CO ₂ (Mg ha ⁻¹)
Coppicing at 1 m	86.7	2.9	317.2
Local	169.6	5.7	620.6
Pollarding at 2 m	123.4	4.1	451.5
1/3 rd top portion undisturbed	356.9	11.9	1306.5

Source: Yadav *et al.* (2016)

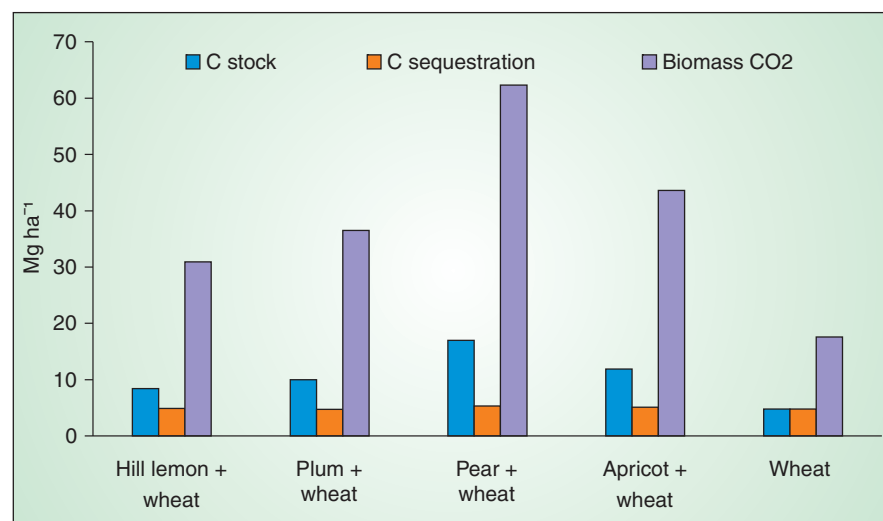


Fig. 2. Aboveground carbon stocks, carbon sequestration and biomass CO₂ in fruit tree based land use systems. Source: Yadav *et al.*, 2015

Table 3. Carbon stock and biomass CO₂ in pecan based agrihorticulture system

Treatment	Carbon stock (Mg ha ⁻¹)	Biomass CO ₂ (Mg ha ⁻¹)
Pecan nut + Lentil	23.92	87.78
Pecan nut + Wheat	25.30	92.85
Lentil	1.17	4.29
Wheat	2.50	9.17

Source: Yadav *et al.* (2017)

numbers of branches can be generated); local practices (slightly above from where the branches split leaves and tender twigs removed randomly); without disturbing the upper 1/3 part of the tree lower 2/3 part pruned for fodder leaves (lopping) (Table 2). At the age of 30 years, oak tree can store 86.7 to 356.9 Mg ha⁻¹ carbon and 317.2 to 1306.5 Mg ha⁻¹ biomass carbon dioxide. The carbon sequestration was recorded in the range of 2.9 to 11.9 Mg C ha⁻¹ yr⁻¹ in various cutting management.

In the fruit based agrihorticulture system the highest carbon stock was found in pear + wheat (17.0 Mg ha⁻¹) followed by apricot + wheat, plum + wheat, hill lemon + wheat and wheat with 11.9, 10.0, 8.4 and 4.8 Mg ha⁻¹, respectively (Fig. 1). Similarly, biomass carbon dioxide was 62.3, 43.6, 36.5, 30.9 17.6 Mg ha⁻¹ in pear + wheat, apricot + wheat, plum + wheat, hill lemon + wheat and wheat, respectively. Based on different treatment carbon sequestration was observed in the range of 4.7 to 5.3 Mg C ha⁻¹ yr⁻¹.

Pecan (*Carya illinoensis*) based agrihorticulture system in which pecan + lentil, pecan + wheat, while lentil and wheat as a sole crop were grown (Table 3). The carbon stock of 23.9 and 25.3 Mg ha⁻¹ with lentil and wheat and biomass CO₂ 92.85 and 87.78 Mg ha⁻¹ with wheat and lentil, respectively was recorded.

SUMMARY

The promotion of agroforestry as envisages in the National Agroforestry Policy (2014) can contribute immensely to food and environmental security. The improved and sustained production will raise the socio-economic levels of small and marginal farmers and reduce pressure on the forest. Therefore, in the context of climate change and to meet the need of a rapidly growing population agroforestry is very important. Agroforestry is also essential for food, fodder, fuel and timber as well as it creates employment opportunities.

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