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Review Article

Significance of Agroforestry in Meghalaya

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Abstract

An attempt has been made in this review to highlight the significance of agroforestry with reference to Meghalaya state. The agroforestry system and related activities followed in Meghalaya as well as prospects and constraints in agroforestry systems has been summarized to give the ideal about status of different aspect of agroforestry. Out of total geographical area of Meghalaya, 41.1% are under forest, 9.40% fallow land and 24.47% uncultivated land; while 15% is reported under agriculture and human settlements. The agroforestry systems such as agri-silviculture, agri-horticulture, home gardens, agri-silviculture, silvi-horti-pasture and multipurpose tree based agroforestry systems are followed and reported from Meghalaya. Combination of different fruit plants such as Khasi Mandarin (*Citrus reticulate*), Alder (*Alnus nepalensis*), Khasi pine (*Pinus kesiya*) and Guava (*Psidum guajava* cv. A*llahabad safeda*) different arable crops such as rice, mustard and pea has been reported in different agroforestry systems. Considering large area of uncultivated terrains and involvement of different components of agroforestry in traditional farming system, agroforestry related activities (research and development) have great potential in state.

Keywords: Agri-Silviculture; Northeast Hill Region; Fallow Land; Multipurpose Tree Based Agroforestry

Introduction

Agroforestry is self-sustained land manage system consisting of deliberate combination of agriculture/arable crops with pasture, domesticated animal and forest plants [1,2]. The agroforestry can be made more complex and self-sustained by incorporating different components of farming system such as moriculture, apiculture, floriculture, back-yard or nutritional garden, etc. Traditionally agroforestry are classified as agri-silviculture, agri-pastural, silvi-pastural and Agri-silvi-pastural; while incorporation of different components of farming system make much better recycling of biomass and energy in agroforestry [3,4]. This will expected to increase returns and sustainability of agroforestry unit. The profitability and feasibility of intercropping of maize with gmelina (*Gmelina arborea* R. Br.) and bagras (*Eucalyptus deglupta* Blume) over sole maize and sole woodlots were reported by Bertomeu [5]; while Fahad., *et al*. [6] and Avasthe., *et al*. [7] reported better nutrient cycling and resource cycling in agroforestry systems. The suitability of agroforestry to different land topography and soil and climatic condition was reported in Ahmad., *et al*. [8]; while use of agroforestry for sustaining agriculture in hilly terrain was reported [9,10]. The soil and water conservation is considered as an important component of hill agriculture which can be also attended through agroforestry. The reduction in rate of soil erosion and stabilization of hills and stream bed are reported in Sharma., *et al*. [11] and Van Ramshorst., *et al*. [12]. The organic matter enhancement of soil and improving soil fertility in different agroforestry system was cited [10,13]; while Bhatt., *et al*. [14] and Tadesse., *et al*. [15] reported increase in productivity of different crops in agroforestry over the duration. Intercropping of different medicinal and aromatic plants in tree based agroforestry system and yield level of 82% to 100% in intercropping compared to sole cropping was reported and review in [16]; similarly they also reported that two to four times higher economic yield in intercropping system of Agroforestry over sole planting of MAP. The poplar (*Populus deltoids* Bartr.) based agroforestry system (In Punjab, India) involving three crop rotation viz., wheat–legume rotation, rice-wheat rotation and maize-wheat rotation showed 6.56 g kg^{-1} soil soil organic carbon and 1.1 g kg^{-1} soil total nitrogen in agroforestry system. It is significantly higher than same recorded rice-wheat rotation system. Besides that, significantly higher microbial biomass carbon was also found in agroforestry system over other crop rotation

[17]. In another study, decrease in yield of wheat (PBW-373, PBW-343, UP-262 and VL-907) (3.67 t ha^{-1} versus 3.79 t ha^{-1}, respectively in agroforestry and sole planting of wheat) intercropped with poplar (*Populus deltoids* Bartr.) based agroforestry system over sole wheat growing was reported at Uttarakhand (Western Himalayan zone of India), India [18].

The economic significance of agroforestry is also explained by its capacity to utilize marginal and sub-marginal area for productive purpose and biomass production with varied level of economic value. The ecological values are expressed by its carbon sequestration potential [19], generation of different ecological services [20,21] and act as important mitigation and adaptation strategy for climate change [22,23]. The hill regions in India are known for different traditional forestry based agricultural system for enhancing the returns and sustain the all life form. The system such as shifting cultivation [24], zabu practice [25,26], *Taungya* cultivation, broom grass cultivation [27], establishment of lowland paddies with fruits crops such as banana, turning hills in to plantation crop orchards (tea and coffee, coconut and arecanut) and vegetable cultivation as well as establishment of traditionally grown fruit plants in forest (citru, cashue, mango, etc.) are some of such examples. Considering these pros and potential to be serves as an important component of farming in hilly region agroforestry system is key role player in North East Hill Region (NEH) region.

Agro-climatic condition of Meghalaya

Meghalaya is one among seven North East Hill (NEH) region state with spread from latitude of 25^0 02' and 26^0 07' N and longitudes of 89^0 49' and 92^0 50' E with large part of state occupied by forest and divided in to three major hill region viz., Khasi hills, Jayantia hill and Garo hills. As the climatic conditions vary significantly in these regions, the agricultural activities, land use pattern, socio-economic status and cultural beliefs are differ significantly across these three regions. Meghalaya has varied type of climate which changes due to variation in altitude (from 150 m to 1965 m). The rainfall varies from 1424.1-3475.9 mm for seasonal (June to September) and 2119.3-6018.9 mm/annum for annual [28] across the state. The soil of Meghalaya has acidic soil reaction and high rate of soil erosion as important distinguishing characters. The soil p^H varies from < 4.5 for 20% soils, < 5.0 for 59% soils and 80% below 5.5 [29]; while reported rate of erosion varies from 5.10 to 68.20 t/ha and much higher in shifting cultivation (30.2 to 170.2 t/ha) [30]. The soil is rich in organic matter which varies from 1.5 to 3.5% [31]. The forest litter, lack of commercial extractive farming, organic production mode, use of traditional organic based crop management practices and active and continuous involvement of animal components and framing system based rather than cropping system based agriculture are important interventions and status of agricultural activities which helps in maintaining the high rate of organic carbon in soil. Shifting cultivation, lowland paddies in stream banks and valleys, upland rainfed rice, winter season vegetable cultivation, broom grass cultivation, pineapple and traditional citrus (mandarin orange and kazyi lime) cultivation, pig rearing, backyard and commercial poultry and cattle rearing for milk and meat purpose and agro and ecotourism are the major agricultural activities in the state. Rice and maize are the major crops occupying 43.96% and 7.81% of net cultivated area, respectively with around 60 to 65 different crops grown in the state [32]. The agriculture and related activities are considered as important source of livelihood in the state with 85% population depends on agriculture directly or indirectly. As only 11.27% area is used for agricultural activities and 41.1% are under forest [32], large area/tract need remain uncultivated (9.40% fallow land and 24.47% uncultivated land) which might be due to soil and climatic constraints. The area has varied level of potential to be explored for productive purpose. These areas are also exposed to different agro-climatic conditions which make them marginal and sub-marginal due to erosion and landslides. At the same time, low productive capacity, low and long time for repaying capacity and difficulty in establishing infrastructure are the major bottleneck of conventional agricultural development in these areas. These areas also carry significant level of diversity in plants as well as insects and animals. This area can be consider as potential area for agroforestry related interventions. Besides that, agricultural areas are also in various elevations and fragmented with various types of soil topography. This can also need to be supported with some components of agroforestry systems.

Different type of agroforestry system and their potentials

The agroforestry system yields multiple products with high product diversity (both economic and ecological services); while the quantity, quality and timing of supply of these products differs significantly across different regions (Table 1). Based on climatic conditions, agroforestry types and component changes and this will leads to different interaction and economical and ecological impacts. Combination of different fruit plants such as Khasi Mandarin (*Citrus reticulate*), Alder (*Alnus nepalensis*), Khasi pine (*Pinus kesiya*) and Guava (*Psidum guajava* cv. Allahabad safeda) different arable crops such as rice, mustard, pea and soybean has been reported in Tomar., *et al.* [33] and Bhatt and Misra [9] in Meghalaya. The ecological and economic benefits of Agroforestry area realized in long term and are in multiple products form. At the same time, the market availability and market demand, non-accountability of ecological services, lack of land allotment in non-cultivated area

Agroforestry system and type	Component/types/treatments	Area/agro-climatic condition	Economic impacts	Ecological impacts	References
Agri-horticulture system (acid alfisol soil)	Rice alone (three rice varieties RCPL-1-24, RCPL-1-25 and RCPL-1-29), Rice + Guava (*Psidum guajava* cv. Allahabad safeda) and Rice + Assam lemon (*Citrus lemon* cv. Local)	North eastern Himalayan region (Meghalaya)	Increase in net returns with guava + rice and assam lemon + rice was Rs. 13653/ha (2.96 fold) and Rs. 6830/ha (1.98 fold) over sole rice planting (Rs. 6957/ha)	-	[9]
Agri-silviculture	Three trees species viz., Poplar (Populus deltoides), Acacia (Acacia nilotica) and Eucalyptus (Eucalyptus tereticornis) were intercropped with three cropping patterns and one control (no intercropping) Cropping patterns were (1) rice (Oryza sativa)-wheat (Triticum aestivum) for four years followed by guinea grass (Panicum maximum)-oats (Avena sativa) for two years; (2) rice-Berseem (Trifolium alexandrium) for four years followed by cowpea (Vigna unquiculata)-Berseem for two years; (3) pigeonpea (Cajanus cajan)/sorghum (Sorghum bicolor)-mustard (Brassica juncea) for three years followed by turmeric (Curcuma longa) for three years	Trans-Indo-Gangetic palin (Karnal, Haryana)	Benefit-cost ratio was highest in Poplar based system (2.88) and minimum in Acacia based system (1.86).	Soil amelioration capacity of Acacia based agri-silvicultural system was highest followed by Poplar based system followed by Eucalyptus based system after six year.	[34]
Home gardens tea gardens and agrisilvicultural systems	-	Biodiversity hotspot region on North East region of India.	-	A total of 516 plant species of 91 families were recorded with maximum species richness of 475 species from 90 families in home garden. Agroforestry systems are harbor rich plant diversity and can be promoted for biodiversity conservation.	[35]
Agrisilviculture	Bhimal (Grewia oppositifolia) based traditional agroforestry system involving intercropping of finger millet (*Eleusine coracana*)and barnyard millet (*Echinochloa frumentacea*)	Garhwal Himalaya, Uttarakhand, India	The crop performance is better at lower elevation (100- 1400 m amsl) and performance of barnyard millet is better than finger millet. The yield of both crops was reduced due to intercropping with Bhimal over sole cropping; while it was not statistically different at both elevation.	Carbon sequestration in tree biomass is 23.29 Mg ha^{-1} was found at 100-1400 m elevation (above mean sea level); while at 1400 – 1800 m elevation carbon sequestration in biomass is 18.09 Mg ha^{-1}.	[36]
Eight agroforestry system were evaluated for their biomass production and carbon storage potential. (agrisilviculture, agrihorticulture, agrosilvohorticulture, agrohortisilviculture, hortiagriculture, silvopastoral, pastoralsilviculture and hortipastoral systems)	-	North-Western Himalayan zone (Himachal Pradesh, India).	-	The maximum aboveground (47.48 mg/ha) and below ground biomass (12.20 Mg/ha) production was recorded in agrohortisilviculture; while maximum soil carbon density (35.77 Mg/ha) and total carbon storage potential (59.75 Mg/ha) was observed under silvopastural system	[10]
Four agroforestry systems were compared for their ecological and economics significance viz. Agri-silvi-horticulture system (ASHS), Agri-silviculture system (ASS), Agri-horticulture system (AHS) and Horti-pasture system (HPS).	Mango + Teak (on boundary) + Brinjal (ASHS), Eucalyptus + Spider lily (ASS), Teak (boundary plantation) + Sugarcane (ASS), Mango + rice (AHS), Mango + cabbage (AHS), Mango + sapota + lemon + Coriander (AHS) and Sapota + Grass (HPS)	Navsari district, Gujarat, India	The highest biomass accumulation was recorded in Eucalyptus + Spider lily (ASS) (99.72 t/ha); while highest benefit cost ratio was recorded in Mango + Teak (on boundary) + Brinjal (ASHS) (6.24) followed by Eucalyptus + Spider lily (ASS) (4.15). The net present value of Mango + rice (AHS) was highest (Rs. 40,00,953) followed by Mango + Teak (on boundary) + Brinjal (ASHS) (Rs. 16,30,526)	The highest soil carbon sequestration was recorded in Eucalyptus + Spider lily (ASS) (47.87 t/ha) (12.36 t/ha) followed by Teak + Sugarcane (ASS). Soil organic carbon content (0.82 %) and available nitrogen (278 kg/ha) was highest in Eucalyptus + Spider lily (ASS) system.	[37]

Farm forestry and agro-forestry	Leucaena and Eucalyptus were sown with different spacing (1x1 m and 3x2 m respectively in farm forestry and 3x0.75m and 7x1.5 m, respectively in agroforestry)	Andhra Pradesh, India	Biomass production carbon accumulation was relatively higher in farm forestry than agro-forestry;	The carbon stock of 62 t/ha for Leucaena and 34 t/ha for Eucalyptus was found after four year indicating their important role in carbon sequestration	[38]
Agri-silviculture (AS) and Agri-horticulture (AH)	Poplar + wheat (AS) and Mango + wheat (AH)	Central Himalaya, India	The yield and harvest index of wheat AS system was higher by 1087 kg/ha 1.4 % over AH system; while reduction in wheat yield in AS and AH was 19.7 % and 36.8 %, respectively over sole cropping. The biomass production in AH system was higher by 43.65 t/ha over AS system (128.3 t/ha); while net primary productivity in AS was 1.8 t/ha higher than AH (14.4 t/ha)	-	[39]
Multipurpose tree (MPT) based agro-forestry system	(Khasi Mandarin (*Citrus reticulate*), Alder (*Alnus nepalensis*) and Khasi pine (*Pinus kesiya*)	Meghalaya, India	-	Khasi mandarin allow more sunlight to reach to ground and also offer less competition for water and nutrient with seasonal crop due to relative low fine root biomass near tree trunk. Hence it is considered as better choice among the three tresses for combining agricultural crops with MPT.	[33]
Five different agro-forestry system with natural forest of same age as control (For 15 year)	Agrisilviculture (multipurpose tree species + annual agricultural crops); Silvi-horti-pastoral (*Alnus nepalensis* + *Ananas comusus* + fodder grasses); Multistoreyed AFS (*Alnus nepalensis* + *Camellia sinensis* + black pepper + annual agricultural crops); Agrihorticulture AFS (*Citrus reticulata* [Khasi mandarin] + annual agricultural crops) and Agrihorticulture AFS with Citrus lemon (Assam lemon) + annual agricultural crops. Natural forest (As control)	Meghalaya, India		Silvi-horti-pastoral and Agrihorticulture AFS with Citrus lemon (Assam lemon) showed increase in soil organic carbon by 0.27 % and 0.10 %, respectively over natural forest. All the studied agroforestry system showed increase in soil available nitrogen by 13.6 to 49.7 mg kg^{-1} over natural forest after 15 years. The highest increase in soil available nitrogen was found in Multistoreyed AFS.	[40]
Four agroforestry systems (Agrisilviculture, Agrihorticulture, Agrihortisilviculture and Agrisilvihorticulture) were compared for their economic returns.	-	Almora district of Uttarakhand state in India in central Himalayan region.	Significantly higher gross and net returns was found in Agrihorticulture with B:C ratio of 2.53. The order of significance for increasing gross and net returns were Agrihorticulture > Agrihortisilviculture > Agrisilvihorticulture > Agrisilviculture. The gross and net returns was decreases with reducing elevation with higher returns at elevation of > 2000 m and least at elevation of < 1100 m.	-	[41]
Four agroforestry system (26 years old) involving multipurpose tree species (MPTs).	*Michelia oblonga* Wall, *Parkia roxburghii* G. Don, *Alnus nepalensis* D. Don, and *Pinus kesiya Royle* ex- Gordon) Control	Umiam, Meghalaya, India.	-	The total organic carbon, particulate organic carbon and carbon stock was increases by 0.46 – 1.06 g 100 g-1, 2.33 – 3.40 g kg-1 and 13.28 – 19.18 Mg ha-1. Respectively over control. Increase in microbial biomass carbon was also recorded in all four agroforestry system over control.	[42]

Table 1

difficulty in management of agroforestry due to remoteness of area and fallow land and less interest on investing in such enterprises are the other conditions for adaptation of agroforestry.

Prospects and potentials

- Large tract of area availability and government programmes for development of these areas,
- Prospect for the establishment of different units such as apiculture, which need less land modification/development activities as well as low investment,
- Conservation of natural resource such as soil and plant biodiversity can be possible with investment on agroforestry in this area,
- Promotion and scaling up of different traditional practices to be a part of different agroforestry systems,
- Increasing attentions for animal components which need consistent supply of fodder/forage and grazing land.

Constraints and difficulties

- Difficult to retain and sustain the agroforestry activities due to lack of access to these area and large investment needed as compared to other area;
- Lack of ownership and reluctant approach due to long and low repaying capacity (gustation period for establishment of agroforestry).
- Intention to use these sub-marginal lands for agricultural cultivation due to quick and more income in agricultural activities.
- Lack of awareness about economic and ecological significance of different agroforestry system,
- Difficulty in getting consistent institutional supports for and after establishment of agroforestry system (seed and planting materials, input needed and information on different management practices under given agro-climatic condition)
- Different weather aberrations and climatic variation leading to lack in establishment of different agroforestry system,
- Less or under development market infrastructure considering the less quantity of output produced, product diversity and lack of market access and demand.
- Different biotic stress with their unknown time and severity of incidence on different components of agroforestry during early stages of establishment.
- Lack of monitory entitlement (price tag) on other service generated form agroforestry excluding provisional services.

Role of agencies

Role of different agencies in facilitating agroforestry needs to be highlighted considering lack of capital investment in such new interventions and long gustation period for realizing complete benefits. As different components from arable crops to forest plant and form insect to animals are involved in agroforestry system the technical guidance for cultivation/domestication and disposal of products in market (including preparation and primary-processing) are needed. This can be catered by different institutional expertise. The establishment of processing unit is not in rich of every farmer; hence creation of facilities of processing units at institutions will be important interventions of stabilizing different components. The ecological evaluation (quantification) and study of suitability of different type agroforestry and their component in different part are also an important work which needs strong institutional support. Establishment of demonstration agroforestry model in area and its promotion is another activity where expertise is needed from different institutions. The Indian Council of Agricultural Research- Research Complex for North East Hill Region with area of activities spread in all NEH region had developed different agroforestry model, which will serve as demonstration unit for promotion and establishment agroforestry systems in different parts of NEH and Meghalaya as well.

Conclusions

The agroforestry activities have very significant role in the sustainable land management in Meghalaya due to availability of large tract of fallow and uncultivated land and difficulty in cultivation of arable crops due to topography and soil related constraints. The remoteness of area, lack of ownership, reluctant approach due to long and low repaying capacity and lack of awareness about economic and ecological significance constraints and conditions the development of agroforestry; while integration of different components of agroforestry in traditional land management system, suitable agro-climatic condition (availability of organic matter rich soil and high rainfall and moderate temperature) and institutional support are expected to facilitate agroforestry activities and help in tacking conditions and constraints to a extend.

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