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REVIEW ARTICLE

SOIL PRODUCTIVITY MANAGEMENT AND SOCIO-ECONOMIC DEVELOPMENT THROUGH AGRO-FORESTRY IN NORTH-EAST INDIA

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ABSTRACT

About 80% of the people of north-east India are directly or indirectly concerned with agriculture. Farmers, in this region, are generally small holders and thus, an attempt with agroforestry practices can result an increase in their earnings without endangering the fragile ecosystem. So far as geographical location and socio-cultural behaviour of the people of north-eastern states of India are concerned, the agroforestry models those have edge over other systems include- Agri-Silviculture (crops + trees), Agri-Horticulture (crops + fruit trees), Silvi-Pasture (trees + fodder crops), Horti-Pasture (fruit trees + fodder crops), Agri-Horti-Silviculture (crops + fruit trees + trees) and Homestead Agroforestry systems. The role of agroforestry systems in ecosystem management and socio-economic development of the people of NE India is described in this article.

INTRODUCTION

The North-Eastern (NE) Region of India, occupying 8% of India's geographical spread lies between 21.5°N to 29.5°N latitude and 85.5°E to 97.5°E longitude. This region comprising eight states (*viz.* Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura) has a total cropped area of 5.3 million hectares and a population of around 39 million. The region falls under high rainfall zone and the climate ranges from subtropical to alpine. The region is characterised by difficult terrain, wide variations in slopes, altitude, land tenure systems and diverse cultivation practices. More than 70 per cent of total geographical area of the region is covered by hills and about 3 million hectare is estimated to be under soil erosion hazard as a result of practice of *Jhum* cultivation. In Assam alone, 83.2 per cent of area are suffered from erosion of slight (35.30%), moderate (37.70%), severe (10.00%) and very severe (0.30%) intensity. Many factors such as natural calamities, large number of smallholders, low availability of agri-inputs *etc*. are threatening the livelihood-sustainability in the region. Besides, the region is dominated by the tribal population and the development of agriculture and production of food grains in the region is highly depends upon the custom, culture and the food habit of the local people. Thus, increasing the yield of crop in such a complex system and in an environmentally positive manner is a challenge in a place like NE region of India.

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Agroforestry is of great importance in recent times primarily because of meeting the diversified needs of people and for sustaining the frazzle ecosystem for generations to come. The area under agriculture and forest has been reduced drastically due to population pressure and this has resulted in a wide gap between demand and production of agricultural and forest products. Now-a-days, there is an acute scarcity and shortage of raw materials for most of the industries in India. Many industries like pulp, paper, ply-wood *etc.* in the country find it difficult to be internationally competitive. At the current level of consumption and production, India will need a minimum of 0.47 ha of forest land per capita against an actual of 0.08 ha. The per capita availability of agricultural land has also declined from 0.48 ha (in 1951-52) to 0.14 ha (in 2000) and it is expected that it will be reduced to 0.08 ha by 2020. Thus, there is remotest possibility of increasing forest and agricultural area separately. Agroforestry, in this context, holds great promise in augmenting wood production in our country in one way and increasing agricultural production in other, without much adverse effect on land and environment. The present study is an attempt to collate information on prevailing agroforestry systems of north-east (NE) states of India and their role in maintaining soil productivity and socio-economic development of the region more particularly in Assam.

SIGNIFICANCE OF THE STUDY

The International Centre for Research in Agroforestry (ICRAF) defines agroforestry as- land-use systems and practices where woody perennials are deliberately integrated

Fig. Agroforestry Models A. Jackfruit + Niger crop; B. Jackfruit + Buckwheat; C. Jackfruit +Pineapple; D. *Albizia* tree+ Black pepper + Tea; E. Agar tree + *Setaria* Grass; F. Agar tree + Patchouli plant; G. and H. Homestead Agroforestry

with crops and/or animals on the same land management unit, either in spatial mixture or in temporal sequence. Thus, agroforestry is an integrated system in which the cultivator works in a tree- crop- livestock systems. There are normally both ecological and economic interactions between the woody and the non-woody components in agroforestry. Evidence shows that the effect of agroforestry on agricultural and forestry output are positive, through not always significant. Thus, with increasing populations and decreasing opportunities for land expansion globally, agroforestry is only the practical way to improving agricultural and forestry growth.

A survey was conducted to study the prevailing agroforestry models in north-eastern states of India during 2013 to 2014. Besides, efforts have been made to collate the available literatures from the journals, books, proceedings, newspapers *etc*. on the aspect of role of agroforestry on soil management and socio-economic development of the north-eastern region of India.

Agro-Forestry: As Sustainable Management Option

A perusal of research report in India as well as abroad has revealed that agriculture itself is not economical in the long run due to loss of soil fertility, moisture, micro-organisms on account of excessive use of chemical fertilizers and pesticides. Agriculture in combination with tree farming with proper admixture of leguminous trees improves the nitrogen level of soil to increase crop yield, biomass and higher returns. The *jhum* cultivation, which is prevalent in almost all the north eastern states, contribute to gradual shrinkage of land and tree cover besides creating a unstable ecosystem. The solution to this problem lies in integrated land-use for agriculture and forestry in such a way to maximize production of goods and services required by the society at large.

Incorporation of fodder grasses and trees in the agroforestry programme will sustain the dairy development ensuring a continuous green fodder supply to cattle. This will increase the economic status of the people where milk production is the key income generating activity. In addition, over exploitation has depleted the medicinal plant resource which warrants propagation of rare, endangered and commercially important medicinal plants under the agroforestry system to provide raw drug or to manufacturing firms.

Intercropping of mulberry with other multi-purpose tree species (MPTS) will ensures quick economic returns through good quality silk. High valued timber trees like Teak, Sissoo, Titasopa, Gomari etc. should get priority as because such trees are needed to local furniture industry as well as to sale outside. Besides providing ecological security, bamboo has been an integral part of cultural, social and economical traditions of north-east India. Bamboo has emerged as a major substitute for timber and other wood products, for which bamboos has tremendous scope in agroforestry practices. Adoption of Agro-forestry practices will help in conservation of soil and water and will always add to the productivity of resource poor farmers. Since agro-forestry is a combination of agricultural and forestry technologies to create integrated, diverse and productive land use systems; it provides ecological resilience and contributes to the maintenance of beneficial ecological functions (Vandermeer, 2002). Trees contribute a lot towards maintenance and improvement of soil fertility and productivity. In an agro-forestry system, soil fertility has been maintained or improved essentially through maintenance of soil organic matter. Soil organic matter is considered as the main component of soil, where low soil organic carbon (SOC) indicates stressed conditions in soil, while high SOC is an indicator of a healthy soil with higher microbial diversity and activity. It is because of the physical and chemical properties which are shaped by biological activity; and biological activity is enhanced or limited by chemical and physical condition of soil. The tree components can absorb the nutrients from the deeper layer of the soil and consequently, decay of litter and roots add carbon and other nutrients to the soil. Moreover, leguminous species of plants in association with some microbes can fix atmospheric nitrogen to soil. Microorganisms like *Actinimycetes, Frankia* etc. fixes N even in association with some non-legume wood trees through the process of symbiosis. Many fungi like VAM can solubilise and mobilize the phosphorus in soil.

Taking up of water from greater depth of soil by tree root systems, agroforestry helps in water retrieval. There is an increased in soil-water storage capacity and a reduction in water loss from evapotranspiration, by shade and litter. Agroforestry practices also protect the soil from erosion and losses of organic matter and nutrients. Soil acidity or rate of acidification may be reduced through bases in litters of the tree component of agroforestry system. There may also be a reduction of soil toxicities, salinity and sodicity by trees in association with other management measures. Agroforestry improves environment through its tree component. It has been already been accepted that one hectare of a close forest can filter about 50 tonnes of dust and dirt. A good stand of tree can reduce wind velocity up to 20 – 60% and air temperature also is 3 – 8^{o}C less in the areas covered with trees. Besides, forest can increases precipitation by about 10% and can increases humidity by 5 – 8%.

Agroforestry Models In North-Eastern States of India

About 80% of the people of north-east India lives in the rural areas and almost all of them are directly or indirectly concerned with agriculture. Farmers, in this region, are generally small holders and an attempt with agroforestry practices can result an increase in their earnings without endangering the fragile ecosystem. So far as geographical location and socio-cultural behaviour of the people are concerned, the following systems has edge over other systems of agroforestry in NE region of India-

- Agri-Silviculture: (crops + trees)
- Agri-Horticulture: (crops + fruit trees)
- Silvi-Pasture: (trees + fodder crops)
- Horti- Pasture: (fruit trees + fodder crops)
- Agri-Horti-Silviculture: (crops + fruit trees + trees)
- Homestead Agroforestry : (may be the mixtures of crops, vegetables, fruit trees, fodder crops and trees)

Thus, agroforestry in north- east India holds a great potential to make a positive and significant contribution to agricultural output, besides raising fuel-wood, timber, fodder, milk and meat production in one way and conserving the soil and water in other.

Realizing such potentials, the following broad categories of agroforestry models have been identified for socio-economic development in a sustainable manner for north- eastern region of India.

Agroforestry with Forest/ Tree Dominant

Agroforestry with tree dominant system generally occurs in natural conditions or artificially forested areas such as orchards or plantations. Here, In order to allow multiple use of the land, some shade loving agricultural crops can be inter-grown without disturbing the stands of initial conditions. The spacing of 2.5 × 2.5 m to 5 × 5 m may be given in between the trees, depending on the species. Fruit trees normally take 4-5 years or even more to mature and to give cash return. As these trees are grown wide apart, there is scope for growing agricultural crops in the initial stage of the growth of the fruit trees along with other multi-purpose tree species (MPTS). Here, the major benefit is that the value of tree products (such as fruit, nut, timber or resin) is typically higher than the value of agricultural goods, which can allow practitioners to increase their income from the given same amount of land.

Agar tree (*Aquilaria malaccensis*) has been identified as a potential agroforestry species, especially for Assam due to their abundance in north- eastern region of India. The essential oil from agarwood is valued in high class perfumery as a fixative and is much priced by Perfumer for mixing their best grade scents. The trade of agar wood has become a fascinating industry, owing to high return in trade, for which the tree is planted in homesteads, plantations and in community lands as a pure-stand or in combination with fodder crops and with other agricultural crops.

Some medicinal plants like patchouli (*Pogostemon cablin*), sarpagandha (*Rouvolfia serpentine*), Brahmi (*Brahmi indica*), Mosundary (*Houttynia cordata*), Mohavingaraj (*Wedelia calendulaceae*), Narasingha (*Musraya koenigii*) etc. are selected for intercropping with Agar trees in Assam. Tea, rubber, cardamom and coffee prefers diffuse sunlight and are most important commercial plantation crops in north- east India. These plantation crops are planted with a number of nitrogen fixing MPTS and some compatible crops such as black pepper, betel vine, arecanut etc. Such high density multi-storied plantation system is found to be profitable and acceptable by the farmers, suiting the environment to the north- eastern region of India. In addition, agricultural crops are also cultivated along with the economically most important forest tree species such as Gomari (*Gmelina Arborea*), Sissoo (*Dilbergia sissoo*), Kadam (*Michelia champaca*), Teak (*Tectona grandis*), Neem (*Azadirachta indica*), Acacia (*Acacia mangium*), Arjun (*Terminalia arjuna*) etc. in the plain areas of NE region of India. The practice of growing agricultural crops along the forest tree species such as *Alnus nepalensis* (Hring), *Exbuclandia populania* can be observed in most of the hilly areas of north-eastern states of India.

Agroforestry with Cops Dominant

Such practices has been commonly be practising in plain areas of north-eastern region, where trees are planted in the fields with crops as intercrop or as shelterbelt. The agricultural crops like rapeseed (*Brassica campestris*), niger (*Guizotia abyssinica*), buckwheat (*Fagopyrum esculentum* L.), sesamum (*Sesamum indicum*) etc. crops and some vegetables are cultivated in between the fruit trees such as jackfruit (*Artocarpus heterophylius* L.), citrus (*Citrus reticulata, Citrus limon* L.), guava (*Psidium guajava* L.), mango (*Mangifera indica* L.), coconut (*Cosos nucifera* L.) etc. In between the fruit trees, growing of spices such as black pepper (*Piper nigrum* L.), ginger (*Zingiber officinale* L.), turmeric (*Curcuma longa* L.) etc. has been a common practice in north-eastern region of India. The Assam tea (*Camellia sinensis*) is famous in all over the globe. Tea plantation grown with shade trees in a two or three tier system of planting plays a pivotal role in maintaining ecosystem sustainability. On the shade trees of tea garden, cultivation of black pepper (*Piper nigrum* L.) and betel vine (*Piper betle* L.) has becoming a most profitable business in Assam and other NE states of India. Above and beyond, most profitable tree species such as arecanut (*Areca catechu* L.), citrus (*Citrus reticulata*) and Agar tree (*Aquilaria malaccensis*) are also planted as shade tree in the tea gardens of Assam and found to be well-matched, ecologically viable and economically most profitable system of cultivations of tea. The perennial, deep rooted and hardy trees are eminently suitable to rainfed situation, not only to minimize the risk of agricultural production but also to provide insurance in natural calamities like flood, draught etc. which are proverbial in north- eastern region of India.

Agroforestry with Pasture- Husbandry Dominant

The acute fodder shortage (both in terms of quality and quantity) is the major cause of low productivity of livestock in NE region. Therefore in this agroforestry system, the trees and shrubs are planted in clusters or belts which allow quality forage production besides other benefits. Here, the trees are generally planted at a wider spacing (5 × 5 m to 9 × 9 m), and grasses are grown (at 0.5 × 0.5 m spacing) in the interspaces. Such silvipastoral system is not suitable but also desirable for improving the condition of wastelands. This system full fills the vital needs of fodder, firewood, timber and food, besides acting as a viable alternative to protect land resources, soils and environment. It is possible to grow 200 to 400 fast growing MPTS like subabul (*Leucaena leucocephala*) per hectare in between other fruit trees (such as guava, ber) in lines, along with some agricultural crops (such as pineapple, citrus etc.) and can be harvested annually to get leaf fodder (11.84 - 13.16 t/ha) and fuel-wood (4.27- 4.96 t/ha) besides other ancillary benefits (Roy and Gill, 1992-93).

Bamboo and other suitable MPTS along with some grasses like *Stylosanthes hameta*, *Cenchrus ciliaris, Panicum maximum, Cenchrus ciliaris etc*. can also be intercropped successfully for optimizing the overall system efficiency. Pathak (1994) reported that grasses like *C. ciliaris* and *Chrysopogon fulvus* while growing with subabul can give forage production of 7.87 and 7.38 t/ha, respectively. In some parts of north-east India, farmers cultivated fodder crops in between the arecanut plants. Cultivations of fodder crops (such as *Setaria*, *Napier* etc.) in between the Agar trees (*Aquilaria malaccensis*) and between the horticultural fruit trees has also been practised more particularly in Assam.

Agroforestry with Fisheries Dominant

Here, trees can be planted alongside rivers, ponds or other water bodies. Such fishery dominated agroforestry model

ensures dams protection against water waves, decrease soil erosion and provide some other ancillary benefits also. Tree species like *Psidium guajava* L. (Guava), *Cosos nucifera* L. (coconut), *Emblica officinalis* (Amala), *Aquilaria malaccensis* (Agar trees), *Terminalia cebula* (Silikha), *Mangifera indica* (Mango), *Citrus* spp., *Litchi chinensis* (Litchi), *Tamarindus indica, Sesbania grandiflora* are found to be suitable and common for such fishery dominated agroforestry model in NE India. Practices of arecanut and banana cultivation are also widespread on the bank of the fishery. To stabilize the embankment some perennial grasses are grown. Plantation of bamboos such as- *Bambusa vulgaries, B. tulda, B. bambos, B. balcooa, B. arundinacea, Dendrocalamus brandisii, D. hamiltonii, D. longispathus, Ochlandra travancorica etc*. can also bind the soil very efficiently. Bamboos are planted on the banks of the pond, and some leguminous crops like soyabean, arahar etc. are intercropped in between bamboo clumps to form a complete food chain. Such crops are harvested as food for fishes and bottom-mud from the ponds are dug-out (in winter) for use as fertilizer for bamboo clumps.

Homestead and Fore-sided Management

Homestead agroforestry is nothing but a combination of all form of agroforestry. In such situation, timber and fruit trees, food crops, cash crops and aquatic crops are grown and poultry, animals and fish are raised in an integrated system. This system reduces cost of cultivation and allows self-sufficiency to the farmer. In homestead garden, different vegetables such as potato, cucurbits, beans, gourds, colocasia, ginger, turmeric, garlic, chilli *etc*. and some other horticultural crops such as pineapple, arecanut, betelvine, black pepper, yam, banana, bamboo *etc*. are grown along with some economically important tree species. Besides, some ornamentals like ferns, cactus, flowers and orchids may also selected in this multistoried system of cropping.

Bamboo based Agroforestry

In north- east India, bamboos form an important component of homesteads, unproductive lands and are of common occurrence in the natural forests. From the utilization point of view there is no other plant than bamboos which is having so much of importance to the rural poor as well as urban people. The features like rapid growth habit, good coppicing ability, role in maintaining the soil fertility etc. make bamboos ideal component in agroforestry. Bamboo can be grown under all forms of agroforestry, involving many kinds of trees, shrubs, grasses, annual crops etc.

Bamboo is often planted at a spacing of 6 × 6 m to 9 × 9 m where other trees and agricultural crops can be intercropped. Tea, Agar tree and some high value horticultural crop are planted with bamboos in Assam. Crops such as pineapple, ginger, turmeric, sweet potato, colocasia, soyabean, sugarcane, vegetables etc. are also intercropped within three years after planting of bamboo under the climatic situation of NE region of India. Plantation of bamboos (*Bambusa bambos*/ *B. tulda*/ *B. nutans*) in rows (at 5m × 5m spacing) with Gomari (*Gmelina arborea)* + turmeric (*Curcuma longa)* has already been reported to be practically feasible and economically viable, besides improving the physic-chemical properties of soil (Gogoi, 2011). In north-eastern region of India, the boundaries of paddy fields are often planted with different bamboo species such as *B. tulda, B. bambos, B. balcooa, D. hamiltonii* etc. This practice not only conserves soil, water and fertility, but also meets immediate requirement of the farmers *viz.* small timber, fuel and fodder.

Agroforestry in Shifting Cultivated Areas

In India, about 2 million tribal people practising the *Jhum* or shifting cultivation in approximately 11 million hectare of forest land of which north-east India accounts 7.76% of total *jhuming* area of the country (Singh *et al.*, 2001). This cultivation system initially was a low input land use system which was sustainable due to low population pressure and availability of large tract of undisturbed forest. But due to increased population pressure the gestation period (*jhum* cycle) of shifting cultivation have reduced drastically, making the system unsustainable that promotes heavy soil erosion and further degradation of the land.

Agroforestry, therefore, can be an alternative to the hilly areas where unscientific *jhumming* method is practised. In such modern techniques of cultivation, the top most area of the hill along the vegetation is allowed to grow without disturbance. The middle portion of the hill is converted to bench terracing that consists of series of bench like structure or platforms, by digging the soil from upper part of the terrace and filling the lower part. The shoulder like bunds is prepared at the end of the each terrace, on which close growing species like *Sesbania,* bamboos *etc*. can be planted to arrest the loss of soil and water. Such hedgerow's belt (single or double rows) after each bench terrace ensures a uniform distribution of moisture and nutrients throughout the terrace.

The foot hill area can be utilized for cultivation of crops such as- pine apple, ginger, turmeric, vegetables etc. In this way with living bamboo bunds, an intensive farming is possible in hilly areas (Gogoi, 2011), even with the slopes from 16 to 33%. This alternate method of cultivation is recognized as environmentally safe, economically profitable and socially acceptable methods for the *Jhumies*, especially in *jhum* prone north eastern region of India. Bamboo based agroforestry with suitable bamboo species planted in single or double rows, across the slope of the hill in *Jhum* cultivated areas hold the top soil in place, which greatly reduces rain run-off and prevents massive soil erosion. Bamboo species like- *Melocanna baccifera, Dendrocalamus* spp*., Bambusa khasiana, Oxytenanthera* spp*., Arundinaria racemosa, Chimonobambusa falcate, B. nutans, B. pallida etc*. are very suitable for hill slopes, ridges and abandoned cleared by shifting cultivation areas (Gogoi, 2011).

Conclusion with the way Forwarded

In present day contest, it is well recognized that systemic and scientific introduction of woody perennials in farming system (with proper operational strategies) is sound for sustainable development and resource conservation for generations to come. In general, an effective agroforestry strategy should provide sustainable productivity, economic viability, ecological suitability and social acceptability to the rural poor. To formulate such strategy in NE India, the following key areas have been identified.

- Basic requirement of the people as well as ecological stability need to be achieved through tree planting of multipurpose species, high yielding agricultural crops and some high value bamboo species on even unproductive waste lands and abandoned *jhum* lands. This will ensure adequate employment opportunities to rural poor besides providing raw materials for agro-based industries, bamboo based cottage industries, medicinal plants for herbal drug manufacturing units, mulberry for sericulture and fodder supply for ensuring dairy development in the region.
- Choice of tree species to be grown in association with crops, selection of site and implementation of scheme should be done keeping in view of the diverse climatic conditions and socio-economic needs of the farmers.
- Agroforestry programme need to be implemented through the active participation of farmers who will be the beneficiaries of the project. Role of women through active participation for self employment should also be vital in agroforestry practices.
- Agricultural universities, Agriculture Department and Environment and Forest Department should work *hand in glove* in an organized manner and have to provide all the technical guidance to the farmers for raising nursery, planting and after care.

Thus, it can be concluded that holistic approach through agroforestry holds promise to satisfy all human needs (food, fuel, fodder, timber *etc*.) and it also can act as an insurance against drought, flood and natural calamities those are familiar to north-east region of India. Besides, agroforestry can provides soil and environmental protection, wasteland development, conservation of biodiversity and long term economic security ensuring high cash return and employment opportunity to the rural poor.

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