Agroforestry: An Integral Component of Natural Resource Conservation in the North Eastern Hill Region

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North eastern hill (NEH) region, spreading over an area of 1, 83,750 km^2 (Anonymous, 2005), comprises of the states of Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura. Its distinct geographical location, typical physiography, the alternating pressure cells in North West India and Bay of Bengal, presence of mountain tropical air masses and local mountain and valley winds give distinct weather and climate to north east region (Barthakur, 2004). Climate of the region is highly variable ranging from tropical to alpine type. The altitude varies from 15 m to more than 5000 m above mean sea level. The extreme variation in the physiography, altitude, precipitation and temperature has influenced the vegetation of the region. This unique and diverse climate has probably resulted in rich biological diversity in this part of India. The region has the highest per capita availability of natural resources in the country. It is one of the 12 mega centers of diversity of the world. The forests of the area are comprised of tropical moist evergreen forest to sub-alpine and alpine forests. About 80 per cent of the population lives in rural areas and majority of them depend on agriculture and allied sectors for their livelihood. Based on the climate, topography, soil, prevalence of crop and livestock species, entire north eastern hill region has been divided into six distinct agro-climatic zones (Table 1).

Table 1: Area under different agro-climatic zones of the NEH region

SN	Agro-climatic zone	Altitudinal range	Appx. area (sq km) in the NEH Region
1	Alpine zone	> 3500 m	47068
2	Temperate sub-alpine zone	1500 – 3500 m	33564
3	Subtropical hill zone	1000-1500 m	29021
4	Subtropical plain zone	400 – 1000 m	812
5	Mild tropical hill zone	200 – 800 m	26349
6	Mild tropical plain zone	0-200 m	29333

Area under agriculture in the NEH region is very less which varies from 2.04 per cent of the total geographical area in Arunachal Pradesh to 22.90 per cent in Tripura. The cropping pattern in the entire NE region is food grain based in which paddy has the major share. In the hilly area, especially among the local tribes, settled agriculture is seldom practiced. Shifting cultivation, called *jhum* cultivation, is the dominant agriculture practice in this region.

Traditional Agroforestry Systems of the NEH region

Jhum is the most primitive and popular agroforestry system practiced across the entire NEH region. *Jhum* in the region is a complex system with wide variation that depends upon the ecological variation in the area and cultural diversity among various tribal clans. However, the basic cropping practice is quite similar. Usually all the essential crops such as paddy, maize, tapioca, colocasia, millets, sweet potato, ginger etc. are grown on the same piece of land as mixed crop. *Jhum* in its most traditional form is not a very unsustainable landuse practice particularly when the *Jhum* cycle is more than 20 years. The soils get enough time to rejuvenate and restore their health and productive capacity. However, with increase in population pressure on land resources, the *Jhum* cycle is getting reduced very fast and reached at 4 years at present. This makes the system unstable and lead to severe land degradation as a result of soil erosion and associated factors such as reduction in soil organic matter, nutrients etc. There is decline of forest cover due to shifting cultivation in the NEH region although the degree varies from one state to the other. The net decrease in forest cover during 1989-1991, 1991-93 and 1993-95 were 387, 448 and 175 km^2, respectively (Satapathy and Bujarbaruah, 2005). Total area under *Jhum* also varies among the different hill states. IRS-IC WiFS (1998) data revealed that maximum area under shifting cultivation is in Mizoram followed by Arunachal Pradesh (Table 2). In terms of percentage of the total geographical area, Nagaland (36.15 %) and Tripura (30.49 %) are the most severely affected by *jhum* cultivation.

Table 2 Area under shifting cultivation in different states of the NEH region

State	**Geographical area (sq km)**	**Area under jhum (% of geographical area)**	**Abandoned *Jhum* (> 10 yrs) (% of geographical area)**	**Current *Jhum* (5-10 yrs) (% of geographical area)**
Arunachal Pradesh	8374	6.25	0.77	5.58
Manipur	2233	18.10	3.51	14.59
Meghalaya	2243	14.42	2.58	11.84
Mizoram	2108	51.90	15.75	36.15
Nagaland	1658	12.22	0.69	11.53
Tripura	1049	32.43	1.94	30.49

Source: Roy *et al*. (2002), Rao and Bhattacharyya (2005)

In the NEH region, trees are deliberately integrated with the crop and livestock production system. A number of crops like maize, ginger, pineapple, coffee, and vegetables are grown with tree species such as *Pinus kesiya*, *Alnus nepalensis*, *Schima wallichii*, *Pyrus communis*, *Prunus domestica*, *Areca catechu* etc. The choice of a particular tree species and intercrop depends upon the climatic conditions of the area and economic importance of the species. Some of the traditional agroforestry systems adopted in the various agroclimatic zones are given below in Table 3.

Table 3 Common agroforestry practices of the NEH region

Agroclimatic zone	Agroforestry practices	Remarks
I. Sub-temperate -Alpine	1. Pine with field/vegetable crops	Pine trees with pea, radish, potato, sweet potato, cabbage, turnip, cauliflower, mustard or maize.
	2. Plums with vegetables	Plums with pea, radish, cabbage or cauliflower.
	3. Pears with vegetables/beans / broom grass	Pears with cabbage, cauliflower, beans or broom grass.
	4. Apple with field/ vegetable crops	(i) Apple + potato
		(ii) Apple + barley
		(iii) Apple + vegetables (beans/radish)
II. Sub-tropical Hills and Plains	1. *Alnus nepalensis*/ *Schima wallichii* with large cardamom	-
	2. *Schima wallichii* with pineapple	-
	3. *Schima wallichii* with ginger/turmeric	-
	4. Khasi mandarin with pineapple/vegetable crops	Mandarin with pineapple/beans/radish /ginger/turmeric/cole crops etc.
	5. Sikkim mandarin with field/vegetable crops	(i) Maize-wheat (ii) Maize + ginger/buck wheat/millet/pulses/ vegetable/beans/ radish/hara simbi/ricebean (iii) Maize+ soyabean/millet (iv) Ginger/rice bean (v) Maize/sweet potato/millet/buck wheat/ vegetable beans/radish
	6. Guava, banana and *Moringa*	Tree tomato (*Cyphomandra betacea*), guava, banana and *Moringa* are the fruit crops grown in kitchen garden or farm boundaries.
III. Mild Tropical Hills and Plains	1. Orange with crops	Intercrops viz. beans/chillies/ginger /turmeric
	2. Arecanut with betel vine	-
	3. Arecanut with pineapple	-
	4. Arecanut with pineapple and betel vine	-
	5. Arecanut with black pepper	-
	6. Arecanut with pineapple and black pepper	-
	7. Banana with pineapple	-
	8. *Erythrina indica* with coffee and black pepper	-
	9. *Terminalia myriocarpa* with coffee and black pepper	-
	10. Coconut, arecanut, jackfruit and banana etc. around fishponds near homesteads	-

Source: Chauhan and Dhyani (1990, 1991)

Some of these traditional agroforestry systems found in the region have very high productive potential. The most productive and widely adopted practices in the mild tropical hills and plain zone is cultivation of pineapple and black pepper with arecanut. This system could generate net return of Rs 43000 ha^{-1}. In the temperate and subalpine zone, plum with potato/cole crops generated a net income of Rs 19000 ha^{-1} (Bhatt *et al*, 2001).

Research and Developments in the Field of Agroforestry in the NEH Region

Agroforestry is a complex landuse system which is practiced by people to derive multiple benefits from a piece of land. The R&D aims to optimize these production systems with respect to economic viability and utilization of the natural resources like soil, water and the biological diversity. It is a continuously evolving process and highly dynamic in nature that changes with time, space and social needs.

Agri-horticulture system

NEH region has ample potential for horticulture based agroforestry systems. For the development of suitable agorforestry system for the region, an experiment was conducted at I C A R Research Complex for NEH Regopn, Umiam in the year 1987 where various fruit trees were grown with different combinations of agricultural crops. The results of different tree crop combinations have been summarized below in Table 4. Khashi Mandarin was planted initially at a tree density of 800 trees per hectare. However, it was observed that 400 trees per hectare produced maximum yield. Average yield of Mandarin was 12.8 kg per tree after 7 years of plantation which increased up to 57.3 kg per tree after 12 years of plantation. In the inter row spaces of fruit trees, groundnut, soybean, turmeric, ginger and taro (local) were cultivated. The average productivity of these crops were 15.6, 15.0, 154, 100 and 170 q ha^{-1}, respectively.

Table 4: Performance of fruit tree based agrihorti systems in the NEH region

Tree crop	Field crop	Variety of field crop	Trees ha^{-1}	Net return (Rs ha^{-1})
Khasi Mandarin	Groundnut	JL-24	400	4541
	Soybean	Alankar	400	19625
	Turmeric	RCT-1	400	30375
	Ginger	Nadia	400	33416
	Taro	Local	400	18583
Guava	Groundnut	JL-24	400	3000
	Soybean	Alankar	400	916
	Turmeric	RCT-1	400	2750
	Ginger	Nadia	400	15791
	Chillies	Local	400	1125
Assam Lemon	Soybean	Alankar	400	2583
	Turmeric	RCT-1	400	1916
	Ginger	Nadia	400	36625
	Radish	Japanese White	400	2583

* Prices are based on the market price of late 1990s

With the increase in age of the tree crop and gradual closure of the over storey canopy, yield of groundnut and soybean started to decline. This opened scope to grow crops like ginger and turmeric and replace these oilseed and pulse crops in the mandarin based system. Among the field crops, ginger was the most remunerative. However, major share of income in these systems was generated by *Khasi mandarin* which was about 80 per cent of the total income irrespective of the associated field crops.

In the guava based system, cv *Allahabad safeda* was planted in association with five field crops namely groundnut, chilli, soybean, turmeric and ginger. Fruit yield of guava increased upto 8th year after which it started to decline because of fruit borer infestation. After two years of plantation, fruit yield was about 56 q ha^{-1} yr^{-1}. Average yield of groundnut, chilli, soybean, turmeric, and ginger were 17.7, 9.8, 6.5, 63.7 and 47.5 q ha^{-1}, respectively. Majority of the income was from ginger crop as the market price of guava is low as compared to mandarin.

Assam lemon based agrihorti system was relatively more profitable than the guava based system. Maximum yield of the fruit trees was attained after 7 years of plantation (34.8 kg per tree). Different intercrops such as ginger, turmeric, soybean and radish were cultivated in the inter row spaces of these tree crops. The net return was maximum in Assam lemon + ginger (Rs 35,000) followed by Assam lemon + radish crop (Rs 14,120).

MPT based agroforestry systems

NEH region is characterized by presence of vast tract of forest areas. Therefore, livelihood of the population is also strongly influenced by the forest wealth especially the tree resources. Farmers deliberately keep some of the multipurpose trees (MPTs) in their fields to meet their multifarious requirements. Therefore some of the MPT based agroforestry systems were also evaluated at the ICAR Research Complex at Umiam for their suitability for the region. Indigenous trees of the region like *Alnus nepalensis*, *Gmelina arborea*, *Michelia oblonga*, *Parkia roxburghii*, *Prunus cerasoides* and *Symingtonia populnia* were planted at a density of 416 trees per hectare. After 12 years of growth, volume production was assessed for each species besides fuel and foliage yields. Volume production varied among different species and it was highest (2.07 m^3 tree^{-1}) for *Parkia roxburghii,* and lowest (0.43 m^3 tree^{-1}) for *Symingtonia populnea.* Though monetary input for each species was not considerably different, the output was highest (Rs. 1854 per tree) for *Perkia roxburghii* followed by *Gmelina arborea* (Rs. 1625 per tree) and *Michelia oblonga* (Rs. 1157 per tree). After twelve years, on an average, farmers could get benefit of Rs. 3.609 lakh from one hectare cultivation of these tree species only.

With these tree species, field crops soybean (cv *Alankar*) and linseed were intercropped upto fifth year (1987-1991). The net return was Rs 1,625 ha^{-1} for soybean. Linseed was not economical as the net return was only Rs 389 ha^{-1}. From 1992 to 1995, pineapple (cv *Kew*) was introduced with a density of 32,625 plants ha^{-1}. This is also most remunerative fruit crop of NEH region. The average net profit through intercropping of pineapple was Rs.18,805 ha^{-1}, irrespective of tree species. After 1996, crop composition was changed, and ginger (cv *Nadia*), turmeric (cv *RCT-1*) and taro (local) were intercropped with MPTs. The net return was highest for ginger as compared to turmeric and taro, irrespective of tree species. Thus, based on twelve years research findings, ginger was found to be the most profitable intercrop, followed by pineapple.

Three tier agroforestry system in the NEH region

Alder (*Alnus nepalensis*-promising nitrogen fixing tree species) was introduced as a tree crop during 1987 and tea (*Camellia sinensis*) was planted in 1993 as second storey crop at a density of 12,350 plants ha^{-1}. The investment for Alder and tea was Rs 11,398 and Rs 36,035 ha^{-1}, respectively. Besides tea, large cardamom, turmeric, ginger, taro and black pepper were intercropped. Alder produced 8.5 q ha^{-1} biomass of pruned material and 24 q ha^{-1} biomass of foliage. Green bud production of tea ranged form 44 to 64 q ha^{-1} for a period of five years with an average production of 59 q ha^{-1}. Productivity of large cardamom was 6.4 q ha^{-1}. Ginger, turmeric and taro produced 79, 165 and 172 q ha^{-1}, respectively. Black pepper was found to be sensitive to frost injury. Therefore, no significant yield could be obtained from this crop. Among various crops, net benefit was maximum (Rs 33,111 ha^{-1}) through large cardamom, followed by tea and ginger. On an average, the multistoried agroforestry system could generate a net annual return of Rs 12,884 ha^{-1}.

Fish based agroforestry system

The composite unit of aquaculture was consisted of paddy, vegetables, large cardamom and fish culture besides bean cultivation on bund area of pond. It was revealed that among various components, fish culture generated maximum monetary returns (Rs. 36,000 ha^{-1}), followed by radish (Rs. 33,850 ha^{-1}), cured large cardamom (Rs. 29,000 ha^{-1}) and brinjal (Rs. 25,500 ha^{-1}) cultivation, respectively. Average income from aquaculture based AFS was Rs. 16,976 ha^{-1}.

Som (*Machilus bombycina*) based agroforestry system

Som tree is suitable for raring of Munga silkworm. This tree attained average height of 6.75 m, 10.30 cm dbh and 0.046 cubic meter volume 5 years after plantation. Maize (*Zea mays*, cv. *Vijay* Composite) and broom grass were intercropped with it. Broom grass was cultivated on the terrace risers, covering total area of 480 sq m. Average grain production of maize was 11.98 q ha^{-1} in association with this tree crop as compared to 13.5 q ha^{-1} in control plots. Broom produced 63 q ha^{-1} flower (most remunerative part of it), 86 q ha^{-1} of green fodder and 36 q ha^{-1} of dry fuel wood. This system generated net return of Rs. 23,444 per ha.

Sericulture based agroforestry system

Seven mulberry varieties, seven silkworm breeds including a bivoltine breed (NB-18) were studied for their yield and rearing performance. The results obtained are presented in the Table 5.

Table 5. Yield of mulberry and silkworm cocoon in sericulture based agroforestry system

Mulberry variety	Plant Height (m)	Yield ($t\ ha^{-1}\ yr^{-1}$)			Net returns from cocoon (Rs ha^{-1})
		Leaf	Cocoon	Fuelwood	
TR-4	1.70	19.1	0.81	6.4	33,449
TR-10	1.69	16.6	0.70	6.3	27,125
BC-259	1.44	15.2	0.65	5.7	23,627
S-1635	1.51	18.2	0.77	6.1	31,085
C-7635	1.52	16.5	0.70	5.6	26,865
Kanva-2	1.43	14.1	0.60	5.7	21,715
Local	1.28	9.1	0.39	4.1	8,215

(Dhyani *et al* 1996)

Intensive integrated farming system

Intensive integrated farming system (IIFS) is based on the concept that there is no waste and waste is only a misplaced resource which can become a valuable material for another product (Edward *et al*., 1986). It is a more refined and holistic approach of land use system through practices in which a number of production components are integrated with the primary objective of developing a self sustainable system. In IIFS all the components of agriculture like crop, fish, forestry, horticulture are integrated in a complementary way

For development of IIFS models, about 10 ha of the waste land were taken up during the year 1999-2000. The average slope of the area ranged from 20-30 per cent with soil depth of less than 1 m. The sloppy land was cleaned and contour bunds were prepared for gradual conversion of the slope to bench terraces at fixed vertical intervals of 3 m. Hedge row of *Tephrosia candida, Flemingia macrophylla, Indigofera tinctoria, Desmodium rensonii, Crotolaria tetragona* and *Cajanus cajan* were raised on contour bunds for soil and water conservation and soil fertility build up. One year old seedlings of multi-purpose tree species (*Gmelina arborea, Alnus nepalensis, Chukrasia tabularis, Michelia champaca, Bauhinia variegata, Symingtonia populnea* and *Morus alba*) and fruit trees (*Psidium guajava, Citrus reticulata, C. lemon, C. sinensis, Pyrus communis, Prunus persica* and *Artocarpus heterophyllus*) were planted during July 2000 at 5 m x 5 m spacing. The area at the lowest elevation of the farm (about 3.31 ha) was marshy where crop cultivation was not possible. Small water harvesting earthen ponds (07 nos) were created over 0.71 ha area and 2.6 ha of marshy land were brought under cultivation of high value crops with assured irrigation facilities. Fish fingerlings were introduced in each ponds @ 6000 fingerlings ha^{-1} with species composition of catla (*Catla catla*)-20 per cent, rohu (*Labeo rohita*)- 10 per cent, mrigal (*Cirrhinus mrigala*)- 20 per cent, silver carp (*Hypopthalmichthys molitrix*)- 20 per cent, grass carp (*Ctenopharyungodon idella*)-20 per cent and gonius (*Labeo gonius*)- 20 per cent. Duck (Indian Runner and Khaki Campbell), pig (Large Black), layer birds (White Leghorn), goat (Black Bengal) and cow (*Holstein*) were reared and integrated with fishery. One pond was kept as control to compare the fish growth without integration of livestock/poultry/ducks. Vermicompost, liquid manure and mushroom cultivation was started in IIFS. The five sub-systems of IIFS were developed as detailed in Table 6.

Table 6. Description of IIFS models

Farming system	Land use component with area	Area (ha)	Description
Broiler chicken-crop-fish-duck-horticulture-nitrogen fixing hedge row	Pond- 0.15 Pond dyke-0.03 Duck shed-0.016 Broiler shed-0.006 Field crop-0.75	1.06	In upland area, finger millet (0.18 ha), maize (0.30 ha) and rice bean (0.12 ha) followed by ginger and turmeric. In lowland area paddy (0.65 ha) and mustard 0.30 ha were cultivated. During rabi season potato, tomato, cabbage, knol khol and radish were cultivated. Nitrogen fixing shrubs were planted on contour bunds, fodder grasses and fruit trees were raised on pond dykes

			and farm boundaries. Ducks were reared (72 nos.) on pond dykes. Composite fish culture was practiced and 900 fingerlings were stocked.
Crop-fish-poultry-multipurpose trees	Pond- 0.12 Pond dyke-0.04 Poultry shed-0.01 Field crop-0.80	0.97	In upland area, paddy (0.45 ha) and rice bean (0.05 ha) during kharif and buckwheat (0.50 ha) in rabi season was cultivated. In lowland area paddy (0.30 ha) in kharif and potato (0.25 ha) and french bean (0.05 ha) were cultivated. Fodder grasses and fruit trees were raised on pond dyke and farm boundaries. Layer bird (52 nos.) were raised on pond dykes. Composite fish culture was practiced and 720 fingerlings were stocked.
Crop-fish-goat-MPTs-hedge rows	Pond- 0.10 Pond dyke-0.035 Goat shed-0.008 Field crop-0.80 Hedge row- 0.10	1.04	In upland area, paddy (0.30 ha), ginger (0.30 ha), turmeric (0.20 ha) during kharif and mustard (0.30), tomato (0.40 ha) and radish (0.10 ha) during rabi season were grown. Fodder grasses, MPTs and fruit trees were cultivated on pond dike and farm boundary. Goats (6 nos) were reared on pond dyke. Composite fish culture was practiced and 600 fingerlings were stocked.
Crop-fish-pig-bamboo-MPTs-fruit trees-hedge rows	Pond- 0.12 Pond dyke-0.035 Pig shed-0.001 Field crop-0.80 Hedge row- 0.09	1.05	In upland area, paddy (0.30 ha), colocasia (0.10 ha) and maize (0.40 ha) during kharif and brinjal (0.10 ha), radish (0.05 ha), potato (0.30 ha) and buck wheat (0.15 ha) during rabi season were cultivated. MPTs and fruit trees were raised on pond dykes and farm boundaries. Edible bamboo species were also cultivated on farm boundary. Hedge rows of different species were planted on contour bunds. Vermicompost was prepared in two units each of 12’ x 6’ x 2’ size. Pigs (2 Nos) on pond dykes. Composite fish culture was practiced and 720 fingerlings were stocked.
Crop-fish-dairy-MPTs-fruit trees-hedge rows-vermiculture-	Pond- 0.12 Pond dyke-0.06 Dairy shed-0.016 Field crop-0.80 Hedge row- 0.17	1.17	In upland area paddy (0.60 ha) was cultivated. Broom grass (0.10 ha) and job’s tear (0.10 ha) were cultivated along the water channels. MPTs and fruit trees with fodder grasses were raised on pond dyke and farm boundary. Cattle (2 milch cows

liquid manure-broom grass			and 2 calves) was reared. Oyster mushroom was cultivated in 8 m x 3 m x 2.5 m size unit. Liquid manure was prepared in 3 units 3' x 3' x 2.5' capacity. Vermi-composting was done in 6 units of 1 m x 1 m x 0.75 m. Composite fish culture was practiced in the six ponds. Composite fish culture was practiced and 720 fingerlings were stocked.
Upland crops, and fish farming without integration (control)	Pond-0.10 Pond dyke-0.05 Crop area-0.80	0.95	In upland area, paddy (0.40 ha) and maize (0.40 ha) during khraif season and buck wheat (0.20 ha) and frenchbean (0.30 ha) were grown. Fruit trees were grown on pond dyke. Composite fish culture was practiced and 600 fingerlings were stocked.

The monetary input and output has also been calculated for each subsystem. The total output/input ratio was highest (1.76) in Crop - fish - dairy - MPTs - fruit trees - hedge rows - vermiculture - liquid manure – broom grass followed by Broiler chicken – crop – fish – duck – horticulture - nitrogen fixing hedge row (1.58) (Table 7). The monetary output/input could further increase if family labour is engaged for adopting IIFS (For detailed report, refer to Bhatt and Bujarbaruah, 2005)

Table 7: Monetary output/input pattern (Rs/yr) of IIFS

Farming system	Total input	Total output	Output/ input ratio (Including labour component)	Output/ input ratio (excluding labour component)
Broiler chicken-crop-fish-duck-horticulture-nitrogen fixing hedge row	1,05,722	1,67,331	1.58	2.24
Crop-fish-poultry-multipurpose trees	60,137	90,625	1.51	2.12
Crop-fish-goat-MPTs-hedge row	59,442	91,880	1.55	2.40
Crop-fish-pig-bamboo-MPTs-fruit trees-hedge rows	77,273	1,09,887	1.42	1.86

Crop-fish-dairy-MPTs-fruit trees-hedge rows-vermiculture-liquid manure-broom	1,70,120	2,98,735	1.76	2.48
Upland crops, and fish farming without integration (control)	31,773	34,894	1.09	1.50

Water Conservation and Utilization

Out of 10 ha experimental site, 3.31 ha area was marshy where cultivation of crop was not possible. To rehabilitate such land, seven earthen water harvesting structures were created. Average cost involved for establishing these small water harvesting structures of 0.10 to 0.15 h, was Rs. 43,200/- per pond. The average capacity of water retention ranged from 1000 to 1800 cubic meter and average cost of one cubic meter water harvesting was estimated to be Rs. 32.36. It indicated that one liter of water could be harvested/conserved at price of Rs. 0.03 in first year itself which includes the cost of excavation, ramming, slope stabilization, plantation cost of planting Congo and guinea grass, spillway making etc. Second year onward there was no cost involved except the maintenance cost whereas water could be harvested regularly. The details of water used for various purposes have been shown in table 8

Table 8: Water harvesting and utilization pattern in IIFS

IIFS	Water harvested in pond (m^3)	Water utilization (m^3)
System-1	1000	Fishery - 924 Vegetables - 70 Fruit trees - 5.3
System-2	1800	Fishery - 1675 Vegetables - 83 Duckery - 37 MPTs - 4.5
System-3	1200	Fishery - 1003 Vegetables - 67.5 Poultry - 126 MPTs - 3.2
System-4	1300	Fishery - 1170 Vegetables - 89.5 Goat - 36.0 MPTs - 4.5
System-5	1320	Fishery - 1123 Vegetables - 76.5 Pig - 54.0 Fruit trees - 3.4 Vermiculture - 63.1

Effect of Agroforestry systems on soil and water resources

Effect on soil physico-chemical properties

Tree species ameliorate soil by adding both above and below ground biomass into the soil system. However, variations do exist in the inherent capacity of different tree species in rehabilitating degraded lands. Five different trees species suitable for agroforestry systems were studied at ICAR Research Complex for NEH Region at Umiam, Meghalaya by Shah *et al* (2007). Soil samples were collected from 0-15 cm and 15-30 cm soil depth under five multipurpose tree species such as Khasi pine (*Pinus kesiya*), Alder (*Alnus nepalensis*), Tree bean (*Parkia roxburghii*), Champak (*Michelia oblonga*) and Gambhar (*Gmelina arborea*). A control plot in the form of natural fallow was also maintained near these tree-based land use systems for the purpose of comparison. Effect of tree species on bulk density (BD), organic carbon (OC) and porosity of the soil was significant. All the tree species lowered BD, and increased OC and porosity as compared to the natural fallow (Table 9).

Table 9 Effect of various multi-purpose trees on soil physical properties

Tree species	**Organic C (g kg^{-1})**	**Bulk density (mg m-^{3})**	**Total porosity (%)**	**Micro aggregates (<0.25 mm)**	**Dispersi on ratio**	**Erosion ratio**	**Erosion index**
Pinus kesiya	3.54 ± 0.33	1.04 ± 0.12	54.3 ± 6.22	17.6 ± 5.68	0.21 ± 0.09	0.20 ± 0.03	0.11 ± 0.01
Alnus nepalensis	3.22 ± 0.47	1.09 ± 0.09	55.6 ± 5.87	22.4 ± 3.30	0.23 ± 0.05	0.23 ± 0.01	0.12 ± 0.02
Parkia roxburghii	2.31 ± 0.61	1.23 ± 0.20	52.2 ± 3.20	28.8 ± 8.22	0.26 ± 0.11	0.30 ± 0.04	0.14 ± 0.01
Michelia oblonga	3.36 ± 0.96	1.05 ± 0.32	55.5 ± 4.58	21.5 ± 7.45	0.23 ± 0.03	0.22 ± 0.03	0.11 ± 0.03
Gmelina arborea	2.86 ± 1.24	1.14 ± 0.09	52.4 ± 6.04	38.0 ± 8.69	0.25 ± 0.04	0.24 ± 0.02	0.12 ± 0.02
Control (no tree)	1.56 ± 0.92	1.32 ± 0.11	48.7 ± 8.09	44.2 ± 6.02	0.35 ± 0.06	0.39 ± 0.03	0.15 ± 0.03
LSD (P<0.05)	**0.39**	**0.15**	**5.06**	**3.05**	**0.06**	**0.05**	**0.03**

The water stable aggregates (> 0.25 mm) increased significantly under the different multipurpose tree species. Water stable aggregates were highest for the soils under *Pinus kesiya* (82.4%) followed by *Michelia oblonga* (78.5%) and *Alnus nepalensis* (77.6%). Soil erodibility decreased with the tree species to the extent of 23.1 – 43.6 per cent as compared to control. Therefore, these species were instrumental in decreasing erodibility of soils of the NEH region. Protection of soils directly against erosive forces of raindrop and surface run off by improving soil physical and hydrological parameters have been reported in many studies in India (Grewal and Abrol, 1986; Deb et al, 2005 and Jha and Mohapatra, 2009, Jha *et al*, 2009).

Effect on soil hydrological properties

Tree species improved moisture retention capacity of soil as compared to the control (Table 10). At -0.03 M Pa suction, soil moisture under different tree species was 21 to 36 per cent more than that of the control. Similar was also the trend in available water under the different tree based systems.

Table 10 Effect of various multipurpose trees on soil water retention characteristics

Tree species	Available water ($m^3 m^{-3}$)	Infiltration rate ($mm\ h^{-1}$)	Hydraulic conductivity ($mm\ h^{-1}$)	Profile moisture storage (cm/60 cm)	
				In dry season	In rainy season
Pinus kesiya	0.220 ± 0.03	8.04 ± 1.28	5.44 ± 2.02	20.45 ± 3.22	24.60 ± 1.04
Alnus nepalensis	0.201 ± 0.02	7.28 ± 0.95	4.82 ± 1.46	19.44 ± 2.50	22.68 ± 0.98
Parkia roxburghii	0.192 ± 0.01	4.85 ± 0.56	3.23 ± 2.11	13.85 ± 3.61	18.52 ± 0.62
Michelia oblonga	0.210 ± 0.02	6.10 ± 1.23	4.84 ± 1.54	18.54 ± 2.37	21.66 ± 1.10
Gmelina arboria	0.183 ± 0.01	5.36 ± 0.82	3.50 ± 1.65	14.60 ± 2.11	19.41 ± 0.24
Control (No tree)	0.151 ± 0.02	3.84 ± 1.46	2.12 ± 2.35	11.45 ± 2.05	15.34 ± 0.72
LSD ($P < 0.05$)	0.11	1.06	0.18	2.17	2.30

Values for soil parameters are the means of three replications under two soil depths (0–15 and 15–30 cm) and two seasons across the year

Infiltration of water in the soil was also influenced by the tree vegetation. Infilltration rate under *Pinus kesiya* was almost twice that of the control (3.84 mm hr^{-1}).

Conclusion

Agroforestry is a composite, diversified and sustainable production system. It provides unique opportunity for integration of different components of the farming systems. This helps to optimize the ecosystem functioning and better management of land, water and biological resources. North east Hill region trees are deliberately grown with various crop and livestock under traditional production systems. Some of the systems developed for the NEH region have positive impact on the soil and water resources. These systems need to be further improved with suitable technological interventions to carter the needs of the local populace and help in improving the socio-economic conditions of the farming communities.

References

Anonymous. (2005). State of Forest Report-2005. Forest Survey of India. Ministry of Forest and Environment. Dehardun. 214 **p**.

Barthakur, M. (2004). Weather and climate. *In* Brahmputra basin water resources. (eds.) V.P. Singh, N. Sharma, S. Shakhar and P. Ojha. Kluwer Academic Publisher: Netharlands. **pp**. 17-30.

Bhatt, B.P. and 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, Meghalaya. 43 **p**.

Bhatt, B.P., Singh, R., Mishra, L.K., Tomar, J.M.S., Singh, M., Chauhan, D.S., Dhyani, S.K., Singh, K.A., Dhiman, K.R. and Datta, M. (2001). Agroforestry practices and research: An overview. *In.* Steps towards modernization of agriculture in NEH region. (*eds*.) N.D. Verma and B.P. Bhatt. ICAR Research Complex for NEH region, Umiam, Meghalaya. **pp**. 365-392.

Chauhan, D.S. and Dhyani, S.K. (1990). Traditional agroforestry practices in north east Himalayan regions of India. *Indian Journal of Dry Land Agricultural Research and Development*. **4(2):**73-81.

Chauhan, D.S. and Dhyani, S.K. (1991) Existing agroforestry practices of Meghalaya. *Journal of Hill Research*. **4(1):**19-23.

Deb, S., Tangjang, S., Arunachalam, A and Arunachalam, K. (2005). Role of litter, fine roots and microbial biomass in soil C and N budget in traditionally managed agroforestry systems. *In*. Agroforestry in north east India : opportunities and challenges. (*eds*.) Bhatt, B.P., Bujarbaruah, K.M. ICAR Research Complex for NEH region, Umiam Meghalaya. **pp** 491-506.

Dhyani, S.K. and Chauhan, D.S. (1995). Agroforestry intervention for sustained productivity in north-eastern region of India. *Journal of Range Management and Agroforestry.* **16(1):**79-85.

Dhyani, S.K. and Tripathi, R.S. (2000). Biomass and production of fine and coarse roots of tree under agri-silvicultural practices in north-east India. *Agroforestry Systems*. **50**:107-121.

Dhyani, S.K., Chauhan, D.S., Kumar, D., Kushwaha, V. and Lepcha, S.T. (1996). Sericulture based agroforestry system for hilly area of north-east India. *Agroforestry Systems*. **34**:247-258.

Edwards, P., Kaewpaitoon, K., McCoy, E.W. and Chantachaeng, C. (1986). Pilot scale crop/livestock/ fish integrated farm. AIT research report, 184, Bangkok, Thailand, 131**p**.

Grewal, S.S. and Aborl, I.P. (1986). Agroforestry on alkali soils: effect of some management practices on soil initial growth, biomass accumulation and chemical composition of selected tree species. *Agroforesty Systems*. **4**:221-232.

Jha, P. and Mohapatra, K.P. (2009). Leaf litter, fine root production and turnover in four major tree species of the semi-arid region of India. *Plant and Soil*. DOI. 10-1007/s 11104-009-0027-9.

Jha, P., Mohapatra, K.P. and Dubey, S.K. (2009). Soil erodibility index for evaluation of impact of land-uses on ravine ustifluvent soils in semi-arid sub-tropical India. *Australian Journal of Soil Research* (Communicated).

Rao Nageswar, P.P. and Bhattacharyya, K.C. (2005). Application of geographic information systems and remote sensing in assessment and management of natural resources. *In*. Agroforestry in North-Eastern India: Opportunities and Challenges. (*Eds*) B.P. Bhatt and

K.M. Bujarbaruah. I C A R Research Complex for NEH Region, Umiam, Meghalaya. **pp** 15-31.

Roy, P.S., Singh, S., Aggrawal, S., Gupta, S., Joshi, P.K., Aung, S., Singh, I.J. and Shukla, Y. (2002). TRESS II-Tropical forest assessment in India and north Myanmar. In: Forest cover assessment in Asia: Proceedings of the international workshop on Asia forest cover assessment and conservation issues. Feb 12-14, Dehrandun, India, **pp** 61-100.

Saha, R., Tomar, J.M.S. and Gosh, P.K. (2007). Evaluation and selection of multipurpose tree for comparing soil hydro-physical behaviour under hilly ecosystem of north east India. *Agroforesty System*s. **69**: 239-247.

Satapathy, K.K. and Bujarbaruah, K.M. (2005). Slash and burn agriculture: Its practice, effects and problem of development. *In* Agroforestry in North-Eastern India: Opportunities and Challenges. (*Eds*) B.P.Bhatt and K.M. Bujarbaruah. ICAR Research Complex for NEH Region, Umiam, Meghalaya. **pp** 1-14.