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A CASE STUDY

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Agroforestry practices and concepts in sustainable land use systems in India

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ABSTRACT : Agroforestry has been defined as a dynamic ecologically based natural resources management system that through the integration of trees on farms and in the agricultural landscape diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels. This paper highlighted agroforestry practices and concepts in sustainable land use systems. The benefit derivable from the interface between forest trees and agricultural crops are enormous. They include the optimal use of land for both agricultural and forestry production on a sustainable basis including the improvement of the quality of soil. This is in addition to the socio-economic benefits that are accruable from agroforestry. Indeed the advantage of agroforestry is all encompassing and germane to a sustainable production system and livelihood.

KEY WORDS : Agroforestry, Sustainable, Land use systems, Agrisilvi, Silvipastoral, Agrisilvipastoral

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INTRODUCTION

India is predominantly an agricultural country and more than 75 per cent of the population lives in villages and depends mainly on agriculture, animal husbandry and forestry. Land is the basic natural resource for man, animal and plants but more than 53 per cent of its area is under various stages of degradation. The daily requirement of food, forage, fuel wood and timber of the human and livestock has to be met from this limited resource base of our country. Drastic reduction of forest cover in the country which is at present about 15 per cent of the total geographical area is one of the main reasons for recurring floods and droughts affecting the agricultural production and creating the environmental problems. Judicious use of degraded land can substantially cover the future needs of food, forage, fuel and timber wood in India. Hence, measures to restore such lands for productive and profitable use besides calling a halt to further degradation are required.

The International Centre for Research in Agroforestry (ICRAF, 1997) defines agroforestry as a dynamic, ecologically based, natural resources management system that through the integration of trees on farms and in the agricultural landscape diversifies and sustains production for increased social, economic and environmental benefits for all land users at all levels.

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Agroforestry is recognized as a land use option in which trees provide both products and environmental benefits. Given the reality of awareness among the farmers of multiple land use management, the need to improve on the existing agroforestry practices becomes necessary in the face of increasing population and limited nature of land.

While agroforestry is about integrating trees and agriculture, it is also very focused on the needs of people, and on sustainability. In developing countries like India, the agroforestry must be linked up with the poverty alleviation programme as the agroforestry is closed link with social or community forestry. Social forestry aims to assist individuals or communities to meet their basic needs. People usually have multiple needs, such as food, wood for fuel and buildings, income and improvement in their socio-economic status. Farmers often want multiple benefits from their land. Farming profitability, most critical issue now days in Indian farming, revolves around generation of income in the most cost effective manners. Profitability should be considered in a reasonably long time frame and be sustainable. Trees play a critical role for ameliorating the climate, preventing erosion, site rehabilitation, protecting water ways, usar reclamation, wasteland utilization and providing additional revenues or enjoyment. Agroforestry practices are also seen as ways of reducing deforestation and maintenance of biodiversity. Often plant or retaining trees or forests are important ways of achieving these and other environmental goals, such as carbon sequestration. The objective of this paper is to highlight the importance and concepts of agroforestry as a veritable tool in sustainable land use systems.

EXPERIMENTAL METHODS

Types of agroforestry systems:

Agroforestry is the most efficient farming system to provide sustained return to the farmers. It involves elements of agriculture and forestry, wherein woody perennials are deliberately mixed or retained with crop or animal production units. The role of woody perennials in agroforestry systems would be productive (producing food, fodder, fuel, wood, etc.) and protective (soil conservation, windbreaks and shelterbelts, etc.). A global overview of the current agroforestry situation indicates that there are several examples of agroforestry systems and practices in different ecological and geographic regions of the world, especially the tropics. The three basic of an agroforestry land use system are the trees or woody perennial, herbaceous component and/or animals. Agroforestry systems must have trees and at least one of the other components. This is the basis of the classification into trees and crops (agrisilvicultural), trees and pasture+/-animals (silvipastoral), and trees and crops and pasture/animals (agrisilvipastoral). It is possible to subdivide these systems according to their component arrangements. The various types of agroforestry systems which are prevailing in Indian sub-continent are listed here:

Agroforestry land use system: A case study of Eastern Uttar Pradesh :

The N.D. University of Agriculture and Technology operate in eastern districts of Uttar Pradesh. The lands in most of the districts are salt affected. Salt affected soils cover an area of about 7.0 million hectares in the country. The largest area of about 1.3 million hectares is found in Uttar Pradesh which comes about 4.4 and 9.5 per cent of total geographical and total wasteland area of the state. Destruction of vegetative cover, water logging due to seepage and lack of proper drainage are the main causes for formation of usar (sodic) lands in the state. The majority of such salt affected soils are currently lying barren. Judicious use of such soils are substantially cover the future needs of food, forage, fuel and timber wood in India. Hence, measures to restore such soils for productive and profitable use besides calling a halt to further degradation are required. Agroforestry is the most efficient farming system to provide sustained return to the farmers. Keeping this point in view the possibility of agroforestry systems for utilization of salt dominated wasteland has been examined at the N.D. University of Agriculture and Technology, Faizabad.

Site and soil characteristics :

The N.D. University of Agriculture and Technology operate in eastern districts of Uttar Pradesh. The lands located near rural area at a distance of 5 kms from the University campus were selected for experimentation. The surface of the land was hard and exposed to vagaries of weather resulting soil erosion. The water table ranged between 5 to 10 metres. The physical and chemical properties of the soil are very poor. IT is characterized

by high bulk density (1.60 – 1.66 g/cc) with low permeability and porosity (34.2-36.5%). The soil water transmission characteristics such as infiltration rate and hydraulic conductivity are very low (0.01 to 0.02 cm/hr). It is further characterized by high pH (9.5 to 10.6) with high exchangeable sodium percentage (76-80) and low organic content (0.1 to 0.2 %). Kankar ($CaCO_3$ nodules) of variable size and density are present all through the depth of profile.

Agro techniques adopted:

Bio-fencing was done by digging trench of 1.0 metre depth and width and *Prosopis juliflora* a most effective live hedge was grown on boundaries at a distance of one metre during rainy season. Layout plan was prepared by dividing land into plots of 0.5 hectare. Boring was done for construction of shallow cavity tubewell. The pit size of 1x1x1 m for fruit species (except Karonda and Phalsa *i.e.* 60 x 60 x 60 cm) and for forest species 90 x 90 x 90 cm were made (Singh and Singh, 1987). Kankar pan or stone were removed. For growing vegetables such as gourds as inter crops, a pit size of 20-30 cm^3 was used. For other vegetables, 4.0 m wide strip between the rows of fruit species and 2.0 m wide strips between forest species were used. The pits of fruit species were filled up with mixture of normal soil + BHC (100 g) + farm

Table A : Description of agroforestry systems practice in India

Sr. No.	Agroforestry system	Description
1.	Taungya system	Food crops are interplanted with trees in a unit area of land for 2-3 years. Food crops cease to exist on the land when the tree crops close canopy. The system has proved effective in providing food for forestry workers and forage for cutting by cattle rearers.
2.	Integrated Taungya	Similar to Taungya farming, but here, when the tree canopy is closed, livestock grazing substitute raising of agricultural crops
3.	Improved fallow in shifting cultivation	Introduction of cover crops on the farmland in an effort to minimize soil degradation associated with agriculture
4.	Alley-cropping (hedge row intercropping)	In this system, arable crops are grown between hedgerows of planted shrubs and trees, preferably leguminous species that are periodically pruned to prevent shading of the companion crops and the pruning applied as mulch for the crops.
5.	Alley farming	Trees, shrubs and other perennials are planted with agricultural crops to supplement the woody plants in the rows.
6.	Trees on farmland	The farmers plant or retain trees on their farmland, both for food, income, soil improvement and environmental amelioration and for shade during the adverse weather condition.
7.	Scattered trees also known as parkland system	This system is characterized by well grown scattered trees on cultivated and recently fallowed land. These parklands develop when crop cultivation on a piece of land becomes more permanent. The trees are scattered far apart so that they do not compete with their neighbours. Parkland trees are deep rooted, have capacity to fix nitrogen, produce litter that decomposes well and add as much as possible to soil organic matter.
8.	Boundary planting	Fast growing trees are planted on the boundary of field, terraces and streams banks, works as live fences, erosion control structures.
9.	Shelterbelts	Agroforestry system in which food crops are planted between rows of trees belts planted as shelter. The trees and shrubs are planted in one or more rows at right angle to prevailing winds
10.	Windbreaks	Here, double rows of trees are planted around the boundary of a food crop farm on the windward side. Each windbreak is 150m long with 100 trees planted at escapement of 3m x 3m.
11.	Home garden	Tropical home gardens consist of an assemblage of plants which may include trees, shrubs, vines and herbaceous plants growing in or adjacent to a homestead or home compound
12.	Multipurpose trees on cropland (Trees on farmland or farm forestry)	Farmers intentionally leave few trees on farms when clearing the land in the practice. The trees commonly left are those of economic importance to the farmers.
13.	Trees in social conservation	Woody plants, whether in hedges or not, planted to stabilize the soil on terrace edges and other conservation
14.	Aquaforestry	This system is a practice that links trees with aquaculture. Trees are planted around fishponds to provide fodder for herbivorous fish.
15.	Apiculture (apisilviculture)	Carefully chosen woody species grown for their nectar-producing flowers and pollen valued by bees can boost wax and honey production.
16.	Protein bank	Woody perennial vegetation judiciously used helps to supply forage during dry seasons or years of low rainfall.

Adapted from Baumer (1990) and Amonum *et al.* (2009)

yard manure (25 kg). In forest species, only normal soil and BHC were used as filling mixture. Basin system was used for providing irrigation of fruit and forest species. 10 kg FYM, 100 g N, 50 g P_2O_5 and 75 g K_2O per plant was given to one year old plant of guava, aonla and ber. This dose was increased every year in the same proportion upto the age of 10 years.

EXPERIMENTAL RESULTS AND ANALYSIS

The results obtained from the present investigation as well as relevant discussion have been summarized under the following heads :

Silvi-horti system :

In this system, forest species are planted in association with fruit species. Species combination used for plantation is presented in Table 1. Fruit species were planted at a distance of 8.0 metre apart. Forest species were planted between the two rows of fruit species at a distance of 4.0 m apart.

Productivity of the system :

Relative productivity of silvi-horti system is given in Table 2. Data indicates that guava plants started yielding at the age of 4th year hence this is more precocious than aonla and bael fruits. The total productivity of guava + eucalyptus + subabul model was found to be the highest followed closely by aonla + eucalyptus + subabul at the age of 7th year (Singh and Singh, 1988). These models are considered very useful for production of fruit, fuel and fodder. Reduction in average yield of fruit trees particularly in guava and aonla was noticed in 7th year. This is possible due to suppression in growth and fruiting by forest species, hence, it was felt desirable to uproot the forest species from the model during this period. Aonla plantation recorded continuously higher yield in 8th, 9th and 10th year followed by guava and bael.

Table 1: Species combination used for silvi-horti system

Sr. No.	Species	Common name	Plant density/ha
1.	*Psidium guajava* +	Guava	144
	Eucalyptus tereticornis +	Eucalyptus	100
	Leucaena leucocephala	Su-babul	80
2.	*Emblica officinalis* +	Aonla	144
	Eucalyptus tereticornis +	Eucalyptus	100
	Leucaena leucocephala	Su-babul	80
3.	Aegle marmelos +	Bael	144
	Eucalyptus tereticornis +	Eucalyptus	100
	Grewia subinaequalis	Phalsa	80

Table 2: Productivity of silvi-horti system

Sr. No.	System	Product	Average productivity (t/ha)						
			4th	5th	6th	7th	8th	9th	10th
1.	Guava +	Fruit	1.8	2.7	3.0	2.5	3.3	3.5	4.0
	Eucalyptus +	Wood	-	-	-	10.5	-	-	-
	Subabul	Fodder +	0.7	1.2	1.4	1.0	-	-	-
		Wood	-	-	-	2.0	-	-	-
2.	Aonla +	Fruit	-	2.2	4.1	3.6	4.0	4.3	4.8
	Eucalyptus +	Wood	-	-	-	9.0	-	-	-
	Subabul	Fodder +	0.6	1.0	1.2	1.0	-	-	-
		Wood	-	-	-	2.1	-	-	-
3.	Bael +	Fruit	-	0.9	1.8	2.2	3.0	3.1	3.5
	Eucalyptus +	Wood	-	-	-	7.8	-	-	-
	Phalsa	Fruit +	0.1	0.2	0.2	0.1	-	-	-
		Wood	0.2	0.3	0.4	0.4	-	-	-

Changes in soil properties :

Data recorded on physico-chemical properties of soil in relation to silvi-horti systems are given in Table 3. Data shows clear cut improvement in hydraulic conductivity and an increase in organic carbon content of the soil with corresponding reduction in soil pH, electrical conductivity and exchangeable sodium with all systems as compared with control. Guava + eucalyptus + subabul were found most effective system in improving the soil properties.

Table 3 : Changes in properties of salt affected soil under system after 7 year (0-45 cm soil depth)

Systems	Hydraulic conductivity (cm/hr)	Organic carbon (%)	pH	ECe (dS/m)	ESP (%)
Guava + Eucalyptus + Su-babul	0.28	0.26	9.2	10.0	49
Aonla + Eucalyptus + Su-babul	0.26	0.20	9.8	13.3	53
Bael + Eucalyptus + Phalsa	0.26	0.21	9.7	12.8	55
Control (barren land)	0.09	0.16	10.4	18.3	76

Table 4 : Productivity of vegetables as intercrops with aonla + guava plantation

System	Variety	Spacing	Average yield (t/ha)	
			1st year	2nd year
Aonla +	Chakaiya + NA 7	8 x 8 m	-	-
Guava +	Sardar	8 x 8 m	-	-
Bottle gourd +	P.S. prolific long	2 x 1.5 m	2.6	3.8
Cabbage	Golden acre	60 x 45 cm	3.0	4.0
Aonla +	Chakaiya + NA 7	8 x 8 m	-	-
Guava +	Sardar	8 x 8 m	-	-
Tomato +	Pusa Ruby	60 x 45 cm	2.3	2.8
Spinach	Allgreen	Broadcasted	2.0	2.6

Table 5 : Productivity of oilseed crops as intercrops in agri-horti system

Combination	Variety	Productivity (q/ha)	
		2nd year	3rd year
Guava +	Sardar	-	-
Mustard +	Varuna	1.4	1.8
Sunflower	Modern	1.0	1.3
Aonla +	Chakaiya	-	-
Mustard +	Varuna	1.1	1.6
Sunflower	Modern	0.8	1.1

Table 6 : Productivity of grasses as intercrops in silvi-pastoral system

Species combination	Common name	Productivity (q/ha)		
		1st year	2nd year	3rd year
Dalbergia sisso +	Shisham	-	-	-
Brachiaria mutica	Para grass	48.7	98.6	132.7
Dalbergia sisso +	Shisham	-	-	-
Stylosanthes species	Stylo	15.6	29.8	33.4
Leucaena leucocephala +	Subabul	-	-	-
Brachiaria mutica	Para grass	35.8	90.3	120.6
Leucaena leucocephala +	Subabul	-	-	-
Stylosanthes species	Stylo	18.2	30.7	36.8

Oleri-horti system :

In this system vegetable crop were grown in association with fruit species. Results of the work done on intercropping of vegetables between the rows of fruit species are briefly summarized. Crop combination and their details are presented in Table 4. Data clearly indicate that productivity of bottle gourd + cabbage was higher than the tomato + spinach with aonla + guava based cropping model. Thus, the interspaces between plant rows of an orchard can be successfully utilized by growing of vegetable crops which can provide some income in the initial years or till the orchard becomes productive.

Agri-horti system :

In this system agricultural crops are grown in association with fruit species. Results of the work done on this system are summarized in the Table 5. Four metres strips between rows of fruit species were used for mustard and sunflower cultivation. Data presented in Table indicates that mustard grown in association with guava or aonla produced higher yield in both the years than sunflower. Total productivity of mustard and sunflower grown with guava fruit was little higher than grown with aonla plantation in both the years. These oilseed crops may be one of the options for utilizing interspaces of guava and aonla orchard during the intervening period.

Silvi-pastoral system :

In this system grasses are grown in association with forest species. Grasses such as para and stylosanthes were tried between the rows of shisham and subabul. The results obtained are presented in Table 6. Data clearly show that para grass is more productive than stylo either grown with shisham or subabul.Higher productivity of grasses was observed in 3rd year. Para grass grown with shisham had higher productivity than grown with subabul but stylo showed just reverse trend (Singh and Khanna, 1995). Grasses in addition to serve as fodder, check soil and water loss and improve soil properties.

The variability exiting among vegetation zones, peculiar environmental problems, farming systems, land use patterns and tenurial rights call for a different Agroforestry system that would be adaptable and adoptable in each community. On-farm research and development activities need to be carried out in all situations to fine tune the technology, assess its productivity and efficiency relative to traditional farmer practice and determine farmer interest, acceptability and potential, for further development. The importance of the farmers' indigenous practices lies in the fact that recent techniques have contributed to environmental degradation, so there is a need to retrace steps and build upon indigenous knowledge. It could be further recognized that plants and animals existing in a region are not there by chance but have become adapted to the environment and other species. The indigenous species are also acceptable and familiar to the people.

Conclusion :

The role of agroforestry in sustainable land use system cannot be over emphasized. Agroforestry practices offer practical ways of applying various specialized knowledge and skills to the development of rural production systems. It evolves a synergy between agricultural production and forestry that is beneficial for increased food production, sustainable wood production and improvement of the quality of the soil. This is a win-win situation. The advantages of Agroforestry are quite quantum. Agroforestry, among other benefits strive to optimize the use of land for agricultural production on a sustainable basis and at the same time meeting other needs from forestry.

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