

Existing Agroforestry Practices in Haridwar, India

Himshikha

Abstract: This study was conducted and analyzed with an objective to explore the status existing of agroforestry in Haridwar, India. In present study, a survey was done in 36 villages after random selection out of which 426 farmers were randomly selected to provide appropriate data. A total of four practices comprising poplar, eucalyptus and other tree species along with other agricultural and fodder crops were reported in the study area. Result has shown that agroforestry is prevalent in the region with 86% adoption rate. Agri-silviculture and pastoral based practice are widespread in the region with a growing percentage of farmers. Four major Practices types reported were: Agro-silviculture and pastoral based (83.05%), Horticulture based home gardens and orchard plantations(3.63%), wood lots (1.94%) and live fences (11.38%). Most of the farmers (91%) are poplar growers. It was also concluded that boundary plantation pattern is widely adopted by the farmers followed by block and scattered plantation patterns. Major cereal crops grown are wheat, paddy and sugarcane. A diverse array in agroforestry practices and their components shows that agroforestry is prevalent in Haridwar and farmers find agroforestry suitable and profitable to them.

Keywords: agroforestry, practices, species, patterns

1. Introduction

Agroforestry is an ancient practice (Roy *et al.*, 2006). Cultivating trees, agricultural crops and pastures and/or animals in intimate combination with one another spatially or temporally is an ancient practice that farmers have used throughout the world (Tolunayet *al.*, 2007). Agroforestry can be defined as “a dynamic, ecologically-based natural resources management system that, through the integration of trees in agricultural landscapes, diversifies and sustains production for increased social, economic and environmental benefits” (Msuya and Kideghesho, 2012, ICRAF, 2006). Modern agroforestry is now based mainly on combination of trees plantation in field which can be grown along with agricultural, vegetable crops species, horticultural crop species, animals’ species, poultry, fisheries etc. or produced simultaneously or subsequently in combined models on the same piece of land. Agroforestry is an integrated approach to land use that is characterized by deliberate maintenance of trees and other woody perennials in fields and pastures. This system is one of the best known traditional practices for livelihood, suitable land management and sustainable development (Parihaaret *al.*, 2014). Several terms, indicating different forms or subdivisions of agroforestry, are being used in various places. For example, "agri-horticulture," "horti-agriculture," "agri-silvi-horti," "silvi-pasture," "sylvo-pastoral," etc. can be seen in some publications. But the rationale and criteria for defining such terms have seldom been explained. These include, mixed-garden horticulture mixed garden or house garden home-garden, Javanese home garden, compound farm, kitchen garden, household garden, and homestead agroforestry (Nair, 1993). Agroforestry has a long history of traditional practice done in many parts of India and in surrounding neighbor countries since ancient time. Adoption of modern agroforestry in Uttarakhand spread mainly due influence of neighboring states like Haryana, Punjab and Uttar Pradesh where agroforestry gain popularity and attention of both farmers and industrialist due to more returns as compared to traditional forestry or agriculture. Since resources are scarce, the analysis of agroforestry becomes important. There are still gaps in understanding the existing agroforestry practices and their socio- economics in Haridwar. The purpose and role of why agroforestry should

be adopted are better explained by the farmers who adopt agroforestry as land management option. Therefore, this study was conducted and analyzed with an objective to explore the existing agroforestry practices in Haridwar, India.

2. Methodology

Study area: Haridwar lies in west himalayan region hill zone (agro climatic zone). Study site experiences the three distinct seasons, viz. dry summer season (March to mid-June), warm rainy season or monsoon (July to October) and winter season (November to February). Crops are raised mainly under Rabi and Kharif season. Average annual rainfall is 1024 mm. major soil type is sandy calcareous type (51.2%). Haridwar district accounts for about 17 percent of the population of Uttarakhand. About 70 per cent of the population resides in rural areas. Nearly 85.7% area is irrigated by tube well followed by canal (12.1) and other resources (2.1). As regards the size of land holdings in the district, a major part (63 per cent) is less than one hectare size (marginal holdings). Another one-fifth of the landholdings are small (1-2 hectare size). Land productivity is also very high due to the fertility of the soil and irrigation facilities. In fact, it is highest in the state for sugarcane and wheat (main crops).

Sampling and survey: Research on agroforestry in Uttarakhand has been done in many parts including hilly terrain to Terai and Bhabar region. Haridwar district was selected for agroforestry research and because of its potential as having diversified terrain including the Gangetic plains, the forest surrounding fields, upper land and low land areas and hence it was on strength prospectus that the whole district was selected as a study area. Surveys have been widely used in India in the past to collect information on forest resources use, joint forest management, social forestry adoption and psychological aspects of forest users (Glendinning *et al.*, 2001; Sood *et al.*, 2012). The form of survey to be conduct will depend upon direct interviews with the people in order to ensure high rate of responses and seriousness of the answers given by the interviewees (Abdrabo and Hassaan, 2003). The information was collected through a field survey using pre-tested semi

structured questionnaire and interview schedules (Pandey and Singh, 2011) with adult members or head of the family. About 36 villages from six blocks of three tehsils and 12 households were selected in all from each sample village for detailed survey. For this purpose, first of all a list villages in each village were prepared and further list was prepared with the help of village head for households in each village. The 432 random households in the selected villages were surveyed to determine area under different land cover-land uses, crops and trees retained for various purposes and management practices. A pre-test of the both questionnaire designs was done within three nearby villages farming communities having adopters and non adopters of agroforestry and reviewed for clarity. The input from pretesting exercise was used to make minor or additional modifications in questionnaires. After required changes done in questionnaire, the survey was conducted in the randomly selected villages.

Data collection: Primary Data were collected using semi structured and simple questionnaires survey that was intended to capture basic demographic data. Majority of these farmers were practicing agroforestry on their field. The questionnaires were designed to capture information related to adoption of agroforestry practices, existing agroforestry practices. Many Focus Group Discussions (FGD) at farmer level including local farmers in discussion on agroforestry practices, were completed to gain farmers' views and perspectives on agroforestry practices. Respondents are asked to describe the extent to which they think a particular question has been solved. First the impact of some questions is recorded as yes, no, very high, high, moderate, low, indifferent, or negative etc. them according to the respondent's replies. Then, the interviewer assigns the values to them. We interviewed 426 focused exclusively on socioeconomic status and 365 farmer respondents for economic analysis during the three household surveys. Only 6 responses out of 432 interviews were discarded as they could not generate sufficient data and information to analyze. The respondents were selected to represent the variation in farmer's welfare, based on the sizes of the land areas they owned. Most of the asked questions were open-ended, accordingly and farmers were permitted to give as many responses as they felt appropriate. This was to allow farmers to fully express themselves and not bias their responses with the expectations or opinions of the researchers.

Observation and transect walk: During surveys, field observations through transect walk were done to assess the presence of agroforestry established plots of farmers. Personal observations were conducted to analyze actual practices by the farmers.

Data analysis: data were cleaned sorted and coded as 0 and 1 based upon farmers response. Then the information is converted to numbering point scale. This information was recorded in tables. Data were analyzed using simple statistics like frequency counts and percentage calculation, mean, average and cross tabulation of data.

3. Result and Discussion

1) Forms of agroforestry: agroforestry practice types and their percentage

Various forms of agroforestry combinations abound in all ecological and geographical regions of the world, but most distinctively in the tropics (Nair, 1993) and India is no exception. Different forms of agroforestry have been observed to exist in the study area. These were observed mainly during the transect walk and field observation by the researcher and confirmed during the individual and Focus Group Discussion, and the Face to Face interviews with these different groups. The major forms of agroforestry in Haridwar can be classified based on their structural basis. In this case emphasis is on the nature of the components, as well as arrangement of such components in space. These were observed to be as follows:

Table 1: different agroforestry practices types in the sampled study area

<i>Agroforestry patterns and structure</i>	<i>Frequency</i>	<i>% of total practices</i>	<i>rank</i>
Agro-silvi & pastoral based	343	83.05	1
Horticulture based (Hone garden & orchard plantation)	15	3.63	3
Multipurpose tree species (Wood) lots	8	1.94	4
Live fence	47	11.38	2
Total	413	100	

This table depicts the distribution percentage of total agroforestry practices being adopted by the farmers in the fields. A total of 413 responses were received from 365 sampled agroforestry farmers from the study area.

Table 2: Number and percentage of agroforestry farmers adopting different agroforestry practices

<i>practice name</i>	<i>number of adopters</i>	<i>% of adopters</i>
Agro-silvi and pastoral sp. based	343	93.97
Horticulture based sp. (Hone garden & orchard plantation)	15	12.88
live fence	47	4.11
Multipurpose tree species (Wood) lots	8	2.19

From survey done in the area, it was confirmed that out of total sampled farmers, all 365 agroforestry were practicing different agroforestry practices which is shown in table 02. Detailed illustration of these two tables is given below.

I. Agro-silviculture and pastoral species based: farmers confirmed agro-silviculture and pastoral sp. most favored agroforestry practice adopted in farm fields. In this category, crops and trees including agricultural and fodder crops are combined in different proportions. Sometimes, both fodder and agricultural or other cereal, vegetable crops are grown either separately on in combination with same tree species in different or same seasons in same piece of land and this has been observed to be dominant in most of the fields throughout the Haridwar region.

II. Live fences: live fences are very common in all ecological regions. Here, the fodder trees are left to grow to

develop sufficient wood so that they serve as fence posts around grazing units or other plots and the trees are lopped periodically for fodder and for poles and posts (Nair, 1993) using trees to create live fences around pasture; or to provide shade and erosion control (Alavalapatiet al., 2004). Live fences are not very popular in the study area. In study area live fences are created either in single rows or in parallel lines to reduce soil erosion and to protect other crop species from animals and human infringement especially surrounding rice and sugarcane fields, hence reducing the chances of low crop production.

III. Horticulture tree species based (orchard plantation or home gardens): In the study region, horticulture tree species based agroforestry makes 3.63% of total agroforestry practices. 4% farmers are reported to have this kind of agroforestry in their fields. Farmers mainly raise poplar, eucalyptus or other tree species with horticulture fruit tree species like guava, mango, litchi etc. either in rows on boundary or in scattered forms anywhere in whole plots. In initial years other crops are also grown in between the tree rows. But in later years only fodder species are grown in one or two seasons around the year or have been left without any management practices. The major attention in such agroforestry is given to fruit tree species and any other activity which could interfere with growth and production of these species is abandoned in later years.

IV. Multipurpose tree species (wood) lots: Woodlots, also known as blocks of trees, are trees that are deliberately planted in special areas mainly for the production of wood; and other purposes such as reduction in ground water infiltration, utilization of excess water and alleviation of land and streams (Chup, 2004). This involves the deliberate planting of trees in concentration, on a piece of land. This practise is however not very common in the region and only around 2% had adopted this practice which constitutes only 1.94 % of total agroforestry practices. There exist different purposes for this practice. These include the production of fuel wood, prevention of erosion, and production of commercial timber. Although, farmers raise and maintain tree species and cultivate other crops in initial years only. Lots are left undisturbed in following years. Grass species are naturally grown in such fields which are later used for animal feeding. However the main aim of this kind of agroforestry is to get any kind of economic benefit from rendered land. Poplar is dominant tree species under this

kind of agroforestry. Usually this kind of agroforestry is adopted by those agroforestry adopters who were having large land holding or who were not growing any kind of crops on their land. Usually they are over aged trees left unmanaged or those which are having not definite rotation period.

2) Land distribution under agroforestry practices

Table 3: Percentage of total land under each agroforestry practices

Agroforestry practices name	Total land(ha)	percentage
Agro-silvi and pastoral sp. based	571	91.03
Horticulture sp. based (Home garden & orchard plantation)	16.56	2.64
live fence	5.48	0.87
Multipurpose tree species (Wood) lots	34.24	5.46
total	627.28	100

As farmers revealed, a total of 627.28 ha land was covered under agroforestry practices. Out of which, 571 ha (91.03%) of total land was covered under Agro-silvi and pastoral based practices. 34.24 ha. (5.46 %) of this land was distributed in to live fences based practices. 16.56 ha. (2.64%) land was distributed in Horticulture tree species based practices like Home garden, orchard plantation etc. rest 5.48 ha. (0.87%) land was covered under Poplar and Eucalyptus tree species wood lots. The land distribution in agroforestry practices, as shown in above table, confirms farmers' rank wise choice of agroforestry practices.

3. Components of agroforestry practices

I. Tree crop species: Nair(1993) noted that in agroforestry system there are three basic sets of elements or components that are managed by the land user, namely, the tree or woody perennial, the herb(agricultural crops) and the animal. A detailed description of component of agroforestry studied in survey area is given below:

Table 4: agroforestry farmers planting different tree species

Tree species	Percentage of agroforestry adopters	Percentage of adopted agroforestry practices
poplar	91.51	83.13
eucalyptus	16.99	11.82
other	7.67	5.05

Table 5: number and percentage of tree species growers different under each agroforestry practices

practice name	counts	Percentage of practices	agroforestry farmers	counts	percentage of farmers
Agro-silvi and pastoral sp. based	343	93.97	Poplar grower	318	92.71
			Eucalyptus grower	55	16.03
			other tree species/mixed tree species grower	26	7.58
Horticulture sp. based (home gardens and orchard plantation)	15	4.11	Poplar grower	13	86.67
			Eucalyptus grower	1	6.67
			other tree species/mixed tree species grower	15	100.00
Live fences	47	12.88	Poplar grower	40	85.11
			Eucalyptus grower	13	27.66
			other tree species/mixed tree species grower	4	8.51
Multipurpose tree species (wood lots)	8	2.19	Poplar grower	6	75
			Eucalyptus grower	3	37.5
			other tree species/mixed tree species grower	0	0

Farmers in the study area suggested the types of tree species, agroforestry components, and their structural arrangements. Different kind of tree species in agroforestry occurred not with the purpose to improve the growth of the major and underlying crop, but rather to receive various products. Poplar tree species was reported dominant tree species, making 83.13% of all tree species plantation in agroforestry practices. A variety of companion crops have been found suitable with poplar tree species. Almost any species (cereals, pulses, vegetables, fruits, forage, cash crops, etc.) can be grown in combination with it. It shows that Poplar is major dominant tree species in agroforestry. Chauhan *et al.* (2009) also reported popularity of Poplar based agroforestry. Eucalyptus constituted 11.82% of total plantation. It was favored and planted by the farmers because it is understood that demand for nutrients by Eucalyptus is less than others, principally because heartwood begins to form at approximately four years hence, creates almost no adverse effect on underlying crops in initial years of establishment. Eucalyptus is one of the trees can be grown with crops establishing it as one of the most popular choice to be planted along the edges, or bunds, of agricultural fields, and appears to be well incorporated and accepted in agroforestry in India as mentioned by Tejwani (1994). Rest plantation was covered by other tree species/mixed tree species mainly horticulture tree species that made around 5.05% of total reported tree plantation in the fields. 92% farmers were adopting Poplar tree species followed by Eucalyptus (17%) of total agroforestry farmers. other mixed tree species were planted or retained by 08% of agroforestry farmers. this shows that farmers are interested in Poplar based agroforestry as compared to Eucalyptus or other / mixed tree species in their field. This interest may be due to higher timber price and more demand and short rotation period of Poplar tree species as compared to Eucalyptus of other tree/ mixed tree species. This also supports the earlier findings mentioned in Forest bulletin (2012) that Uttarakhand have adopted poplar-eucalypt us based agroforestry in a big way.

ii. Agriculture crop species

Table 6: Major agricultural crops and their percentage

Agricultural Crop	Frequency	Percentage	Rank	Frequency	Percentage
Wheat	365	36.07	1	365	100
Paddy	245	24.2	3	245	67.12
Sugarcane	308	30.4	2	308	84.38
Maize	9	0.89	6	9	2.46
Mustard	45	4.45	4	45	12.32
Others	40	3.95	5	40	10.95

These are summarized in table given below. Most favored crop grown reported were wheat, Paddy, Sugarcane, Mustard, Maize, Pulses and some other species (Sorghum, Millet, Ground nut etc.). The magnitude and proportion of these cultivated crops growers are like; wheat (100%), Paddy (67.12%), Sugarcane (84.38%), mustard (12.32%), maize (2.46%) and other crop species (Sorghum, Millet, and Ground nut etc., 10.95%). Hence, in terms of total farmers involved, wheat was the commonest crop, as it was grown by all of the respondent agroforestry farmers. These crop species are grown mainly to provide food for farming

families. The crop residue (both dry and green) is either used as fodder for animals reared by them or was used as dry fuel material. However, extra quantity of both crop residue and cereal content is sold in local markets. It indicates that in most of the cases the nature and production of agricultural crops not only meet with farmers' food requirements but also provide subsequent economic returns which points out the probability of long term investment in agroforestry by the farmers.

iii. Fodder crop species

Table 7: fodder types and their percentage

Fodder Type	Frequency	Percentage	Rank	Adopters	Percentage
Berseem	334	39.71	1	333	91.51
Sorghum	211	25.09	3	210	57.81
Chari	279	33.17	2	278	76.44
Other Sp.	17	2.02	4	17	4.66

100% farmers were growing fodder crops in their fields. In the study area, fodder species were grown agro-silvi and pastoral based practices. Berseem was major fodder species grown by agroforestry farmers either as sole crop or in combination with other crop species as 92% of total agroforestry respondent were growing it in their field. Berseem was winter fodder crops grown between November to January (millet fodder) and November to April (Berseem)month. Whereas sorghum, and other fodder species were grown from June to August-September period. Some farmers tend to grow another crop species usually agricultural and hence, harvesting time was reduced for these fodder crops in these cases.

iv. Livestock

Table 8: livestock and their percentage

Livestock Information			
Animal Species	Counts	Percentage	Rank
Buffalos	659	33.24	01
Cows	456	23.01	02
Bull/Ox	422	21.29	03
Calves	299	15.09	04
Other Sp.	146	7.37	05

Livestock are the third common component of agroforestry in the surveyed study area. Major cattle species were Buffalo, Cow, Bull/Ox, Calves, and other species like goat, sheep etc. among which buffalos were reared by most of the farmers The maximum number of Buffalos shows that they are dominant animal species in the study area.

v. Vegetables grown in Agroforestry

Table 9: Vegetables species grown in study area

Vegetable Crop	Frequency	Percentage	Rank
peas	31	8.49	2
potato	11	3.01	4
cabbage	48	12.88	1
other	15	4.11	3

Vegetable species reported most were Cabbage, Peas and Potatoes A few number of farmers were growing vegetables under agro-silviculture and pastoral practices in their fields.

As they were not growing vegetable crops as an additional crop type only a limited period of time, they were not given a specific practise name.

4. Pattern wise distribution of Agroforestry practices

Table 10: plantation patterns in agroforestry practices

Practice name	% agroforestry practices	Plantation pattern	Pattern %
Agro-silviculture and pasture sp. based	83.05	boundary	70.38
		block	26.69
		scattered	2.93
Horticulture sp. based	4.11	Boundary scattered	80
		scattered	20
Wood lots	1.94	Blocks	62.5
		scattered	37.5
Live fences	11.38	boundary	100

Above table shows the result of surveyed agroforestry farmers and their percentage of different agroforestry practices adoption.

- 1) **Plantation patterns in agro-silviculture and pastoral sp. based agroforestry practices:** In study area, agro-silvi and pastoral based agroforestry practices which were making 83% of total practices prevalent in the area, were comprised of boundary, block and scattered plantation patterns of tree species with other crops. Boundary plantation covered 70% of total agro-silvi and pastoral based practices while its 27% was covered by block plantation of tree species and rest 3% was covered with scattered form of arrangement of tree species in the field. The scattered tree cultivation (also known as random mix) as well as boundary and block plantation could be observed in all parts of the territory and this corresponds with the general situation and plantation patterns in the northern parts of India. Almost all responding agroforestry farmers in the study area practice this form of agroforestry.
- 2) **Plantation patterns in horticulture tree species based (home garden or orchard plantation) practices:** In this kind of practices 80% of tree species were planted in boundary+ scattered forms. Here, boundary plantation was done by forestry tree species like Poplar/Eucalyptus tree species and horticultural tree species were retained in scattered form in between the field. Usually they are retained for indefinite years but the forest tree species are harvested on their rotation age or whenever farmer finds conditions suitable for harvesting and selling of timber. Rest 20% of this practice was reported in scattered form. Here, all tree species were mixed, and retained in scattered form. Farmers in these types of pattern in horticulture species based practices do not harvest tree species on basis of their rotation age, rather; they left their tree species in orchard plantation/home garden for indefinite time.
- 3) **Plantation patterns in Multipurpose tree species (wood) lots:** 72.5% of total woodlots reported in the region were planted in blocks, while rest 22.5 % woodlots were reported in scattered forms. Though this practice is not much popular in the area, except boundary plantation patter, only block and scattered forms were reported in woodlots. Here one thing is need to be noted

that, as in woodlots; farmers usually harvest tree crops according to their own wish and it may be either whole plot or only some number of trees which are harvested at a time. So, there are chances that with harvesting of tree species block patterns may converted in to scattered forms of retained tree species.

- 4) **Plantation patterns in live fences:** tree species were planted in boundaries around the field in all live fence practice reported in the study area and no other kind of pattern was reported.

5. Conclusion

Farmers had confirmed that they were planting tree species under four main agroforestry forms. The most widespread application is agri-silvi-oleo and pastoral based agroforestry practices which the households have spontaneously adopted. Agroforestry is a land use practice which combines trees with crops in various combinations. Farmers in the study area have been retaining trees, crops and animals in different niches. Farm boundary, block plantation, orchard plantation, and live fence are the niche where these species plantation have been undertaken. In tree crop combination, agriculture crop species were mainly cultivated either in boundary or in block plantation in all the area tehsils. Pattern wise distribution of agroforestry practices clearly indicated that farmers are adopting more than one agroforestry structures and spatial patterns making it the major kind of agroforestry practices in the study area. The results of this study showed that most of the farmers In which more than three –four respondents are planting in boundary pattern, one-fourth in block patterns and around 1 in each 10 respondent under these category have rendered trees in scattered forms. Farmers were practicing horticulture tree species based agroforestry mostly in scattered form. Very few farmers were engaged in woodlots and that too was mostly in scattered form. In the study area, agroforestry farmers had also reared different kind of cattle species along with adoption of agroforestry. From study it is revealed that Wheat is the dominant species grown by all agroforestry adopters. Sugar cane is the second most agricultural crop with 30.40% of occurrence in the field. About one fourth of total grown crops are constituted by Paddy. Berseem most preferred species for cattle fodder. It is followed by Chari i.e. millet fodder. Sorghum is another reported crop. A diverse array in agroforestry practices and their components shows that agroforestry is prevalent in Haridwar and farmers find agroforestry suitable and profitable to them.

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