



Status And Economic Evaluation Of Agroforestry Practices In Five Districts Of Uttarakhand

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ABSTRACT

Key Words:

Agrisilviculture, agrihorticulture,
B:C ratio, Eucalyptus, mango,
net returns, poplar

The study evaluates agroforestry practices adopted by farmer in Udham Singh Nagar, Haridwar, Dehradun, Nainital and Pauri districts of Uttarakhand. Tree species like *Populus deltoides*, *Eucalyptus* spp., *Tectona grandis* and horticulture spp. *Mangifera indica* and *Litchi chinensis* were dominant commercial species of agroforestry. The patterns of planting were found in blocks as 72.06%, 53.74%, 35.50%, 71.65% and 11.56% followed by boundary plantation 27.94%, 46.26%, 61.30%, 28.35% and 11.53% in Udham Singh Nagar, Haridwar, Dehradun, Nainital and Pauri districts respectively. The overall net return from block system (Rs. 1,96,950/-) per ha per annum was found higher than the bund system (Rs. 1,02,249/-) per ha per annum in agri-silviculture system. The B:C ratio was found higher from block planting of poplar (3.85) compared to bund planting (2.22) in agri-silviculture system. The B:C ratio in Eucalyptus was (2.00) in agri-silviculture system. In agri-horticulture system, higher B:C ratio (2.17) was in litchi based model as compared to mango based model (2.10) in 14 years rotation respectively. Therefore, commercial agroforestry systems are promising as compared to traditional agroforestry and also relevant to the farmer's livelihood.

INTRODUCTION

Agroforestry is a land management system that optimizes land productivity by

harnessing positive interactions between tree-crop-livestock system on a same land unit area. Though forestry activities are mainly with government, rural people have

been practicing tree planting in their farms and homestead, to meet household requirements for fuel, fodder, poles, timber, fruits and non-timber forest produce. While in the small land holdings it is a livelihood strategy, in larger holdings it may take a commercial dimension. Agroforestry may be evolved along with compatible livestock management both of land and water and integrated land and water development planned for various biomass productions, regeneration of land resource base, and increase in employment and income. The development of non-forest areas for their sustainable use would call for regenerating or recreating an integrated, interdependent land management system.

The fast growing species like *Populus deltoides*, Eucalyptus species, *Casuarina equisetifolia*, *Acacia nilotica*, *Prosopis juliflora*, Bamboo have been recommended by Greening India Task Force for mass plantation under Joint Forest Management (JFM) and agroforestry practices. Developing the resources and finding ways to link Non Timber Forest Produces (NTFPs) and agro-forestry products with market is therefore essential. In order to facilitate rural development using the resources available on NTFPs and agroforestry systems in rainfed areas, providing training to different categories of stakeholders on capacity building to understand the opportunities along with constraints and threats is essential. This will facilitate better planning and execution of works in the field.

Agroforestry concerns the ways in which the presence of a plant can change the environment of its neighbors, generating a favorable balance between negative and positive plant interaction and thereby increasing total yield, reducing yield variance and conserving resources. When trees are added to cultivable land there are a number of possible outcomes of the interactions between tree and crop. Trees may affect the environment in a negative way with respect to crop or in a positive way and hence trees may cause an increase, decrease or have no affect on the crop. Competition between the tree and

crop for limited resources leads to a reduction in the growth of both species and the aim of good agroforestry practices is to reduce competition by planting combinations, results in greater productivity per unit of land from mixtures of species than from pure stands. The presence of a tree/ plant can affect the growth of another by reducing the light intensity, changing light quality, transpiring limited water, changing the humidity profile absorbing limited nutrients, providing limited nitrogen, sheltering or excluding predators, favoring or reducing pathogenic activity, raising the level of organic matter in soil etc. The study was conducted aiming to know the pattern and status of agroforestry practices with economic perspectives under different agroforestry models adopted by farmers.

MATERIALS AND METHODS

Study area

The Uttarakhand state spreads longitudinally from 28° 42'N to 31° 28' N and the latitudinally from 77° 35'E to 81° 5'E. The major part of the state of Uttarakhand is mountainous and rich in forests with wide variety of flora found in the area. Like most of India, agriculture is one of the most significant sectors of the economy of Uttarakhand. Besides, agroforestry is also under practice on a large scale. Among tree component, mainly *Populus deltoids*, *D. sissoo* and *Eucalyptus* species are commercial tree species. The agriculture crops like Basmati Rice, Wheat, Soybeans, Groundnuts, Sugarcane, Potato, Coarse Cereals, Pulses, and Oil seeds are the most widely grown crops. Under horticulture, fruits like Apples, Mango, Oranges, Pears, Peaches, Litchis, and Plums are prevalent and important to the large food processing industry. The districts surveyed for the study are briefly described as under:

Haridwar district has an area of about 2,360 km², is in the southwestern part of Uttarakhand state of India. Temperature in summers varies from 35°C – 42°C and in winters from 6°C –

16.6°C. Average annual rainfall in the district is 904 mm.

Udham Singh Nagar district occupies an area of approximately 2908 square kilometres. Annual rainfall in the district is 1296.85 mm.

Dehradun District receives an average annual rainfall of 2073.3 mm. Mean temperature of area is 20° C (Max. temperature 28° C & Min. Temperature 13° C).

Nainital District has maximum temperature of 27°C and minimum 7°C. In winter, Nainital receives snowfall between December and February. Average annual rainfall in the district is 1467 mm.

Methods

The reconnaissance field surveys of agroforestry were done in blocks of Haridwar, U.S. Nagar, Dehradun, Nainital and Pauri districts. The study sites were chosen through stratified random sampling. On the basis of survey, representative three villages each from four blocks viz. Gurukul Narson, Roorkee, Bhagwanpur and Laksar in Haridwar; Rudrapur, Gadarpur, Sitarganj and Bajpur in U.S. Nagar; Raipur, Sahaspur, Doiwala and Vikasnagar in Dehradun and three blocks viz. Haldwani, Kotlabagh and Ramnagar in Nainital and Pauri, Dugada & Khirsu in Pauri districts were selected. The economy of these villages is mainly based on agriculture. *Rabi* and *Kharif* crops of the areas are wheat, paddy and sugarcane. Farmers also grow fodder crops like Barseem (*Trifolium sp.*), Chari (*Sorghum vulgare*) in substantial quantity except in Pauri district. Fruits species like apples, mango, oranges, pears, peaches, litchis, and plums are widely grown.

Irrigation facilities are excellent through canals and tube wells. Rainfall varies from 1,400 to 1,800 mm and temperature ranges from 5-30°C. The entire study areas lie in the plains and hills of Uttarakhand.

Participatory Rural Appraisal (PRA) technique was followed to ascertain the status and economics of agroforestry practices in the selected villages. In addition to direct field observations, data were collected by interviewing twelve families in a village four each in the category of landless, small, medium and large farmers using a standardized questionnaire in each district. While selecting the farmers, only those farmers were interviewed, who were by and large practicing agroforestry. While computing the economic returns from poplars, eucalyptus and horticulture species with 10 % mortality was presumed in all plantations, which was generally observed on account of damage by wind, insects and pests.

While calculating economics of various crops, current market rates were taken into account. Wage rate for agricultural laborers has been taken as Rs. 200/day.

RESULTS AND DISCUSSIONS

Status of socio-economic study

On the basis of survey, representative twelve families in a village and three villages in each block in the district Haridwar, U.S. Nagar, Dehradun, Nainital and Pauri districts were visited to collect socio-economic data and agroforestry status through questionnaire. The data on total land, population, families and landholding categories of average value/village was calculated by sampling 3 villages in each block are given in table 1 to 5.

Table 1. Description of land & landholding wise categories of families in selected blocks of Uttarakhand

District	Block	Av. total land (ha.) per village	Av. total population per village	Av. nos. of families per village	Landholding wise categories of average Nos. of families per village			
					Landless	Small	Medium	Large
Haridwar	Gurukul Narson	193	2333	330	227	35	40	28
	Bhagwanpur	576	1667	192	47	109	28	8
	Roorkee	336	3933	689	450	183	42	14
	Laksar	192	4167	733	534	127	55	17
U.S. Nagar	Rudrapur	500	3400	328	230	47	33	18
	Gadarpur	75	333	57	28	13	13	3
	Sitarganj	411	4333	728	358	163	207	-
Dehradun	Bajpur	176	633	117	2	77	33	5
	Raipur	361	1377	227	19	159	49	-
	Sahaspur	56	293	51	15	20	16	-
	Vikasnagar	75	800	115	30	25	30	30
Nainital	Doiwala	450	1200	200	10	90	50	50
	Haldwani	127	1367	170	25	142	3	-
	Kotabagh	79	925	130	30	86	12	2
Pauri	Ramnagar	270	1073	176	36	100	36	2
	Pauri	37	264	62	7	29	21	5
	Dugada	63	370	89	14	26	40	9
	Khirsu	38	750	100	10	48	37	5

As land holding is a pre-requisite for the adoption of agro forestry, families were classified according to their land holdings in small families with less than 2 hectares, medium families with ranging 2 to 4 hectare and big families with above 4 hectares (Table 1).

Haridwar: The data showed that total land was found maximum (576 ha) in Bhagwanpur & minimum (192 ha) in Laksar; total population was maximum (4167) in Laksar and minimum (1667) in Bhagwanpur; The maximum number of families (733) were in Laksar and minimum (192) in Bhagwanpur; Maximum landless families were in Vikasnagar (30) and minimum (10) in Doiwala; Maximum small landholding families (159) in Raipur & minimum (35) in Gurukul Narson; Maximum medium landholding families

(55) in Laksar & minimum (28) in Bhagwanpur and the maximum large landholding families (28) in Gurukul Narson & minimum (08) in Bhagwanpur were also found in district Haridwar.

Udham Singh Nagar: Total land were found maximum (500 ha) in Rudrapur and minimum (75 ha) in Gadarpur ; Total population was maximum (4333) in Sitarganj & minimum (333) in Gadarpur; The maximum number of families (728) in Sitarganj & minimum (57) in Gadarpur; Maximum landless families (358) in Sitarganj & minimum (02) in Bajpur; Maximum small landholding families (163) in Sitarganj & minimum (13) in Gadarpur; maximum medium landholding families (207) in Sitarganj & minimum (13) in Gadarpur; Maximum large landholding families (18) in Rudrapur & zero in

Sitarganj were also found in district Udham Singh Nagar.

Dehradun: The average data showed that total land were found maximum (450 ha) in Doiwala and minimum (56 ha) in Sahaspur; Total population was maximum (1377) in Raipur & minimum (293) in Sahaspur; The maximum number of families (227) in Raipur and minimum (51) in Sahaspur; Maximum landless families (30) in Vikasnagar & minimum (10) in Doiwala; Maximum small landholding families (159) in Raipur & minimum (20) in Sahaspur; Maximum medium landholding families (50) in Doiwala & minimum (16) in Sahaspur; Maximum large landholding families (50) in Doiwala & zero in Raipur & Sahaspur were also found in district Dehradun.

Nainital: The total land were found maximum (270 ha) in Ramnagar and minimum (79 ha) in Kotabagh; Total population was maximum (1367) in Haldwani & minimum (925) in Kotabagh; The maximum number of families (176) in Ramnagar & minimum (130) in Kotabagh; Maximum landless families (36) in Ramnagar & minimum (25) in Haldwani; Maximum small landholding families (142) in Haldwani & minimum (86) in Kotabagh; Maximum medium landholding families (36) in Ramnagar & minimum (03) in Haldwani; Maximum large landholding families (02) in Ramnagar & Kotabagh and minimum in zero in Haldwani were also found in district Nainital.

Pauri: Total land were found maximum (63 ha) in Dugada and minimum (37 ha) in Pauri; Total population was maximum (750) in Khirsu and minimum (264) in Pauri; The maximum number of families (100) in Khirsu and minimum (62) in Pauri; Maximum landless families (14) in Dugada and minimum (07) in Pauri; Maximum small landholding families (48) in Khirsu & minimum (26) in Dugada; Maximum medium landholding families (40) in Dugada & minimum (21) in Pauri; Maximum large landholding families (09) in

Dugada & minimum (05) in Pauri & Khirsu were also found in district Pauri.

Data in table 2, indicated that poplar based agroforestry is being practiced by farmers 85.09% in Udham Singh Nagar followed by Haridwar (77.12%), Dehradun (39.37%) & Nainital (10.93%) except Pauri in Uttarakhand. This is because of fast growth, soil enriching properties, leaflessness during winter, compatibility with various agricultural crops and high and quick financial returns of poplar as compared to other species. *P. deltoides* with high productivity (up to 50 m³ha⁻¹yr⁻¹), in 6-12 years rotation is being preferred for various agroforestry systems in different parts of India (Tewari, 1993). Agricultural crops grown under the poplar are wheat (*Triticum aestivum*), turmeric (*Curcuma longa*), sugarcane (*Saccharum tuberosum*), chari (*Sorghum vulgare*), maize (*Zea mays*) and barseem (*Trifolium* species). Eucalyptus is planted by (20.55%) farmers in Nainital, followed by Haridwar (18.26%), Udham Singh Nagar (12.44%), Pauri (5.56%) & Dehradun (3.71%). The similar agriculture crops are also grown with eucalyptus species.

Horticulture based agroforestry is adopted by (82.21%) farmers of Pauri followed by Dehradun (50.25%), Nainital (47.31%), Haridwar (3.36%) & Udham Singh Nagar (1.72%). Mango and litchi are two main horticulture species planted orchards by farmers in Dehradun and Naintal district. Guava and citrus are planted in Pauri district. Teak based agroforestry is also found (13.48%) in Nainital followed by Pauri (11.11%), Udham Singh Nagar (0.72%) & Dehradun (0.19%). Teak is valuable and long rotation tree species and planted by some farmers due to heavy demand in the market. Agriculture crops are also grown with teak. Other species viz. *Melia dubia*, Bhimal, Kachnar, Khadik, Shisham, Neem *etc.* are planted & naturally grown in their fields with agriculture crops (11.12%) in Pauri followed by Nainital (7.73%), Dehradun (6.48%), Haridwar (1.26%) & Udham Singh Nagar (0.30%).

Table 2. Species composition (%) in different systems of agroforestry in some districts of Uttarakhand

S.N.	Name of District	Species composition (%)				
		Poplar	Eucalyptus	Horticulture	Teak	Other
1.	Udham Singh Nagar	85.09	12.44	1.72	0.72	0.30
2.	Haridwar	77.12	18.26	3.36	-	1.26
3.	Dehradun	39.37	3.71	50.25	0.19	6.48
4.	Nainital	10.93	20.55	47.31	13.48	7.73
5.	Pauri	-	5.56	82.21	1.11	11.12

Data in table 3 reveals that three types of plantation geometry viz. block, boundary & scattered were found in Uttarakhand. The maximum block plantation was established by (72.06%) farmers in Udham Singh Nagar followed by Nainital (71.65%), Haridwar (53.74%), Dehradun (35.50%) & Pauri (11.56%). Block plantations of poplar were planted by mostly big farmers in their field. In poplar block plantations, 500 ha⁻¹ are planted at a spacing of 5m x 4m with rotation period of six years and land under the trees is used for agricultural purposes. This spacing allows movement of tractor in the field for undertaking various agricultural operations. Few blocks of eucalyptus plantations & orchards of mango & litchi were also established by farmers in the above districts. Boundary plantations of poplar, eucalyptus and other species were planted by farmers (61.30%) with 1m to 3m spacing in Dehradun followed by Haridwar (46.26%), Nainital (28.35%), Udham Singh Nagar (27.94%) & Pauri (9.92%). Boundary plantations have been taken by small farmers, who are financially weak and unable to sacrifice agricultural production. The plants of Neem, Shisham, horticulture & other species were also planted scattered by (78.52%) farmers in Pauri & Dehradun (3.20%). The data in table 4 reveals that farmers adopted minimum in Pauri (30.29%) and maximum in Haridwar (51.31%) in three systems viz. Agri-silviculture, Silvi-pasture systems & Agri-horticulture on the basis of land utilization on their fields in study areas of Uttarakhand. However, they utilized their

land 48.69% to 69.71% on agriculture crops as mostly farmers have small land holdings less than 2 hectares and they could not compromised on agriculture crops. As far as within three systems Agri-silviculture system was found maximum land utilization followed by Agri-horticulture and then Silvi-pasture system. In Agri-silviculture system Udham Singh Nagar has maximum (40.19%) land utilization followed by Haridwar (39.20%) than Dehradun (13.99%), Nainital (12.09%) & Pauri (1.77%). In Agri-horticulture system Pauri have maximum (28.52%) land utilization followed by Nainital (20.43%) than Dehradun (14.50%), Haridwar (4.55%) & Udham Singh Nagar (2.56%). In Silvi-pasture system Haridwar has maximum (7.56%) land utilization followed by Dehradun (4.88%) than Udham Singh Nagar (4.73%) & Nainital (1.44%).

Data (Table 5) showed that farmers adopted maximum agroforestry practices included on the basis of land holding categories in Nainital (93.52%) followed by Haridwar (91.53%), Udham Singh Nagar (84.72%), Pauri (68.54%) & Dehradun (60.98%). Agroforestry models of Poplar-Sugarcane-Wheat-Paddy-Fodder in Haridwar, Dehradun & Udham Singh Nagar; Eucalyptus-Wheat-Paddy-Fodder in Haridwar & Udham Singh Nagar & Teak-Wheat-Paddy-Fodder in Nainital district were found under Agri-silviculture system. Similarly, Mango-Wheat-Fodder in Haridwar, Udham Singh Nagar & Dehradun; Litchi-Wheat-Fodder in Dehradun; Mango-Wheat-Tomato & Litchi-Wheat-Tomato in Nainital and Malta-Wheat

& Guava-Wheat in Pauri were also found under Agri-horticulture system. The study reveals that two promising Poplar-Sugarcane- Wheat- Chari agroforestry model in block plantation and Poplar-Wheat-Paddy model in boundary plantation under Agri-silviculture system were adopted by farmers in Haridwar, Udham Singh Nagar & Dehradun. The net profit of Rs. 11,81,700 & Rs. 6.13,499 with Benefit-Cost

(B : C) ratio as 3.85 & 2.22 were found in these two poplar models respectively (Singh *et al.* 2016). Similarly, two Horticulture models viz. Litchi-Wheat-Fodder and Mango-Wheat-Tomato in block plantation under Agri-horticulture system were adopted by farmers with net profit & B:C ratio of Rs.13,26,866 (2.17) and Rs.21,85,138 (2.11) in Dehradun & Nainital respectively.

Table 3. Geometry of plantation in some districts of Uttarakhand

Name of District	Geometry of Plantation (%)		
	Block	Boundary	Scattered
Udham singh Nagar	72.06	27.94	-
Haridwar	53.74	46.26	-
Dehradun	35.50	61.30	3.20
Nainital	71.65	28.35	-
Pauri	11.56	9.92	78.52

Table 4. Scenario of agroforestry systems in some districts of Uttarakhand.

Name of districts	Number of blocks	Agroforestry systems (%) basd on land utilization			
		Agri-silvi system	Silvi-pasture system	Agri-horticulture system	Agriculture
Udham Singh Nagar	04	40.19	4.73	2.56	52.52
Haridwar	04	39.20	7.56	4.55	48.69
Dehradun	04	13.99	4.88	14.50	66.63
Nainital	03	12.09	1.44	20.43	66.04
Pauri	03	1.77	---	28.52	69.71

Table 5. Adoption and existing of agroforestry systems in some districts of Uttarakhand.

Name of districts	Agroforestr y adoption (%)	Existing agroforestry system
Udham Singh Nagar	84.72	Agri-silviculture system (i) Poplar- Sugarcane -Wheat - Paddy-Fodder; Eucalyptus-Wheat - Paddy-Fodder Agri-horticulture system (i) Mango - Wheat - Fodder
Haridwar	91.53	Agri-silviculture system Poplar- Sugarcane -Wheat - Paddy-Fodder; Eucalyptus - Wheat - Paddy-Fodder Agri-horticulture system (i) Mango - Wheat - Fodder
Dehradun	60.98	Agri-horticulture system (i) Litchi - Wheat- Fodder; Mango - Wheat -Fodder Agri-silviculture system (i) Poplar - Sugarcane-Wheat - Paddy - Fodder
Nainital	93.52	Agri-horticulture system (i) Mango - Wheat - Tomato; Litchi - Wheat - Tomato Agri-silviculture system (i) Teak - Wheat -Paddy -Fodder
Pauri	68.54	Agri-horticulture system (i) Malta - Wheat; Guava- Wheat

Economic evaluation of agroforestry models

Agroforestry models adopted by farmers belong to Agri-silviculture, Agri-horticulture and Silvi-pastoral systems in a same unit area. In block plantation of Poplar models, 500 trees ha⁻¹ are planted at a spacing of 5m×4m with rotation period of six years and land under the trees is used for agricultural purposes. As the rotation of poplar adopted by the farmers for all the agroforestry models are of six years duration. Poplar can greatly contribute towards production of wood for industrial and other commercial purposes, besides maintaining ecological balance, uplifting of socio-economic status of the farmers and at the same time diversify the traditional rice-wheat agricultural rotation. Poplar and eucalyptus based commercial agroforestry systems are comparatively profitable than both the traditional agroforestry systems and conventional cropping patterns in the western Uttar Pradesh (Dwivedi *et al.* 2007).

Eucalyptus plantings in fields are on the boundaries at a spacing of 3m with rotation period of six years. Horticulture plantings *viz.* mango, litchi is planted as orchards at a spacing of 8m x 8m. Lands are used under orchards for agriculture purpose up to 14years. Malta & guava are planted in 6m x 6m spacing and land under orchards is also used for agriculture.

While presenting economic details of costs and returns for various poplar based agroforestry models 1 & 2 in block and boundary (Tables 6 & 7) which was reckoned in each year from February to January. Same as model 3 of Eucalyptus based on bund (Table 9) which was reckoned in each year from July-June of six year rotation. In regard of Agri-horticulture based model-4 Mango-tomato-wheat (Table 10) & model-5 Litchi-maize fodder-wheat (Table 11) was also reckoned in each year

from July to June and May to April respectively. Net profit and Cost, Benefits have been shown against the year in which they are received. Poplar & other viable agroforestry models as seen in the study areas are as follows:

Model 1: Poplar-sugarcane-wheat-chari block plantation model

As described in the model-1, poplar and sugarcane was planted in the first year and for the first two years two crops of sugarcane was harvested. In the second year, wheat was sown in December, which was harvested in April of the third year. Then in May, *chari* fodder was sown, which was harvested during August-September. Similarly chari and wheat crops was taken in alternation till sixth year. Poplar crop was harvested after six year of age. For this model, net profit of Rs.11,81,700 with Benefit-Cost (B : C) ratio was found as 3.85 respectively (Table 6). The local farmers generally adopt the cultivation of *chari* from 3rd year onwards. Though there is reduction in the yield of *chari* but the rates of *chari* are more in the successive years of plantation. The gross returns mention is on average basis of the total six years. Similarly, as per farmers the management cost is calculated on average basis from second year to six year of total cost except establishment cost of poplar in 1st year. Viable agroforestry models and their economics in Yamunanagar district of Haryana and Haridwar district of Uttarakhand was also studied by Kumar *et al.* (2004). He observed that the poplar based agroforestry has left a profound impact on the upliftment of the socio-economic status of the people in the region and also contribute toward environment amelioration (Panwar *et al.* 2017) and improves soil properties (Chauhan *et al.* 2019).

Table 6. Economics of Poplar-sugarcane-wheat-chari block plantation model (6 yrs).

Year	Forestry and agricultural crop	Cost and benefit (Rs. ha ⁻¹)	
		Cost (Rs. ha ⁻¹)	Gross Returns (Rs. ha ⁻¹)
I	Poplar-	38850	000.00
	Sugarcane-	72500	1,50,000

II	Poplar-	13000	000.00
	Sugarcane-	45000	1,12,500
	Wheat-	36425	000.00
III	Poplar-	13000	000.00
	Wheat-	36425	67500
	Chari fodder-	12000	18000
IV	Poplar-	13000	000.00
	Wheat-	36425	67500
	Chari fodder-	12000	18000
V	Poplar-	13000	000.00
	Wheat-	36425	67500
	Chari fodder-	12000	18000
VI	Poplar-	13000	9,92250
	Wheat-	000.00	67500
	Chari fodder-	12000	18000
Total		4,15,050	15,96,750
	Net Profit	11,81,700	
	B : C Ratio	3.85	

Model 2: Poplar-paddy-wheat boundary plantation model

Under this model, poplar was planted on the raised bunds along the field boundary in the first week of February. Then paddy was sown in June and harvested in November of the same year. In the November itself wheat crop was sown, which was harvested in April of the second year. Then paddy and wheat crops were taken alternately till sixth year. At the end of sixth year poplar crop was also harvested. The gross returns mention is on average basis of the total six years. Similarly, as per farmers the management cost is calculated on average basis from second year to six year of total cost except establishment cost of poplar in 1st year. For this model, net profit of Rs. 6,13,499 with Benefit - Cost (B : C) ratio was found as 2.22 respectively (Table 7). Gross returns were found minimum due to relatively from the less numbers of poplars and short rotation of agricultural crops (as compared to return from the block plantation) after six years of rotation.

Farmers with marginal and small land holding adopted boundary plantation models. In general, these farmers are financially weak and unable to sacrifice nominal agricultural production in lieu of much higher return from block plantation of poplar at the end of six years. For

boundary plantations, poplar is now getting popularized with the farmers (Sharma and Dadhwal 1996). In general, poplar plants (133) has been taken along two boundaries and one field bund in the middle at 3m spacing from plant to plant in one ha field area. For boundary plantation, cost of raising and gross income (Rs.11,15,100 ha⁻¹) is proportionately reduced as compared to the block plantation (Rs.15,96,750 ha⁻¹) in view of reduced number of trees. Net returns from the trees comes to Rs. 2,41,374 ha⁻¹ and from crops comes to Rs.3,72,125 ha⁻¹ on boundary plantation in six years of agri-silviculture system respectively (Table 8).

The lower net returns from agri-silviculture system was mainly due to the fact that during initial years for plantation required some cost without any economic returns But it is evident that the cost of establishment of plantation can be meet out through intercropping during the gestation period of plantation. Higher net returns from melia+dhaincha-berseem crop rotation have also been reported by Nandal and Kumar (2010). Similarly, the yield of different crops was not affected by different tree combinations during initial two years also studied by Kaushik *et al.* (2011), Kaushal *et al.* 2019. According to a study, on economics of poplar plantation with agricultural crops, maximum B:C ratio in 6

years tree rotation were found to be (3.85) ¹ yr⁻¹ from the block plantation of poplar on in block system as compared to bund system (2.22) respectively. Comparatively eight years rotation has been reported as per net returns and B : C ratio, the block systems were found more economic to bund down to 6 years with better economic returns.

Table 7. Economics of Poplar-paddy-wheat boundary plantation model

Year	Forestry and agricultural crop	Cost and benefit (Rs. ha ⁻¹)	
		Cost (Rs. ha ⁻¹)	Gross Returns (Rs. ha ⁻¹)
I	Poplar-	9226	000.00
	Paddy-	49375	85,500
	Wheat-	36425	67,500
II	Poplar-	2800	000.00
	Paddy-	49375	85,500
	Wheat-	36425	67,500
III	Poplar-	2800	000.00
	Paddy-	49375	85,500
	Wheat-	36425	67,500
IV	Poplar-	2800	000.00
	Paddy-	49375	85,500
	Wheat-	36425	67,500
V	Poplar-	2800	000.00
	Paddy-	49375	85,500
	Wheat-	36425	67,500
VI	Poplar-	2800	2,64,600
	Paddy-	49375	85,500
Total		5,0,1601	11,15,100
	Net Profit	6,13,499	
	B : C Ratio	2.22	

Table 8. Comparative actual cost and returns from tree and agriculture crops in block and bund systems (6 years rotation).

S.N.	Particulars	Block system (Rs. ha ⁻¹)	Bund system (Rs. ha ⁻¹)
1.	Cost of crops	3,11,200	4,78,375
2.	Cost of trees	1,03,850	23,226
	Total cost (in Rs./ha)	4,15,050	5,01,601
1.	Gross returns from crops	6,04,500	8,50,500
2.	Gross returns from trees	9,92,250	2,64,600
	Total gross returns (Rs. ha ⁻¹) *	15,96,750	11,15,100
	Net Returns from (agri-silvi) system	11,81,700	6,13,499
	Net Returns from crops (Rs. ha ⁻¹)*	2,93,300	3,72,125
	Net returns from trees (Rs. ha ⁻¹)*	8,88,400	2,41,374
	Net Returns from crops (Rs. ha ⁻¹ yr ⁻¹)	48,883	62,021
	Net Returns from trees (Rs. ha ⁻¹ yr ⁻¹)	1,48,067	40,229
	Net Returns from (agri-silvi) system (Rs. ha ⁻¹ yr ⁻¹)	1,96,950	1,02,250
	Benefit : Cost Ratio	3.85	2.22

* For 6 years rotation

Model 3: Eucalyptus-paddy-wheat boundary plantation model

Under this model, Eucalyptus was planted on the raised bunds along the field boundary in the month of July. Then paddy is sown in July and harvested in November of the same year. In the November itself wheat crop was sown, which was harvested in April of the second year. Then paddy and wheat crops were taken alternately till sixth year. At the end of sixth year Eucalyptus crop was also harvested. For this model,

Table 9. Economics of Eucalyptus-paddy-wheat boundary plantation model

Year	Forestry and agricultural crop	Cost and benefit (Rs. ha ⁻¹)	
		Cost (Rs. ha ⁻¹)	Gross Returns (Rs. ha ⁻¹)
I	Eucalyptus -	6980	000.00
	Paddy-	49375	85,500
	Wheat-	36425	67,500
II	Eucalyptus -	2700	000.00
	Paddy-	49375	85,500
	Wheat-	36425	67,500
III	Eucalyptus -	2700	000.00
	Paddy-	49375	85,500
	Wheat-	36425	67,500
IV	Eucalyptus -	2700	000.00
	Paddy-	49375	85,500
	Wheat-	36425	67,500
V	Eucalyptus -	2700	000.00
	Paddy-	49375	85,500
	Wheat-	36425	67,500
VI	Eucalyptus -	2700	1,50,000
	Paddy-	49375	85,500
	Wheat	36425	67500
Total		5,35,280	10,68,000
	Net Profit	5,32,720	
	B : C Ratio	2.00	

Model 4: Mango-tomato-wheat model (14 yrs).

Under this model, Mango was planted as orchard with spacing of 8m x 8m in July. Then tomato saplings are prepared in July & sown in August and harvested from October to November of the same year. In the November itself wheat crop was sown, which was harvested in April of the second year. Then Tomato and wheat crops are taken alternately till fourteen years. From sixth year mango fruit yield was started. Annual yield of mango fruit in tonne per hectare with 90% survival were

net profit of Rs. 5,32,720/- with Benefit-Cost (B : C) ratio was found as 2.00 respectively (Table 9). Dwivedi and Sharma (1990) studied the growth performance and biomass production of *Eucalyptus tereticornis* (*E. hybrid*) trees grown on agriculture field bunds. *E. tereticornis* at 6 years age grown on two sides and all sides of the field boundary in single row produces above ground biomass (t/ha) of the order of 16.62 and 27.22, respectively.

1.4, 2.1, 4.2, 6.3, 8.4, 3.5, 11.2, 4.2 & 16.8 from six years to fourteen years respectively. The rates of mango are calculated @ Rs.12000 per tonne. Similarly, the study of fruit yield of mango was also reported as tonne per hectare between 1.89 and 15.31 with cowpea-toria, 1.26 and 12.50 with sesame-toria, 1.75 and 14.58 with pigeon pea, 1.63 and 14.94 with black gram-toria, 1.15 and 13.79 with okra-toria and 1.02 and 13.97 in sole mango respectively during (1999 -2005) in first phase and ranged from 4.75 to 18.44 in association of turmeric followed 3.90 to

17.53 during second phase (2006 -2010) Cost (B : C) ratio was found as 2.10 (Table by Rathore *et. al* (2013). For this model, the net profit of Rs.21,84,338 with Benefit - 10).

Table 10. Economics of Mango-tomato-wheat model (14 yrs).

Year	Horticulture and agricultural crop	Cost and benefit (Rupees per hectare)	
		Actual Cost (Rs. ha ⁻¹)	Actual Returns (Rs. ha ⁻¹)
I	Mango-	62512	000.00
	Tomato	80000	180000
	Wheat	36425	67500
II	Mango-	7500	000.00
	Tomato	80000	180000
	Wheat-	36425	67500
III	Mango-	7500	000.00
	Tomato	80000	180000
	Wheat -	36425	67500
IV	Mango-	7500	000.00
	Tomato	95000	180000
	Wheat-	36425	67500
V	Mango-	7500	000.00
	Tomato	80000	180000
	Wheat -	36425	67500
VI	Mango-	12700	16800
	Tomato	80000	180000
	Wheat -	36425	67500
VII	Mango-	14800	25200
	Tomato	80000	150000
	Wheat	36425	67500
VIII	Mango-	21100	50400
	Tomato	80000	180000
	Wheat	36425	67500
IX	Mango-	27400	75000
	Tomato	80000	180000
	Wheat	36425	67500
X	Mango-	33700	100800
	Tomato	80000	180000
	Wheat	36425	67500
XI	Mango-	20000	42000
	Tomato	80000	180000
	Wheat	36425	67500
XII	Mango-	43100	134400
	Tomato	80000	180000
	Wheat	36425	67500
XIII	Mango-	22100	50400
	Tomato	80000	180000
	Wheat	36425	67500
XIV	Mango-	59900	201600
	Tomato	80000	180000
	Wheat	36425	67500
Total		19,77,262	41,61,600
	Net Profit	21,84,338	
	B : C Ratio	2.10	

Model 5: Litchi-maize fodder-wheat model (14 yrs).

Under this model, Litchi was planted as orchard with spacing of 8m x 8m in July. Then in June, maize fodder was sown, which was harvested during August-October. In the November itself wheat crop was sown, which was harvested in April of the second year. Then Maize and wheat crops were taken alternately till fourteen years. From sixth year Litchi fruit yield was started. Annual productions of litchi in tonne per hectare with 90% survival were 0.42, 1.4, 2.24, 3.50, 4.20, 4.90, 5.60, 6.30 & 7.00 from six years to fourteen

respectively. The rates of litchi are calculated @ Rs.25000 per tonne. For this model, net profit of Rs. 13,26,866 with Benefit-Cost (B : C) ratio was found as 2.17 (Table 11).

According to a study, on economics of mango & litchi orchard with agricultural crops were found maximum B:C ratio to be (2.17) in litchi based model as compared to mango based model (2.10) in 14 years rotation respectively. Comparatively as per net returns and B:C ratio of litchi based model were given higher returns to mango based model.

Table 11. Economics of Litchi-maize fodder-wheat plantation model (14 yrs).

Year	Horticulture and agricultural crop	Cost and benefit (Rupees per Hectare)	
		Actual Cost (Rs. ha ⁻¹)	Actual Returns (Rs. ha ⁻¹)
I	Litchi	63122	000.00
	Maize fodder	23938	45000
	Wheat	36425	67500
II	Litchi -	7500	000.00
	Maize fodder	23938	45000
	Wheat-	36425	67500
III	Litchi -	7500	000.00
	Maize fodder	23938	45000
	Wheat -	36425	67500
IV	Litchi -	7500	000.00
	Maize fodder	23938	45000
	Wheat-	36425	67500
V	Litchi -	7500	000.00
	Maize fodder	23938	45000
	Wheat -	36425	67500
VI	Litchi - fruit	9760	10500
	Maize fodder	23938	45000
	Wheat -	36425	67500
VII	Litchi -	12700	35000
	Maize fodder	23938	45000
	Wheat	36425	67500
VIII	Litchi -	15220	56000
	Maize fodder	23938	45000
	Wheat	36425	67500
IX	Litchi -	19000	87500
	Maize fodder	23938	45000
	Wheat	36425	67500
X	Litchi -	21100	105000
	Maize fodder	23938	45000
	Wheat	36425	67500
XI	Litchi -	24200	122500
	Maize fodder	23938	45000

	Wheat	36425	67500
XII	Litchi -	26300	140000
	Maize fodder	23938	45000
	Wheat	36425	67500
XIII	Litchi -	28400	157500
	Maize fodder	23938	45000
	Wheat	36425	67500
XIV	Litchi -	42250	175000
	Maize fodder	23938	45000
	Wheat	36425	67500
Total		11,37,134	24,64,000
	Net Profit	13,26,866	
	B : C Ratio	2.17	

CONCLUSIONS

The outcome of this study reveals that there are three major agro forestry systems were found in five districts Udham Singh Nagar, Haridwar, Dehradun, Nanital & Pauri (Haridwar) of Uttarakhand. Maximum adopted agroforestry system was agri-silviculture in which tree *P. deltoides* and *Eucalyptus* species are dominant and under storey main crops are wheat, sugarcane and paddy and maize & chari are fodder crops being grown in these districts. In agri-horticulture system having mango and litchi as fruit component and inter-crops are wheat, mustard and fodder crops are also maize & chari. Block, boundary & scattered types plantation of *P. deltoides*, *Eucalyptus* species, *T. grandis*, *Mangifera indica*, *Litchi chinensis* & other species are found on their fields with different agriculture crops. The socio-economic study showed that large land holding farmers are maximum benefitted to adopt agroforestry systems. Comparison of all four models in the all above agroforestry systems with net return and B:C ratio of the Poplar based block plantation model was given maximum returns to the farmers as compared to other models. Agroforestry has given a great impact to development among rural people of the region of Uttarakhand.

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