Journal of Forestry Research (2009) 20(2): 137−143
DOI 10.1007/s11676-009-0024-0

RESEARCH PAPER

Productivity status of traditional agrisilviculture system on northern and southern aspects in mid-hill situation of Garhwal Himalaya, India

Arvind Bijalwan[1*], Chandra Mohan Sharma[2], V. K. Sah[3]

[1] *College of Forestry and Environment, Allahabad Agricultural Institute- Deemed University, Allahabad-211 007, Uttar Pradesh, India*
[2] *Department of Botany, H.N.B. Garhwal University, Srinagar (Garhwal)- 246 174, Uttarakhand, India*
[3] *Department of Forest Ecology, College of Forestry and Hill Agriculture, G. B. Pant University of Agriculture and Technology, Hill Campus, Ranichauri, Tehri Garhwal, Uttarakhand-249 199, India*

Abstract: The productivity of traditional agrisilviculture system (agricultural crops + trees) was investigated in the northern and southern aspects of mid-hill situation in Garhwal Himalaya, Uttarakhand, India during the 2004−2006. A total of 19 tree species were studied in both northern and southern aspects, out of which 17 tree species were selected in northern aspect and 12 tree species in southern aspect for phytosociological characteristic analysis of trees in agrisilvicultural system. The most dominant tree species are *Grewia optiva*, *Celtis australis* and *Melia azedarach* and successively grown under traditional agrisilviculture system. The results show that the annual productivity of all tree species was 3 775 $kg \cdot ha^{-1} \cdot a^{-1}$ in northern aspect (site-N) and 3 101 $kg \cdot ha^{-1} \cdot a^{-1}$ in southern aspect (site-S). *G. optiva* had the highest productivity in both site-N and site-S among the tree species, followed by *M. azedarach*, *Quercus leucotrichophora* and *C. australis*. The dominant agricultural crops were *Eleusine coracana* in summer cereals, *Phaseolus vulgaris* in summer pulses-oilseeds and *Triticum aestivum* in the winter season in the area. The average biological productivity of agricultural crops in northern aspect was about 16% higher than that in southern aspect under traditional agrisilviculture system. The sole agricultural crop productivity (without trees) in northern aspect was also higher than that in southern aspect. An obvious difference in annual productivity of trees and agriculture crops was observed between northern aspect and southern aspect. The overall productivity in traditional agrisilviculture system (crop + tree) was 24% (in northern aspect) and 21% (in southern aspect) higher than that in sole cropping system.

Keywords: traditional agrisilviculture system; sole agricultural system; productivity; phytosociology; sole crop; importance value index

Introduction

Traditional agrisilviculture system is an important system in the Garhwal Himalaya. The structural and functional of tree species in traditional agroforestry systems greatly affect the overall productivity of the system. In hilly terrain, the productivity of components under traditional agrisilviculture systems is greatly influenced by different aspects and elevation of terrain. The phytosociological analysis of agroforestry systems helps us to elucidate the production potential under specific site condition (Sharma et al. 2006). The present study is to estimate the composition and productivity of traditional agrisilviculture system and the compatibility of trees with agricultural crops. Generally, the overall productivity (crops + trees) in agroforestry systems is higher than that in sole cropping systems (Chaturvedi 1981). Few researches focus on the productivity of traditional agrisilviculture system in the Garhwal Himalayan regions. Therefore, the present study was conducted on phytosociological characters and productivity parameters of traditional agrisilviculture system in mid-hills of Garhwal Himalaya in Uttarakhand, India to evaluate the feasibility of this system.

Materials and methods

Study area

The study was carried out in northern and southern aspects (78º12' 30" to 79º 18' 20" E and 29º 16' 14" to 30º 21' 30" N) of Chamba block of Tehri Garhwal district in Uttarakhand, India at different elevations ranging from 1000 m to 2000 m a.s.l. during the 2004−2006 (Fig. 1). The studied area has sub-tropical to temperate climate with monthly highest temperature from 11.6ºC in January to 26.0ºC in June, and mean monthly lowest temperature from 2.3ºC in January to 16.8ºC in July. The mean annual precipitation is 1 240 mm. The trees studied are mostly on the agricultural fields in the traditional agroforestry system.

Received: 2008- 09-24; Accepted: 2008-10-30

The online version is available at http://www.springerlink.com
Biography: Arvind Bijalwan (1975-), Corresponding author, male, Assistant Professor in College of Forestry and Environment, Allahabad Agricultural Institute- Deemed University, Allahabad-211 007, Uttar Pradesh, India. E-mail: arvind276@rediffmail.com
Responsible editor: Zhu Hong

Analysis of phytosociological characteristics

The phytosociological characteristic analysis in traditional agrisilviculture system was carried out by laying randomly selected quadrats with each area of 10 m ×10 m in size for trees and 50 cm × 50 cm for agriculture crops in the five different sites in northern and southern aspect. The stratified random sampling and multi-stage sampling were carried out on each selected site to study the vegetation. Twenty sample plots were set for trees and 40 for agricultural crops (Mishra 1968). The vegetation data (frequency, density and abundance) in each stratum were quantitatively analyzed by using the standard expressions (Curtis et al. 1950). Ratio of Abundance to Frequency (A/F) was used to interpret the distribution pattern of the tree species (Whitford 1949). The importance value index (IVI) was determined as the sum of relative frequency, relative density and relative dominance/basal area (Phillips 1959).

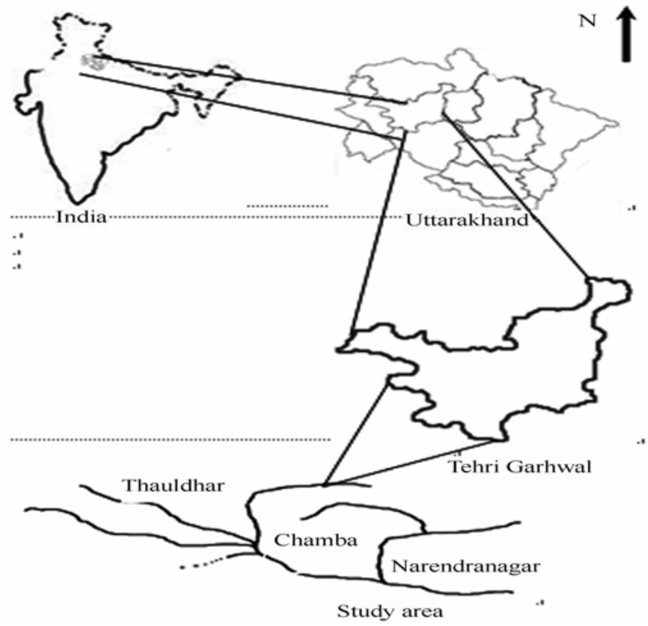

Fig. 1 Location map of the study area

Estimation of standing volume

Diameter at breast height (DBH) and height of trees were measured in traditional agrisilviculture systems in each quadrat for computation of standing volume for different tree species. The specific volume equations for tree species compiled by Forest Survey of India (FSI, 1996) were used to compute the volume of forest trees. Local, regional and general volume equations were used to compute the volume for all the agrisilviculture tree species. The volumes of all individual trees in a quadrat were summed to obtain the total volume present in the sampling quadrat. Mean standing volume was calculated by averaging the volumes of all sampling quadrats.

Computation of aboveground biomass

In order to estimate the biomass of forest tree species, the volume of individual tree in each sampling quadrat was multiplied by its wood density. Later, the stem biomass was multiplied by the biomass expansion factor of respective species to derive aboveground biomass (Haripriya 2000). The aboveground biomass of individual agrisilviculture trees in a quadrat was summed to obtain total aboveground biomass in sampling quadrats. The mean aboveground biomass was calculated by averaging biomass values in all sampling quadrats. The mean values were extrapolated on hectare basis to obtain aboveground biomass storage per hectare. The Biomass Expansion Factors (BEF) was calculated following Brown and Lugo (1992).

$$A_{GB} = V \times W_D \times B_{EF} \tag{1}$$

where, A_{GB} is the aboveground biomass, V is the volume of tree, W_D is the wood density, and B_{EF} is the biomass expansion factor.

Productivity of trees

The aboveground annual productivity is also termed as Current Annual Increment (C_{AI}) and expressed as $kg \cdot ha^{-1} \cdot a^{-1}$. Productivity of trees was studied through measurement of DBH and height in a sample plot in two successive years under the DBH and height classes *i.e*. 2004 to 2005 and 2005 to 2006. The annual increment in DBH and height of the sampled trees was recorded and the average annual volume increment (difference in volume) was computed for the trees. Further, the annual increment in volume was converted to productivity ($kg \cdot ha^{-1} \cdot a^{-1}$).

Productivity of agriculture crops

The productivity of agriculture crops was estimated during winter and summer seasons in a year. The samples of agriculture crops were taken from farmers' fields in Randomised Block Design (RBD). Mature agriculture crop was harvested and separated in grain (seeds) and straw (vegetative portion including shoots and leaves). Agriculture productivity included grain productivity, straw productivity, and the biological yield which is referred to as the total productivity of agriculture crops including grain and straw yield. The Harvest Index (HI) was also calculated using following equation:

$$H_I = (E_Y/B_Y) \times 100 \tag{2}$$

where, H_I is the harvest index, E_Y is the economic yield (grain yield), and B_Y is the biological yield (grain + straw).

The stratified random sampling and multi-stage sampling approaches were adopted for laying out quadrats on different sites to estimate the phytosociology and productivity of traditional agrisilviculture systems. The productivity of sole agricultural crop was performed in Randomize Block Design (RBD) and estimation was done in agronomical method. Further, the least significant difference (LSD) test was performed between different pairs (combination types) to separate the significant differ-

ence in means.

The statistical analysis was performed using MSTAT C and SPSS statistical software under PC environment.

Results

A total of 19 tree species were studied in both northern and southern aspects, out of which 17 tree species were selected in northern aspect and 12 tree species in southern aspect for phytosociological characteristic analysis of trees in agrisilvicultural system (Table 1). In the northern aspect, *Grewia optiva* has maximum values of frequency (65%), density (1.60×100^{-2} plants·m^{-2}), Total Basal Cover (TBC) (6.3643 cm^2·m^{-2}) and Importance Value Index (IVI) (63.03). *Ficus palmata* and *Myrica esculenta* have lowest IVI value (4.58) among the tree species. In southern aspect (site-S), *G. optiva* has the highest frequency (55%), density (1.05×100^{-2} plants·m^{-2} and IVI value (62.83), while *F. palmata* and *Dalbergia sissoo* have the lowest IVI values (Table 1). Therefore, *G. optiva* was considered to be the most dominant species.

Table 1. Phytosociological analysis of tree species in the traditional agrisilviculture (AS) system

Species	Frequency (F, %)	Tree density (Individual·m^{-2})	Abundance (A)	A/F ratio	TBC (cm^2·m^{-2})	IVI
Northern aspect (site-N)						
Fodder Trees						
Grewia optiva	65	1.60×100^{-2}	2.46	0.038	6.3643	63.03
Celtis australis	45	0.95×100^{-2}	2.11	0.047	5.2731	44.08
Ficus roxburghii	35	0.45×100^{-2}	1.29	0.037	2.2.98	23.11
Quercus leucotrichophora	30	0.40×100^{-2}	1.33	0.044	2.1656	20.97
Morus serrata	10	0.10×100^{-2}	1.00	0.100	0.7071	6.40
Alnus nepalensis	10	0.10×100^{-2}	1.00	0.100	0.4911	5.66
Timber and fuelwood trees						
Melia azedarach	60	0.85×100^{-2}	1.42	0.024	4.9968	45.05
Pinus roxburghii	40	0.40×100^{-2}	1.00	0.025	1.5911	21.35
Toona ciliata	25	0.25×100^{-2}	1.00	0.040	1.2277	14.14
Pyrus pashia	20	0.20×100^{-2}	1.00	0.050	0.7955	10.67
Prunus cerasoides	15	0.15×100^{-2}	1.00	0.067	1.0607	9.60
Rhododendron arboreum	15	0.15×100^{-2}	1.00	0.067	0.7366	8.49
Cedrus deodara	15	0.15×100^{-2}	1.00	0.067	0.3961	7.31
Lyonia ovalifolia	10	0.15×100^{-2}	1.50	0.150	0.1604	5.33
Populus deltoides	10	0.10×100^{-2}	1.00	0.100	0.4911	5.66
Ficus palmata	10	0.10×100^{-2}	1.00	0.100	0.1768	4.58
Myrica esculenta	10	0.10×100^{-2}	1.00	0.100	0.1768	4.58
Total		6.20×100^{-2}			29.0206	
Southern aspect (site-S)						
Fodder trees						
Grewia optiva	55	1.05×100^{-2}	1.91	0.035	4.2209	62.83
Celtis australis	35	0.80×100^{-2}	2.29	0.065	3.9286	48.77
Ficus roxburghii	20	0.35×100^{-2}	1.75	0.088	1.9208	24.01
Quercus leucotrichophora	20	0.30×100^{-2}	1.50	0.075	1.1065	19.03
Timber and fuelwood trees						
Melia azedarach	50	0.90×100^{-2}	1.80	0.036	5.2403	62.67
Pinus roxburghii	30	0.45×100^{-2}	1.50	0.050	1.8344	29.38
Pyrus pashia	15	0.25×100^{-2}	1.67	0.111	0.8662	14.99
Prunus cerasoides	10	0.15×100^{-2}	1.50	0.150	0.3961	8.76
Toona ciliata	10	0.10×100^{-2}	1.00	0.100	0.4911	8.14
Bombax ceiba	10	0.10×100^{-2}	1.00	0.100	0.4911	8.14
Ficus palmata	10	0.10×100^{-2}	1.00	0.100	0.1768	6.63
Dalbergia sissoo	10	0.10×100^{-2}	1.00	0.100	0.1768	6.63
Total		4.65×100^{-2}			20.8496	

Notes: TBC is Total Basal Cover; IVI is Importance Value Index.

Composition and distribution of agricultural crops under traditional agrisilviculture systems are presented in Table 2. The agricultural crops have generally a short rotation; therefore, two seasonal crops were taken each year as summer and winter crops. The composition and distribution of agricultural crops under traditional agrisilviculture system in northern aspect (site-N) showed that in summer, cereal crops with the maximum IVI values were recorded for *Eleusine coracana*, which was the dominant crop species, and the lowest IVI value for *Fagopyrum esculentum*. In summer season, the pulses with the highest IVI value of 98.68 was recorded for *Phaseolus vulgaris* and lowest for *Dolichos uniflorus*. In the winter season, *Triticum aestivum*

was found with highest IVI value on northern aspects, which accounts for 2/3rd portion of the total agricultural crops in the winter season in the area (Table 2).

In the southern aspect (site-S), *Echinochloa frumentacea* (124.12) and *P. vulgaris* (137.34) in the agricultural crops had the highest IVI values in summer season, and *Amaranthus caudatus* (27.77) and *D. uniflorus* (37.84) in cereals and pulses had the lowest IVI values in summer season. Among the winter crops, *T. aestivum* has highest IVI value (232.73), which accounts for more than two-third of the agricultural crops under the agrsilvicultural system (Table 2).

Results of standing volume of trees under traditional agrisilviculture systems show that standing volume of trees in northern aspect is 25.06 $m^3 \cdot ha^{-1}$, higher than that in southern aspect (19.87 $m^3 \cdot ha^{-1}$) (Table 3). In traditional agrisilviculture systems, it is recorded that *G. optiva* has highest standing volume in northern aspect (5.54) and southern aspect (4.52 $m^3 \cdot ha^{-1}$), followed by *Pinus roxburghii* (3.64 $m^3 \cdot ha^{-1}$) in northern aspects (sites-N) and *Melia azedarach* (2.88 $m^3 \cdot ha^{-1}$) in southern aspects (sites-S). *Prunus cerasoides* and *Lyonia ovalifolia* had the lowest volume in all the sites under agrisilviculture systems. The aboveground biomass of all the tree species was 30.34 $t \cdot ha^{-1}$ on site-N and 25.16 $t \cdot ha^{-1}$ on site-S under agrisilviculture system. The distribution of biomass under traditional agrisilviculture system shows that *G. optiva* has highest biomass followed by *Celtis australis* in both the aspects. *L. ovalifolia* and *P. cerasoides* are observed to have lowest biomass (Table 3).

Table 2. Phytosociological analysis of agricultural crops under traditional agrisilviculture (AS) systems

Summer-cereals crop	IVI N	IVI S	Summer- pulses & Oilseeds	IVI N	IVI S	Winter- ag. crops	IVI N	IVI S
Zea mays	45.81	31.12	*Dolichos uniflorus*	47.59	37.84	*Triticum aestivum*	244.94	232.73
Eleusine coracana	107.83	116.99	*Phaseolus vulgaris*	98.68	137.34	*Coriandrum sativum*	19.60	67.27
Echinochloa frumentacea	80.77	124.12	*Vigna umbellata*	56.64	44.65	*Pisum sativum*	35.46	-
Amaranthus caudatus	44.41	27.77	*Glycine max*	97.09	80.18			
Fagopyrum esculentum	21.19	-						

Notes: N- Northern aspect, S- Southern aspect

Table 3. Standing volume, biomass and productivity of trees under traditional agrisilviculture (AS) system

Species	Volume ($m^3 \cdot ha^{-1}$)		Biomass ($t \cdot ha^{-1}$)		Volume Increment ($m^3 \cdot ha^{-1} \cdot a^{-1}$)		Productivity ($kg \cdot ha^{-1} \cdot a^{-1}$)	
	N	S	N	S	N	S	N	S
Fodder trees								
Grewia optiva	5.54	4.52	8.59	7.01	0.785	0.525	1218	815
Celtis australis	3.15	2.86	4.58	4.16	0.350	0.260	509	378
Ficus roxburghii	2.12	1.65	2.23	1.74	0.335	0.120	353	126
Quercus leucotrichophora	1.82	1.38	3.05	2.31	0.320	0.150	537	252
Morus serrata	0.61	-	0.83	-	0.110	-	149	-
Alnus nepalensis	0.52	-	0.32	-	0.120	-	74	-
Timber & fuelwood trees								
Melia azedarach	2.48	2.88	2.43	2.83	0.375	0.640	369	629
Pinus roxburghii	3.64	2.39	2.72	1.78	0.390	0.090	292	67
Toona ciliata	1.28	0.45	1.27	0.45	0.050	0.030	50	30
Lyonia ovalifolia	0.18	-	0.11	-	0.015	-	9	-
Pyrus pashia	1.24	1.35	1.84	1.97	0.040	0.350	58	511
Ficus palmata	0.44	0.40	0.48	0.42	0.060	0.010	63	11
Myrica esculenta	0.21	-	0.22	-	0.010	-	12	-
Prunus cerasoides	0.18	0.24	0.21	0.25	0.015	0.075	15	76
Bombax ceiba	-	0.55	-	0.42	-	0.070	-	53
Dalbergia sissoo	-	1.20	-	1.82	-	0.100	-	153
Populus deltoides	0.62	-	0.48	-	0.030	-	23	-
Cedrus deodara	0.65	-	0.46	-	0.030	-	23	-
Rhododendron arboreum	0.38	-	0.52	-	0.015	-	21	-
Total	25.06	19.87	30.34	25.16	3.050	2.420	3775	3101

Notes: N- Northern aspect, S- Southern aspect

The total annual tree productivity of all tree species was 3 775 $kg \cdot ha^{-1} \cdot a^{-1}$ in site-N and 3 101 $kg \cdot ha^{-1} \cdot a^{-1}$ in site-S. The *G.optiva* had the highest productivity in both the aspects (site-N and site-S) followed by *M. azedarach* (629 $kg \cdot ha^{-1} \cdot a^{-1}$ in site-S), *Quercus*

leucotrichophora (537 kg·ha^{-1}·a^{-1} in site-N) and *C. australis* (509 kg·ha^{-1}·a^{-1} in sites-N). *L. ovalifolia* was observed to have the lowest productivity (9 kg·ha^{-1}·a^{-1}) in site-N (in northern aspect) and *F. palmata* in site-S (in southern aspect) (Table 3). Among different tree species, the *G. optiva* has significantly ($p<0.01$) higher production followed by *M. azedarach*, *C. australis* and *Q. leucotrichophora* on different sites of agrisilviculture systems. A comparison of the average annual productivity of the agrisilviculture systems in both the aspects shows that *G. optiva* alone accounts for 32 % of the total tree productivity among all the trees species present in northern aspect and 26% in southern aspect.

The biological productivity of agricultural crops in both the aspects under traditional agrisilviculture systems were 3 553kg·ha^{-1}·a^{-1} (northern aspect- site-N) and 2 970 kg·ha^{-1}·a^{-1} (southern aspect-site-S). The productivity of agriculture crops in northern and southern aspects had significant difference. In northern aspects, the average agricultural productivity was about 16% higher than that in southern aspects under traditional agrisilviculture system. The sole agricultural crop productivity (without trees) in northern aspects was also higher than that in southern aspects (Table 4). The grain yield and biological yield decreased by 35.54% and 36.37%, respectively, in northern aspect and decreased by 39.58% and 37.02%, respectively, in southern aspect. However, this decrease in yield is supplemented by the yield of wood produced.

Table 4. Productivity of agriculture crops under traditional agrisilviculture (AS) systems

Agricultural crops	Agrisilviculture system(kg·ha^{-1}·a^{-1})*				Control (Sole agricultural crop)(kg·ha^{-1}·a^{-1})*				Decrease from control (%)	
	Grain	Straw	B.Y.	H.I.	Grain	Straw	B.Y.	H.I.	Grain	B.Y.
Northern aspect (site-N)										
Summer season										
Zea mays	685	1954	2639	25.96	921	2689	3610	25.51	25.62	26.90
Eleusine coracana	763	1610	2373	32.15	1087	3786	4873	22.31	29.81	51.30
Echinochloa frumentacea	811	1774	2585	31.37	1194	2344	3538	33.75	32.08	26.94
Amaranthus caudatus	487	2178	2665	18.27	658	3643	4301	15.30	25.99	38.04
Fagopyrum esculentum	697	2482	3179	21.93	936	3022	3958	23.65	25.53	19.68
Phaseolus vulgaris	587	611	1198	49.00	941	897	1838	51.20	37.62	34.82
Vigna umbellata	394	618	1012	38.93	515	832	1347	38.23	23.50	24.87
Glycine max	673	749	1422	47.33	1065	1115	2180	48.85	36.81	34.77
Average	637	1497	2134	29.85	915	2291	3206	28.54	29.62	32.16
Winter season										
Triticum aestivum	662	1321	1983	33.38	1082	1983	3065	35.30	38.82	35.30
Coriandrum sativum	213	539	752	28.32	383	932	1315	29.13	44.39	42.81
Pisum sativum	838	684	1522	55.06	1425	1274	2699	52.80	41.19	43.61
Average	571	848	1419	40.24	963	1396	2360	40.81	41.47	40.57
Total (summer +winter)	1208	2345	3553	34.00	1878	3687	5565	33.75	35.54	36.37
Northern aspect (site-N)										
Summer season										
Echinochloa frumentacea	610	1340	1950	31.33	934	2170	3104	30.12	34.65	37.17
Phaseolus vulgaris	526	564	1090	48.17	665	894	1559	42.66	20.98	30.10
Dolichos uniflorus	377	759	1136	33.19	848	1140	1988	42.66	55.47	42.85
Glycine max	730	819	1549	47.13	1137	1237	2374	47.89	35.81	34.76
Average	561	870	1431	39.20	896	1360	2256	39.72	36.73	36.22
Winter season										
Triticum aestivum	657	1358	2015	32.61	1147	1849	2996	38.28	42.73	32.74
Coriandrum sativum	243	767	1010	24.06	413	1189	1602	25.78	41.22	36.95
Pisum sativum	750	842	1592	47.11	1324	1507	2831	46.77	43.33	43.78
Average	550	989	1539	35.74	962	1515	2477	38.84	42.43	37.82
Total (summer +winter)	1111	1859	2970	37.41	1858	2875	4733	39.26	39.58	37.02

Notes: BY- Biological Yield, HI- Harvest Index, Control- sole/pure agriculture crops; * The decimal values are rounded to one, hence, the difference of one is observed.

Net productivity includes the sum of productivity of trees and agricultural crops. In northern aspects, the productivity under traditional agrisilviculture system (crop + tree) was 24% higher than that of sole/pure agricultural crop, whereas in southern aspect it is 21% higher than that of pure agricultural crop (Table 5). Overall the average productivity in northern aspect was recorded to be 16.50% higher than that in southern aspect.

Table 5. Productivity in traditional agroforestry systems on northern and southern aspect

Region/Aspect	Productivity of existing agrisilviculture system ($kg\cdot ha^{-1}\cdot a^{-1}$)			Control (Sole agricultural crop)	Increase in productivity under
	Trees	Agricultural crops	(Trees +Ag. crops)	($kg\cdot ha^{-1}\cdot a^{-1}$)	agroforestry (%)
Northern (N)	3775	3553	7328	5565	24
Southern (S)	3101	2970	6071	4753	21

Discussion

In the present study, the common agroforestry tree species reported in the region are *G. optiva*, *C. australis*, *M. azedarach, F. roxburghii*, etc. (Singh 1986) in Himanchal Pradesh between 1000 to 2000 m a.s.l. *G. optiva*, *C. australis*, *Melia azedarach*, *Eucalyptus* spp., *Bauhinia* spp., *Juglans regia*, *Toona ciliata*, *Q. leucotrichophora*, *Populus* spp., *Prunus* spp., *Cedrus deodara*, *Quercus floribunda*, *Morus serrata*, etc. were the prominent tree species raised by farmers on bunds of their fields. Tejwani (1987) also enlisted that the tree species used in agroforestry systems in Uttar Pradesh and Himanchal Pradesh between 500 to 2300 m elevations are *G. optiva, C. australis, Quercus* spp. as reported in this study, except for few tree species *i.e.*, *Bauhinia variegata* and *F. roxburghii* from Himanchal Pradesh (Toky et al. 1989). The *M. azedarach* is also a promising agroforestry tree species (Luna et al. 2006), though it is not a highly preferred fodder species. Selection of tree species in the traditional agrisilviculture system depends mainly on edapho-climatic conditions of the area, farmer's need/traditions and resource availability (Saroj et al. 1997). As in the Kashmir valley, the trees of *Salix* spp., *Robinia pseudoacacia*, *Poplars* and *Toona ciliata* were planted in the field boundaries due to their multipurpose nature which are fit to satisfy the basic needs of the frames (Tewari 1995).

The biomass under various types of forest had been analyzed out by many researchers (Singh et al. 1991; Roy et al. 1996; Haripriya 2000; Hall et al. 1991; Brown et al. 1989). The *Grewia optiva* being a multipurpose species was widely preferred in traditional agrisilviculture systems in North-Western Himalaya. This species provide the fodder during the lean period (winter) and deliberately cultivated by farmers mostly on the bunds of the agriculture fields, because it does not cause any adverse effect on the agricultural crops. According to Sehgal et al. (2003), *Grewia optiva* is one of the most important fodder tree species of north-western and central Himalaya and is found distributed throughout the Sub-Himalayan tracts from 600m to 1800m elevations. *G. optiva* is considered as a boon for the temperate Himalayan regions due to its wide adaptability and multipurpose uses to provide fuel wood, fodder (in scare period), fibres and good soil binding ability (Sehgal et al. 1989; Khybri et al. 1992; Nautiyal et al. 1998; Bhatt et al. 2003). *C. australis* and *M. azedarach* are also used among the highly preferred tree species in the region after *G. optiva*. *M. azedarach* is extensively used for the fuel wood purpose, whereas, *C. australis* is used as the substitute of *G. optiva* as a fodder during summer season.

The grain yield is generally reduced under the tree shade, the reduction of grain yield under different agrisilviculture systems was in conformity with the findings of Wahua and Miller (1978), Shivaramu and Shivashankar (1992) and Sharma and Chauhan (2003), who had also recorded poor performance of soybean crop under tree species. The studies of Khybri et al. (1992) on tree-crop interaction under *G. optiva, Morus alba* and *Eucalyptus hybrid* with rice and wheat cropping systems showed that all tree species had adverse effects on crop yields, whereas, wheat product was mainly affected by *G. optiva*. The distance of tree from the crop significantly influenced the crop yield particularly up to 5 m and there was 39% reduction in crop yield up to 1 m, 33% from 1–2 m, 25% from 2–3m and 12% from 3–5m distance. It was observed that the agriculture crops yield increased with an increase of crop distance from the tree (Sharma et al. 1996). Further it was also reported that in agroforestry systems the productivity was improved as the distance from the tree was increased (Dhyani et al. 1999). Overall, there is slight reduction in the agricultural yield in agrisilviculture system due to completion for light, water and nutrients among trees and agricultural crops. The study from Newaj et al. (2003) showed that the grain yield of pure crops was higher than that from the tree-crop systems.

The productivity in traditional agrisilvicultural systems in the study was significantly influenced in the northern and southern aspects. The availability of higher moisture content in the northern aspect leads to the luxuriant vegetation which increases the more amount of organic matter in the soil and improves the fertility status and higher productivity from the traditional agrisilviculture system. The earlier studies had also demonstrated that slope and topography of field influenced on the growing stock and productivity (Swamy 1998; Dhanai et al. 1999; Gurung et al. 2002).

The agriculture and forestry products are the mainstay of livelihood in the Garhwal Himalayan region. Growing trees along with agricultural crop is the well-known agrisilvicultural system in the region. The dominant traditional agrisilviculture trees like *G. optiva*, *C. australis* and *M. azedarach* supplements the fuel, fodder, fibre and timber to the rural community, hence these trees are encouraged by the farmers of the region. The cultivation practices are more dominated in the northern aspect due to high moisture content to lead to high vegetation coverage and productivity. The productivity of agricultural crops was retarded under traditional agrisilviculture system but this loss is supplemented by the production of fuel, fodder, fibre and timber from the existing trees, hence highly preferred by the farmers. The study revealed that the traditional agrisilviculture system in the region is not in steady state and needs to be strengthening through proper silviculture techniques.

References

Bhatt RK, Pathak PS. 2003. Upscaling quality fodder production in semi-arid tropics by *Grewia optiva*. ICAR News, India, **9** (1): 18.

Brown S, Lugo AE. 1992. Aboveground biomass estimates for tropical moist

forests of the Brazilian Amazon. *Interciencia*, **17**: 8–18.

Brown S, Gillespie AJR, Lugo AE. 1989. Biomass estimation methods for tropical forests with application to forest inventory data. *Forest Science*, **35:** 881–902.

Chaturvedi AN. 1981. Poplar for planting. In: Uttar Pradesh Department Bull. India: no-50 Lucknow, pp 27.

Curtis JT, Mc Intosh RP. 1950. The interrelationship of certain analytic and synthetic phytosociological characters. *Ecology*, **31:** 434–455.

Dhanai CS and Panwar VP. 1999. Role of aspect and soil on the structure and composition of Quercus floribunda natural stands in Garhwal Himalaya. *Indian Forester*, **125**(12): 1204–1213.

Dhyani SK, Tripathi RS. 1999. Tree growth and crop yield under agrisilvicultural practices in north-east India. *Agroforestry Systems*, **44**: 1–12.

FSI. 1996. Volume equations for forests of Indian, Nepal and Bhutan. Dehradun: Forest Survey of India, 226pp.

Gurung NR, Sankhayam PL, Hofstad O. 2002. Forest volume and biomass at watershed level: A study in annapurana conservation area, Nepal. *Indian Forester*, **128**(4): 379–390.

Hall CAS, Uhlig J. 1991. Refining estimates of carbon released from tropical land use change. *Canadian Journal of Forest Research*, **21**: 118–131.

Haripriya GS. 2000. Estimates of biomass in Indian forests. *Biomass and Bioenergy*, **19**(250): 245–258.

Khybri ML, Gupta RK, Ram S, Tomar HPS. 1992. Crop yields of rice and wheat grown in rotation as intercrops with 3 tree species in the outer hills of Western Himalaya. *Agroforestry Systems*, **7**(3): 193–204.

Luna RK, Singh B, Sharma SK. 2006. Assessment of 51 progenies of Melia azedarach Linn. A promising agroforestry tree. *Indian Forester*, **132**(8): 941–951.

Mishra R. 1968. Ecology Work Book. Calcutta: Oxford and IBH Publishing Co, 244pp.

Nautiyal S, Maikhuri RK, Semwal RL, Rao KS, Saxena KG. 1998. Agroforestry Systems in the rural landscape – a case study in Garhwal Himalaya, India. *Agroforestry Systems*, **41**(2):151–165.

Newaj R, Bhargava MK, Yadav RS, Ajit, Shanker AK. 2003. Tree-crop interaction in Albizia procera based agroforestry system in relation to soil moisture, light and nutrients. *Indian Journal of Agroforestry*, **5**(1&2): 17–29.

Phillips EA. 1959. Methods of vegetation study. Holt Dryden Book Henry Hold publishing Co: 124pp.

Roy PS, Ravan SR. 1996. Biomass estimation using satellite remote sensing data – An investigation on possible approaches for natural forest. *Journal of Biosciences*, **21**(4): 535–561.

Saroj PL, Dadhwal KS. 1997. Present status and future scope of mango based agroforestry systems in India. *Indian Journal of Soil Conservation*, **25**(2): 118–127.

Sehgal RN, Chauhan V. 1989. Farm Forestry News. USA: Winrock International Publishing Co, 64pp

Sehgal RN, Rathore A, Chauhan SK. 2003. Divergence studies in selected genotypes of Grewia optiva. *Indian Journal of Agroforestry*, **5**(1&2): 99–102.

Sharma KK, Khanna P, Gulati A. 1996. The growth and yield of wheat and paddy as influenced by Dalbergia sissoo Roxb. Boundary plantation. *Indian Forester* , **122**(12): 114–126.

Sharma SB, Pandry S, Upadhyaya SD, Agarawal R. 2006. Phyto-sociological studies of tree species outside forest in traditional agroforestry of Chhattisgarh. *Indian Journal of Agroforestry*, **8**(1): 26–34.

Sharma SK, Chauhan SK. 2003. Performance of soybean crop under tree species. *Indian Journal of Agroforestry*, **5**(1& 2): 137–139.

Shivaramu HS, Shivashankar K. 1992. Performance of sunflower and soybean (Glycine max) in intercropping with different plant populations and planting patterns. *Indian Journal of Agronomy*, **37**: 231–236.

Singh L, Singh JS. 1991. Species structure, dry matter dynamics and carbon flux of a dry tropical forest in India. *Annals of Botany*, **68**: 263–273.

Singh RV. 1986. People's participation in social forestry programme in Himachal Pradesh. Dehradun, India: Forest Research Institute: 28pp.

Swamy SL. 1998. Estimation of Net Primary Productivity (NPP) in an Indian tropical evergreen forest using Remote Sensing data. Ph.D. Thesis, Hyderabad, India, In Jawaharlal Nehru Technology University: 288pp.

Tejwani KG. 1987. *Agroforestry: Realities, Possibilities and Potentials*. The Netherlands: Martinus Nijhoff publishers, Dordrecht, 137pp.

Tewari DN. 1995. Agroforestry for increased productivity: sustainability and poverty alleviation. Dehradun: International book distributor publishing, 539pp.

Toky OP, Kumar P, Khosla PK. 1989. Structure and function of traditional Agroforestry Systems in the western Himalaya. I. Biomass and productivity. *Agroforestry Systems*, **9**(1): 47–70.

Wahua TAT, Miller DA. 1978. Effect of shading on the N_2 fixation, yield and place composition of field grown soybeans. *Agronomy Journal*, **70**: 387–392.

Whitford PB. 1949. Distribution of woodland plants in relation to succession and clonal growth. *Ecology*, **30**: 199–208.