

Full Length Research Paper

Productivity assessment of agricultural crops in existing agrihortisilvicultural system of mid hills of Central Western Himalaya, India

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The paper summarizes the productivity of various agricultural crops under existing agrihortisilviculture (AHS) system in northern and southern aspects of mid hills of Central Western Garhwal Himalaya (Narendra Nagar block of district Tehri Garhwal, Uttarakhand), India between 1000 to 2000 m asl during Rabi (winter) and Kharif (summer) seasons. The northern aspect was more diverse and formed good vegetation composition, both in terms of forest crops and in agricultural productivity. The tree diversity and richness was recorded to be higher in northern aspect. A total of 18 tree species were reported in the northern aspect and 13 in the southern aspect of AHS systems. The *Grewia optiva* was observed as dominant tree species and *Citrus sinensis* as co-dominant species in the northern and southern aspects. The northern aspect observed with higher grain productivity under tree (1326 kg/ha/year) and sole cropping (2471 kg/ha/year) compared to southern aspect; similarly, the northern aspect proved to be higher in straw productivity under trees (3587 kg/ha/year) and treeless (4510 kg/ha/year) situation for both Rabi (winter) and Kharif (summer) crops. Overall, there is an average reduction of 45.05% in grain yield and 29.53% in biological yield compared to sole agricultural cropping in northern aspect. The average reduction in the grain yield (29.08%) and biological yield (28.77%) was lower in the southern aspect. It was summarized that the reduction in the agricultural produce under agrihortisilviculture system is supplemented by multifarious benefits of woody perennials which is life supporting to the rural community of this hilly landscape.

Key words: Agrihortisilviculture (AHS) system, grain productivity, biological productivity, northern aspect, southern aspect, IVI (importance value index).

INTRODUCTION

Agroforestry is a unique and very common practice in the Central Western Himalayan region of Uttarakhand, India. Trees have always been associated in the different places on agricultural fields of this region. These trees are deliberately enhanced by the farmers in order to fulfill their multifarious need namely fodder, fuel, fiber, fruits, small timber, agricultural implements etc along with the agricultural produce. The agrihortisilviculture is very common practice by the farmers of this region which includes the cultivation of agricultural crops in association of forest and horticultural trees present in the fields. The tremendous pressure on forest for the fuel and fodder purposes, the presence of these trees on the agricultural

fields become more significant. The arrangement of agrihortisilviculture (agricultural crops + horticulture tree + forest tree) systems on the same piece of land provides the stable and better output to the farmers. It is worthwhile, that in hilly regions the existence without agroforestry is difficult because trees not only supplement the fodder, fuel, fiber, fruits etc but also reduces the pace of land sliding in the fields, protect crops to adverse wind and climatic condition, conserve the moisture, improve the soil quality through nitrogen fixing and organic matter in terms of leaf fall etc.

The storey does not finish here with profits; there are some harmful aspect of the presence of trees like

antagonism for the light, water and nutrients between trees and crop which generally lower down the productivity of the agricultural crops. The cultivation of fruit-forest trees with agricultural crops is a common fashion in the Himalayan region for twofold benefits under the practices of the agrihortisilviculture (AHS) system. Considering the profit for the marginal family members, these existing agroforestry systems are more compassionate and sustainable than the single agricultural system, even there is more crop production in pure agricultural operations. The presence of trees, their structure, compositions and effect on crop is an important area to study in this region. In the Himalayan region, a number of indigenous agroforestry systems have been familiar from Himachal Pradesh and Uttarakhand (Atul et al., 1990) out of which agrihortisilviculture, agrisilviculture and agrihorticulture are very frequent. On the other hand, Singh et al. (1980), Dadhwal et al. (1989) and Toky et al. (1989) have recognized these three agroforestry systems with their multifarious benefits.

The assortment of trees on the edges of the agricultural field is farmer friendly and compatible. Selection of intercrops depends mainly on edapho-climatic conditions of the area, farmer's need/traditions and resource availability (Saroj and Dadhwal, 1997). The effect of aspect (the direction a slope is facing) on plant species distribution and growth pattern play a significant role. It has been reported that, even northern and southern facing slopes are at the same elevation, there are a number of environmental differences which form the variant microclimatic situation for the growth and development of the vegetation. Bearing this in mind, the present investigation is an effort to examine the aspect-wise study on productivity of agricultural crops in the existing agrihortisilvicultural system in the Garhwal region of the Central Western Himalaya of Uttarakhand, India.

MATERIALS AND METHODS

The study was carried out in the existing agroforestry systems of four selected sites (two each in the northern and southern aspect) in Narendra Nagar block of district Tehri Garhwal in Uttarakhand, India; between 1000 to 2000m asl elevation during Rabi (winter) and Kharif (summer) seasons in the year 2004 to 2006. The study area lies between 77° 51' 30" to 80° 30" E longitudes and 29° 40' to 31° 28" N latitudes. Geographically, the area falls between sub-tropical to temperate zone, with the luxuriant and green lush natural vegetation. The area receives an average annual rainfall of 1240 mm, with most of the rain occurring during July to September (monsoon period) with the mean annual temperature of the study area ranging from 9 to 33°C. In the present study, 20 quadrats were laid in each site with 4 replications having sample size of 10 x 10 m for trees and 0.5 x 0.5 m for agricultural crops. The productivity of different existing agriculture crops were calculated and compared with the sole agricultural productivity (control).

The existing agrihortisilviculture (AHS) system was selected for the study. The impact of existing trees and aspect (northern and southern aspects) on the vegetation was analyzed in the existing system. The frequency, density, abundance, A/F ratio, Total Basal Cover (TBC), and Importance Value Index (IVI) of existing trees

were computed in different aspects following Curtis and Mc Intosh (1950); Phillips (1959). The diversity parameters of trees were analyzed following (Shannon and Wiener, 1963), concentration of dominance (Simpson, 1949), equitability (Pielou, 1975), species richness (Margalef, 1958), Beta diversity (Whittaker, 1972, 1977). The assessment of productivity status of agricultural crops under AHS system was estimated to understand the feasibility of the systems. The random selection of samples of agriculture crops were taken from farmers' fields. The agriculture crops from the quadrats were harvested at the maturity stage from the agroforestry systems, as well as in sole agriculture system (controlled) to estimate the reduction in yield under agroforestry system, as compared to pure agriculture system. The mature agriculture crop was harvested and separated into grain (seeds) and straw (vegetative portion including shoots and leaves). Further, grain and straw were dried in natural conditions, so as to obtain the net yield (kg/ha) on crop and season basis. The Harvest Index (HI) is used to denote the fraction of economically useful products of a plant, in relation to its total productivity (grain to straw ratio) and calculated using the following formula as given by Khandakar (1985):

$$HI = (EY/BY) \times 100$$

where; HI = Harvest Index, EY = Economic Yield (grain yield), BY = Biological Yield (grain + straw)

RESULTS AND DISCUSSION

Phytosociology of tree crops

Agroforestry systems in the Garhwal Himalayan region are practiced by the farmers in order to meet their basic needs from the same piece of land. Agrihortisilviculture (AHS) system is one of the predominant systems in this region and the results of trees and agricultural crops recorded in AHS system are presented and discussed hereafter. Results on tree structure of agrihortisilviculture system on northern aspect of Narendranagar block (site-N) have shown that, the *Grewia optiva* was present with highest frequency, density, Total Basal Cover (TBC) and IVI (30%, 0.65 plants/100 m², 359.69 cm²/100 m² and 46.89 respectively), while lowest IVI values were recorded for *Prunus amygdalus* as 7.15 (Table 1). A total of 18 tree species were recorded in the northern aspect.

Data on structural parameters of agrihortisilviculture system on the southern aspect of Narendranagar block (site-S) showed that, the frequency, density, TBC and IVI values were again found to be highest for *G. optiva* as 70%, 1.20 plants/100 m², 513.33 cm²/100 m² and 73.53, while the lowest values were recorded for *Citrus aurantifolia* (Table 1). The *Musa paradisiaca*, *Mangifera indica* and *Melia azedarach* were identified as co-dominant plant species due to their higher IVI values, while *Toona ciliata*, *Ficus palmata*, *Embllica officinalis*, and *Citrus limon* were considered to be the suppressed plant species. There were a total of 13 tree species on this site under agrihortisilviculture system. The analytical characters of woody vegetation of traditional agroforestry systems have made it clear that *G. optiva*, *Celtis australis*, *M. azedarach* and *Malus domestica* have

Table 1. Phytosociology of tree layer in the northern and southern aspect of Agrihortisilviculture (AHS) system

Species	% Frequency (F)	Density (Trees/ 100 m ²)	Abundance (A)	A/F Ratio	TBC (cm ² /100 m ²)	IVI
Northern aspect (site-N)						
Fodder trees						
<i>Grewia optiva</i>	30	0.65	2.17	0.072	359.69	46.89
<i>Celtis australis</i>	25	0.35	1.40	0.056	213.41	30.24
<i>Quercus leucotrichophora</i>	5	0.20	4.00	0.800	98.21	11.89
<i>Ficus roxburghii</i>	10	0.15	1.50	0.150	73.66	11.76
<i>Alnus nepalensis</i>	10	0.10	1.00	0.100	96.26	11.68
Timber and fuelwood trees						
<i>Melia azedarach</i>	10	0.15	1.50	0.150	73.66	11.76
<i>Prunus cerasoides</i>	10	0.25	2.50	0.250	103.91	15.63
<i>Pyrus pashia</i>	15	0.25	1.67	0.111	23.77	13.95
<i>Myrica esculenta</i>	5	0.10	2.00	0.400	96.25	9.41
<i>Lyonia ovalifolia</i>	10	0.15	1.50	0.150	8.18	8.52
<i>Pinus roxburghii</i>	5	0.10	2.00	0.400	70.71	8.15
Temperate fruit plants						
<i>Juglans regia</i>	15	0.20	1.33	0.089	165.98	19.78
<i>Prunus armeniaca</i>	15	0.25	1.67	0.111	103.91	17.91
<i>Malus domestica</i>	10	0.25	2.50	0.250	143.20	17.57
<i>Prunus amygdalus</i>	5	0.15	3.00	0.600	26.52	7.15
Subtropical fruit plants						
<i>Citrus sinensis</i>	20	0.45	2.25	0.113	306.54	34.95
<i>Citrus aurantifolia</i>	15	0.25	1.67	0.111	44.20	14.95
<i>Citrus limon</i>	5	0.20	4.00	0.800	15.71	7.81
Total (18)		4.20			2023.77	
Southern aspect (site-S)						
Fodder trees						
<i>Grewia optiva</i>	70	1.20	1.71	0.024	513.33	73.53
<i>Ficus roxburghii</i>	15	0.35	2.33	0.156	213.41	22.18
<i>Celtis australis</i>	20	0.30	1.50	0.075	189.23	21.98
Timber and fuelwood trees						
<i>Melia azedarach</i>	20	0.40	2.00	0.100	177.28	23.52
<i>Ficus palmata</i>	10	0.15	1.50	0.150	73.66	10.08
<i>Toona ciliata</i>	10	0.10	1.00	0.100	49.11	7.98
Temperate fruit plants						
<i>Prunus armeniaca</i>	25	0.30	1.20	0.048	167.62	22.93
Subtropical fruit plants						
<i>Citrus sinensis</i>	30	0.60	2.00	0.067	314.61	37.40
<i>Musa paradisiaca</i>	15	0.60	4.00	0.267	204.61	26.95
<i>Mangifera indica</i>	20	0.25	1.25	0.063	268.91	24.42
<i>Citrus limon</i>	15	0.25	1.67	0.111	33.20	12.26
<i>Embllica officinalis</i>	10	0.15	1.50	0.150	73.66	10.08
<i>Citrus aurantifolia</i>	5	0.20	4.00	0.800	15.71	6.70
Total (13)		4.85			2294.34	

contributed more than 50% of the total IVI values (Table 1). The IVI values of present investigation were in concurrence with the studies conducted in the traditional agroforestry systems in the Bilaspur and Raipur districts of Chhattisgarh region (Sharma et al., 2006). The results also showed that, the aspect significantly influenced the concentration of dominance, species richness and beta diversity in different agroforestry systems. The earlier studies have also demonstrated that, the aspect had a marked effect on the structure and diversity of forest ecosystems (Kusumlata and Bisht, 1991; Bijalwan, 2002; Dhanai and Panwar, 1999; Sharma and Baduni, 2000; Kusumlata and Bisht (1991) had reported that, phytosociological characters differ among aspects and position even in the same vegetation type.

Diversity indices of trees

The data presented in Table 2 reveals that, Shannon index (diversity) values was higher (1.118) on northern aspect (site-N), while it was lower (0.994) on the southern aspect (site-S) of AHS system. Contrary to this, the Simpson index values were found to be highest (0.120) in the southern aspect (site-S). The higher species richness value (2.233) was recorded in northern aspect. The higher equitability (0.388) was observed in the southern aspect of AHS systems. Beta diversity was higher (2.154) on the southern aspect while it was lower (1.556) on the northern aspect of the AHS system. The diversity parameters of these agroforestry systems are comparable with the diversity indices reported by different workers for other regions in agroforestry and non-agroforestry systems (Toky et al., 1989; Sharma et al., 2006; Ralhan et al., 1982; Singh and Sigh, 1991). Tewari et al. (1999) reported the Shannon-Weaver index values from 0.41 to 2.31, concentration of dominance from 0.38 to 1.00 in the Thar desert, under natural silvipastoral system which are higher than the present study. The Simpson Index for the home garden of Kerala varied from 0.44 to 0.86 (Mohan et al., 1994; Jose, 1992) which is quite higher than the present study. In the present study, the higher diversity values on the northern aspects, may be due to the higher moisture content and low insolation rates, as compared to the southern aspects, which receive Sun rays in the later part of the day, when the atmosphere is sufficiently warmed. The effect of aspect on structure and diversity of vegetation was also quantified by several workers (Joshi and Tiwari, 1990; Singh et al., 1991; Jha, 2001).

Productivity of agricultural crops

The annual agriculture productivity under agrihorti-silviculture system (summer + winter season), when compared with control/sole agriculture system, a

significant difference in the productivity of agricultural crops was observed. The productivity of agricultural crops includes the productivity of grain or seeds (also referred to as economic productivity), straw productivity (includes other than the grain that is shoot and leaves) and biological productivity or total productivity (includes both grain and straw). In an agroforestry system, the agricultural crop production is generally lower due to competition with trees, but the biomass production is adequately compensated due to overall productivity (tree + crop), which is generally greater than sole agriculture system (Newaj et al., 2003).

Biological productivity (grain and straw)

Table 3 shows that under AHS systems, the biological yield of agriculture crops is 4913 kg/ha/year on site-N with a reduction of 29.53% as compared to the sole agriculture crops (6981 kg/ha/year). In the site-S, the biological yield was recorded to be 3413 kg/ha/year as compared to 4833 kg/ha/year in the control condition (sole cropping) with a reduction of 28.77% from sole cropping. It was observed that the biological yield was reduced under trees, as compared to the sole cropping. The reduction in crop yield under agroforestry systems was mainly due to competition for the light, water, nutrients and allelopathic effect etc. The competition may be interspecific or intraspecific (Carnell, 1990).

Shading was found to be more important than below ground competition in an intercropping study of pearl millet and groundnut in India (Willey and Reddy, 1981). The nutrient status in agroforestry systems was shared by agriculture and forestry components; hence, the resource sharing resulted into the retardation of growth of the agriculture crops. Beside this competition for usable water, allelopathic effects also retarded the biological yield of the agriculture crops.

Productivity of grains (economic yield)

The economic productivity includes the productivity of grain /seeds or edible parts of the agriculture crops. Table 3 shows the economic yield of agriculture crops under AHS system as 1326 kg/ha/year on site-N with a reduction of 45.05% compared to the sole agriculture crops (2471 kg/ha/year). In the site-S, the economic yield was recorded to be 1200 kg/ha/year as compared to 1749 kg/ha/year in the control condition (sole cropping) with a reduction of 29.08% from sole cropping.

In the present study, the reduction of grain yield under different agroforestry systems was in conformity with the findings of Wahua and Miller (1978), Shivaramu and Shivashankar (1992), Sharma and Chauhan (2003), who had also recorded poor performance of soybean crop under tree species. The studies of Khybri et al. (1992) on

Table 2. Aspect wise diversity of trees in Agrihortisilviculture (AHS) system.

AF system/Aspect	Shannon index	Simpson Index	Richness	Equitability	Beta diversity
AHS/N	1.118	0.094	2.233	0.387	1.556
AHS/S	0.994	0.120	1.551	0.388	2.154

AHS = Agrihortisilviculture; N = Northern aspects, S = southern aspects, quadrat size 10 x 10 m.

Table 3. Aspect-wise productivity of Agriculture crops (kg/ha/yr) under the Agrihortisilviculture (AHS) systems.

Agricultural crops	AHS system (productivity in kg/ha/year)*				Control/Sole agriculture crop (productivity in kg/ha/year)*				% Decrease from control	
	Grain	Straw	B.Y.	H.I.	Grain	Straw	B.Y.	H.I.	Grain	B.Y.
Northern aspect (site-N)										
Kharif (Summer season)										
<i>Zea mays</i>	621	1982	2603	23.86	1052	2398	3450	30.49	40.91	24.53
<i>Eleusine coracana</i>	830	1963	2793	29.72	1353	4020	5373	25.18	38.64	48.01
<i>Echinochloa frumentacea</i>	958	2648	3606	26.57	1331	1733	3063	43.45	28.00	17.72
<i>Amaranthus caudatus</i>	471	3919	4390	10.73	749	4188	4937	15.17	37.02	11.07
<i>Fagopyrum esculentum</i>	515	2184	2699	19.08	747	3055	3802	19.65	31.06	29.01
<i>Phaseolus vulgaris</i>	588	513	1101	53.41	988	957	1945	50.80	40.53	43.41
<i>Glycine max</i>	623	852	1475	42.24	1067	1112	2179	48.97	41.64	32.32
Average	658	2009	2667	24.67	1041	2494	3535	29.45	36.83	24.38
Rabi (Winter season)										
<i>Triticum aestivum</i>	659	1676	2335	28.18	1435	1910	3345	42.93	54.15	30.21
<i>Pisum sativum</i>	678	1479	2157	31.43	1425	2121	3546	40.19	52.39	39.17
Average	668	1578	2246	29.74	1430	2016	3446	41.50	53.27	34.69
Total (Rabi + Kharif)	1326	3587	4913	26.99	2471	4510	6981	35.40	45.05	29.53
Southern aspect (site-S)										
Kharif (Summer season)										
<i>Zea mays</i>	674	1875	2549	26.44	836	2292	3128	26.73	19.38	18.51
<i>Eleusine coracana</i>	615	1745	2360	26.06	721	1582	2303	31.31	14.70	-2.48
<i>Echinochloa frumentacea</i>	700	1382	2082	33.62	1056	2194	3250	32.49	33.71	35.94
<i>Amaranthus caudatus</i>	582	2185	2767	21.03	702	2733	3435	20.44	17.09	19.45
<i>Phaseolus vulgaris</i>	603	689	1292	46.67	753	1113	1866	40.35	19.92	30.76
<i>Dolichos uniflorus</i>	327	643	970	33.71	739	837	1576	46.89	55.75	38.45

Table 3. Contd.

<i>Vigna umbellata</i>	423	666	1089	38.84	534	1223	1757	30.39	20.79	38.02
<i>Glycine max</i>	578	777	1355	42.66	911	1098	2009	45.35	36.55	32.55
Average	563	1245	1808	31.14	782	1634	2416	32.37	27.24	26.40
Rabi (Winter season)										
<i>Triticum aestivum</i>	798	1284	2082	38.33	1295	1921	3216	40.27	38.38	35.26
<i>Brassica campestris</i>	382	838	1220	31.31	490	1154	1644	29.81	22.04	25.79
<i>Coriandrum sativum</i>	623	813	1436	43.38	785	983	1768	44.40	20.64	18.78
<i>Pisum sativum</i>	745	937	1682	44.29	1298	1743	3041	42.68	42.60	44.69
Average	637	968	1605	39.69	967	1450	2417	40.01	30.92	31.13
Total (Rabi + Kharif)	1200	2213	3413	35.16	1749	3084	4833	36.19	29.08	28.77

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.

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 was mainly affected by *G. optiva*. The deleterious effect on the average varied from 28 to 34%, depending upon the species. 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 is increased (Dhyani and Tripathi, 1999). Similarly in comparison to sole crop, linseed yielded 79, 73, 65 and 56% grain yield, when grown with *Albizia*, Mandarin, Alder and Cherry tree species (Dhyani et al., 1994). Overall, the reduction in the yield of intercrops due to the presence of trees may be attributed to differential patterns of canopy spread, resulting in variation in light interception, severe competitions of the tree roots for moisture and shade effects. The study carried by Newaj et al. (2003) showed that, the grain yield of pure crops was higher, as compared to the grain yield from the tree-crop

systems.

Productivity of straw

The productivity of straw includes the yield of shoot and crop herbage from the unit area. Table 3 shows that under AHS system, the straw yield of agriculture crops is 3587 kg/ha/year on site-N as compared to 4510 kg/ha/year in sole agriculture crops. In site-S, the straw yield was recorded to be 2213 kg/ha/year as compared to 3084 kg/ha/year in the control condition (sole cropping). The straw yield was comparatively low under agrihortisilviculture system, as compared to sole agriculture system. The higher straw yield in the sole cropping system was attributed to the availability of high PAR (Photosynthetic Active Radiation), which helped in more reproductive phase development (Bellow, 2004).

In the present study, north aspect shown more diversity and luxuriant vegetation though there are more number of trees of a single species like *G. optiva* was observed in the southern aspect of the AHS system. Although, both northern and

southern aspects receive almost the same amount of rainfall with alike soil and the similar elevation in this study area, still there are numerous environmental factors which make the difference in the growth and development of the vegetation (both trees and agricultural crops). The logic behind is, the northern aspect of the agrihortisilviculture site is shadier and cooler as in winter and spring; the sunlight is primarily fall on the southern aspect as compared to little direct fall on the northern aspect. As a result of this, the rate of evapotranspiration slow down and there is more moisture conservation in the northern site which resulted in good diversity and agricultural growth in the northern aspect.

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