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Agroforestry systems in the rural landscape – a case study in Garhwal Himalaya, India

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Abstract. A mid altitude (700–1200 m *amsl.*) village in Garhwal Himalaya was analysed in terms of energy and economic efficiency of different land use-land cover types constituting the landscape. Simultaneous agroforestry, sequential agroforestry, home garden and community forests accounted for 27.47%, 27.47%, 1.1% and 43.96% of the total geographical area of the village. Simultaneous agroforestry is the traditional land use involving substantial input of manure derived from forest litter and animal excreta and was practised on terraced slopes in private ownership. Tree cover in this system was represented by nine species with total average density of 390 trees ha^{-1}, *Grewia optiva* and *Boehmeria rugulosa* being the most dominant. Sequential agroforestry system involving slash-burn practice and cultivation on unterraced slopes without tillage and manuring was an illicit land use on community lands where forestry land use is desirable as per the government policy. Per ha annual energy input in simultaneous agroforestry system was 305267 MJ compared to 279 MJ in sequential agroforestry and 27047 MJ in home garden. In monetary terms, highest per ha annual output was obtained from simultaneous agroforestry (Rs 25370, Rs 35 = US$1) followed by home garden (Rs 18200) and sequential agroforestry (Rs 9426). Local food, fodder and fuelwood production was in excess of the local consumption. While most of the surplus food was stored, surplus fodder and fuelwood were sold for cash. Production in simultaneous agroforestry system in private lands was sustained with substantial biomass and nutrient inputs from the community and government forests. Land use-land cover changes in the region are driven by the interaction of ecological, policy and human factors. It is concluded that present policy of treating forests and agriculture as closed and independent ecological or production systems needs to be replaced by an integrated land use policy.

Introduction

Himalaya is a vast mountain system covering partly/fully eight developing countries of south Asia including Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal and Pakistan. Agroforestry land use, covering 20% of the total geographical area of the Indian Himalaya, is distributed as patches in the matrix of forests covering 52% area. Hence, land development planning in the region needs to be based on an integrated consideration of agroforestry and forestry systems rather than considering the two systems as independent or alternative land uses. Though a number of studies on Himalayan agroforestry systems are available (Toky et al., 1989; Gilmour and Nurse, 1991; Ralhan et al., 1991; Sundriyal et al., 1994; Thapa et al., 1995; Sharma et al., 1995; Semwal and Maikhuri, 1996; Singh et al., 1997), knowledge on ecosystem diversity within the village landscape and linkages between different ecosystem types and efficiency of different land use systems is fragmentary. This study aimed to analyse the energy and economic efficiency of agroforestry systems and linkages between agroforestry systems and forest ecosystems in a village landscape in Garhwal Himalaya.

Study area

Location and terrain

The Garhwal Himalaya, spread over a geographical area of 29698 km^2 (29°26′ to 30°28′ N latitude and 77°49′ to 80°6′ E longitude) comprises five districts of Uttar Pradesh state of India *viz*. Uttarkashi, Chamoli Pauri, Tehri and Dehradun. The study village Pali, a typical mid altitude village, is located at a distance of 52 km from Srinagar, an urban centre of District Pauri. The village is spread over an elevation range of 700 m–1200 m *amsl.* on south facing slopes. The angle of slope varies from 30° to 40°.

Climate and soil

The climate is warm temperate with mean annual temperature of 21 °C and annual rainfall of 1485 mm. The year consists of three seasons: dry summer season (April to June), warm rainy season (July to September) and winter season (October to March). About 80% of total annual rainfall is received during July to September. The parent material is represented by schistose phyllite, biotitequartz, schist/phyllite and, in places, flaggy quartzite and sericite quartz schist. Soils are 30 to 80 cm deep and of sandy-loam to loamy-sand texture.

Human population

The village consists of 53 households. Total population of the village is 356 of which 32.3% are adult males, 33.7% adult females and 31.2% children (< 12 years old). Average family size is 6.7.

Livestock

Total livestock population of the village is 246 of which 16.2% are buffaloes, 8.1% cows, 20.7% bullocks, 50.8% goats and 4.1% mules and horses. Livestock provide draught power, manure, milk, meat and wool. Livestock are also considered as capital asset. Litter collected from the forests is used as bedding material in the cattle-shed. The mixture of litter and cattle excreta is used as manure.

Land cover-land use

The village landscape could be divided into four land cover-land use types: (a) simultaneous agroforestry system characterized by cultivation of food crops every year on terraced slopes with scattered trees (b) sequential agroforestry system characterized by shifting agriculture involving slash-burn practice on unterraced slopes devoid of trees (c) home gardens (d) village community forests. The village is surrounded by government forests. Forests dominated by *Shorea robusta* represent climax vegetation up to 800 m elevation and oak-pine forests in 800 to 1200 m elevation zone.

Methods of study

37 Random households (70% of total households in the village) were surveyed to determine average land holding size, area under different land cover-land uses, crops, trees and shrubs used for various purposes and management practices. The information was collected through informal discussions with adult members. Each household was visited at least four times.

20 Households selected randomly out of 37 that were monitored for estimating inputs/outputs to/from simultaneous agroforestry system, sequential agroforestry system, home gardens and the forests. Family heads were contacted once in a week to have advance information on the household activities. Products collected from the forests were weighed on 15 days, 5 days in each of three seasons. Estimates of food, fodder and fuelwood consumption and, products supplied to/purchased from the market were derived based on fortnightly observations. Durations of sedentary, moderate or heavy works by males and females in various activities (Leach, 1976) and bullock power use were noted.

One medium size animal of each type of livestock in each household was maintained exclusively on stall feeding for one week in each of three seasons and the feed given was measured. Biomass consumed through grazing in forests was estimated as the difference in fodder consumed by totally stall fed animals and stall fodder consumed by those that were sustained through the normal practice of stall feeding combined with grazing.

Three plots of each crop grown in simultaneous agroforestry system, five plots of sequential agroforestry system during second year of cropping following slash-burn, and five home gardens wre randomly selected. Density of annual crops and weeds was measured in twenty 0.5 m × 0.5 m quadrats in each plot. Twenty individuals of each species from each plot at harvesting time were sampled, separated into edible/economic yield, by-products used as fodder and other components for determining mean plant values. In simultaneous agroforestry system, half of the total samples were taken from areas below and half from area outside the tree canopy; average production was obtained using relative acreage of area below and outside the canopy and mean density and mean plant production values in the two microhabitats.

Tree density in simultaneous agroforestry system was measured in sixty 10 m × 10 m random quadrats. Nine random trees of each species were selected to monitor production of fuelwood, fodder and other products per tree.

Fodder available from bunds of terraces in simultaneous agroforestry system where sowing was not done was measured by harvesting the biomass in 60 random 0.5 m × 0.5 m quadrats. Fuelwood and litter availability from the fallows in sequential agroforestry system were estimated based on sampling of sixty 1 m × 1 m quadrats.

Standard energy values of various inputs and outputs used for budgeting are given in Table 1. Hours spent by males and females for sedentary, moderate and heavy works were multiplied by per hour energetic value of a given type of work and the products summed up to obtain total human labour input per year in a given land use system. Similarly, duration of bullock power use

Table 1. Energetic values of different inputs and outputs in the agroforestry systems in Garhwal Himalaya, India.

Category	Energy
Grains	16.2 MJ kg^{-1}
Pulses	17.0 MJ kg^{-1}
Oilseeds	23.07 MJ kg^{-1}
Potato	3.9 MJ kg^{-1}
Leafy vegetables	2.8 MJ kg^{-1}
Other vegetables	2.4 MJ kg^{-1}
Milk	4.2 MJ kg^{-1}
Green fodder	3.9 MJ kg^{-1}
Hay	14.5 MJ kg^{-1}
Straw	13.9 MJ kg^{-1}
Fuelwood	19.7 MJ kg^{-1}
Farmyard manure/compost	7.3 MJ kg^{-1}
Human labour – male	
Sedentary work	0.418 MJ h^{-1}
Moderate work	0.488 MJ h^{-1}
Heavy work	0.679 MJ h^{-1}
Human labour – female	
Sedentary work	0.331 MJ h^{-1}
Moderate work	0.383 MJ h^{-1}
Heavy work	0.523 MJ h^{-1}
One bullock-day	72.7 MJ day^{-1}

Source: Mitchell (1979).

was multiplied by energetic value of bullock power to compute total energy of this input. Energy inputs through seeds and manure and outputs through edible yields, fuelwood, fodder and litter were calculated by multiplying the amount of an input/output related to a given land use and its standard energetic value. Monetary values of various inputs and outputs were calculated on the basis of buying and selling price in the village in 1995–96, the period of study.

Results

Village landscape

Simultaneous agroforestry, sequential agroforestry, home garden and village forests accounted for 27.47%, 27.47%, 1.1% and 43.96% of the total geographical area of the village. Average farm holding was 1.89 ha fragmented in 5–8 isolated plots. Simultaneous agroforestry land was near to the dwellings compared to the land under sequential agroforestry (Table 2).

Simultaneous agroforestry system

The simultaneous agroforestry system on terraced slopes was practised on land in private ownership. Trees were the permanent features of this land use as only non-timber forest products were utilized. Absence of stumps suggested that trees were not cut. Total average tree density was 390 trees ha^{-1}. *Boehmeria rugulosa* and *Grewia optiva* were the most dominant species (Table 3).

Area under simultaneous agroforestry system of the village was divided into two halves called Malli Sar, the upper part of the slope, and Mulli Sar, the lower part towards ridge. Each household had at least two plots, one in Malli Sar and the other in Mulli Sar (Figure 1). The age old traditions were (a) to fallow a Sar during one winter crop season over a period of two years to be observed by all households (b) independent decison making by the

Table 2. Land use-land cover of village Pali, Garhwal, India.

Land cover-land use	Area (ha)*
Village community forests	80 (43.96)
Simultaneous agroforestry	50 (27.47)
Sequential agroforestry	50 (27.47)
Home garden	2 (1.10)
Total land area	182
Average farm holding	1.89

* Values in parentheses are % of total in a given category.

Table 3. Density of agroforestry trees in simultaneous agroforestry system in village Pali, Garhwal, India.

Species	Density (trees ha^{-1})	Relative density
Adina cardifolia	25	6.4
Bauhinia retusa	40	10.2
Bauhinia variegata	35	9.0
Boehmeria rugulosa	91	23.1
Celtis australis	40	10.3
Cordia macleolis	30	7.7
Grewia optiva	85	21.8
Mallotus phillipensis	30	7.7
Terminalia tomentosa	15	3.8
Total	390	100

households in respect of selection of crops and tree-crop management practices.

Cropping patterns were built around two seasons locally referred to as Kharif (rainy season) and Rabi (winter season). *Echinochloa frumentacea*, maize (*Zea mays*), soyabean (*Glycine max*), fingermillet (*Eleusine coracana*), gingelly (*Sesamum indicum*) and beans (*Phaseolus radiatus*) were dominant rainy season crops. Wheat (*Triticum aestivum*), barley (*Hordeum vulgare*) and rape seed (*Brassica campestris*) were dominant crops of winter season. A plot owned by a family was divided into a number of sub-plots locally called as 'Khet' varying in size from 30 m^2 to 100 m^2. A 'Khet' was homogeneous in respect of agricultural crops and management practices. Only one crop species was sown in a 'Khet' during winter season. In rainy season, one cereal or millet crop was always mixed with a pulse (grain legume) and vegetables were sown as minor crops at places where the major cereal/millet/pulse crops germinated poorly. In all, four crops during winter season and 11 during rainy season were observed in simultaneous agroforestry system. All these crops were grown by all farmers.

Sequential agroforestry system

Discussion with the people and subsequent clarification from the land records revealed that sequential agroforestry system was practised on land which had a legal status of 'village community land'. This land which used to be common grazing land till 1970s, was equitably distributed. Each family had divided its plot into two halves. Each half was cropped for a period of 2 to 4 years followed by 2 to 4 years of fallowing. Trees were absent and shrub *Rhus parviflora* dominated the regeneration during fallow phase. During March-April, natural regeneration was slashed and 80–85% of woody biomass was removed to be used as fuelwood and then ground fire was set in the field. The intensity of fire was so low that only litter and small twigs could be

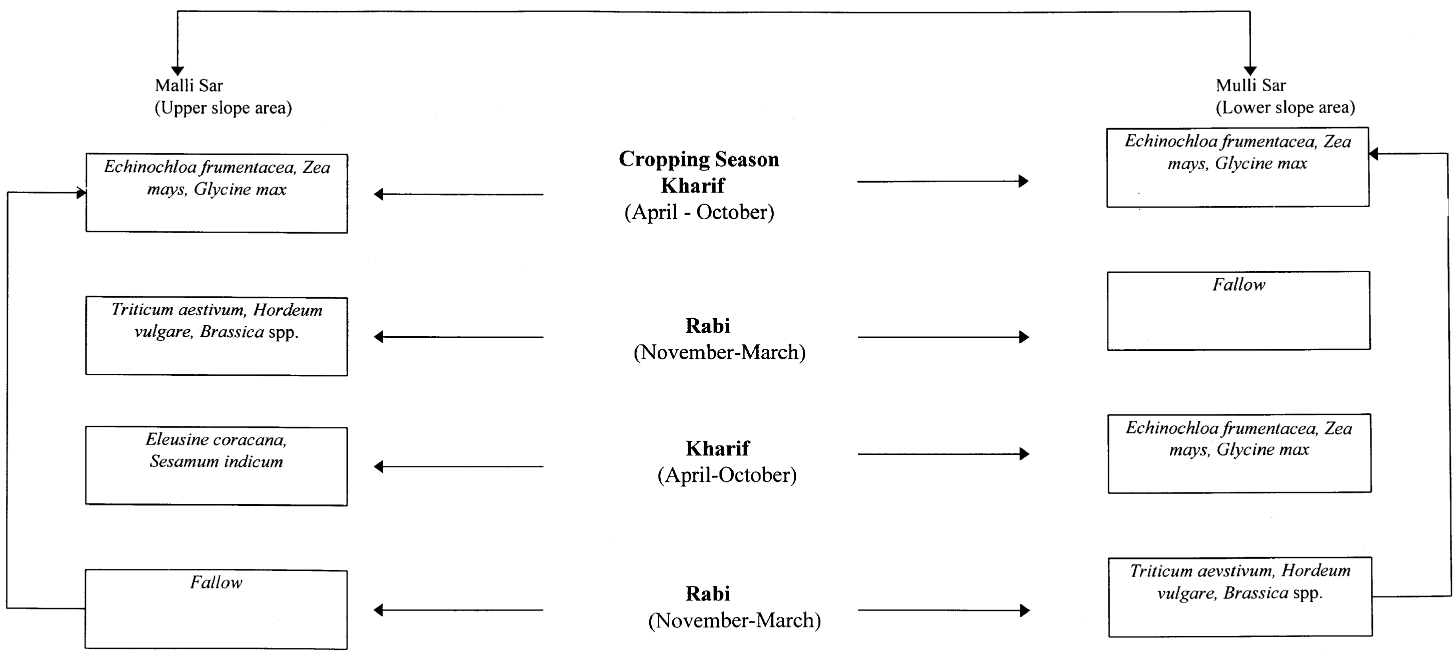

Figure 1. Crops and cropping patterns in simultaneous agroforestry system in village Pali, Garhwal Himalaya, India.

completely burnt. Fire period was decided by the community and fire operation was completed over a week. The land was not terraced and was cropped only during rainy reason. *Phaseolus radiatus* and *Glycine max* were sown as a mixed crop by dibbling. Manure was not applied.

Home garden

Home gardens were multispecies mixed agroecosystems comprising 10 vegetables including *Colocasia antiquorum*, *Cucumis milo*, *Cucurbita* spp. (two local varieties), *Cyclenthera pedata*, *Momordica charantia*, *Solanum capsicum*, *Solanum tuberosum*, *Raphanus sativus and Zingiber officinale* and maize.

Trees and shrubs used by the people

Twenty tree species and one shrub species were used by the people for fuelwood, fodder, fibre, fruits and timber. *Rhus parviflora* was considered to be the best quality fuelwood, *Grewia optiva* and *Boehmeria rugulosa* as the best quality fodder, *Dalbergia sissoo* as the best quality wood for house construction and *Celtis australis* as the best quality wood for agricultural implements. Six species were found exclusively in the agroforestry system, nine exclusively in the forests and 4 common to forests and agroforestry system. *Morus alba* and *Melia azedarach* were introduced as roadside plantation (Table 4).

Energy and monetary budgets

Total per ha annual energy input in simultaneous agroforestry system was 305267 MJ compared to 279 MJ in sequential agroforestry system and 27047 MJ in home garden. In simultaneous agroforestry and home garden, about 99% of total energy input was accounted by manure, an input not used in sequential agroforestry system. Labour input in simultaneous agroforestry was nearly three times of that in home garden and five times of that in sequential agroforestry. Total per ha annual energy output from simultaneous agroforestry was 193182 MJ compared to 21000 MJ from home garden and 54221 MJ from sequential agroforestry. Energy output per unit of energy input for simultaneous agroforestry system was 0.63 compared to 0.78 for home garden and 194.3 for sequential agroforestry. For one unit human labour input, sequential agroforestry gave energy output of 497.4 units, simultaneous agroforestry 336.6 units and home garden 102.9 units. Highest per ha monetary output was observed in case of simultaneous agroforestry (Rs 25370, Rs 35 = US$1) followed by home garden (Rs 18200) and sequential agroforestry (Rs 9426). Monetary output/input ratio was highest in sequential agroforestry (7.28) followed by home garden (5.32) and simultaneous agroforestry (2.62) (Table 5).

Table 4. Trees and shrubs used by the local communities in village Pali, Garhwal Himalaya, India.

Botanical Name	Local name	Habitat	Uses
Acacia catechu	Khair	FOR	Fu, Fo, Ti
Adina cardifolia	Haldu	FOR/SIAG	Fu, Ti
Albizzia labbek	Siris	FOR	Fu, Fo, Ti
Anogeissus latifalia	Daur	FOR	Fu, Fo
Bauhinia retusa	Kanadh	FOR/SIAG	Fu
Bauhinia variegata	Kuriyal	SIAG	Fu, Fo, Ed
Boehmeria rugulosa	Genthi	SIAG	Fu, Fo, Ti
Celtis australis	Kharik	SIAG	Fu, Fo, Ti
Cordia macleodi	Dhai	SIAG	Fu, Fo
Dalbergia sissoo	Shisham	FOR	Ti
Ficus bengalensis	Bar	FOR	Ti
Ficus glomerata	Timla	FOR	Ti
Ficus relegiosa	Pipal	FOR	Fo
Grewia optiva	Bhimal	SIAG	Fu, Fo, Fi
Mallotus phillipensis	Ruina	FOR/SIAG	Fu, Fo
Melia azedarach	Dainkan	Roadside plantation	Fo, Ti
Morus alba	Saitoot	Roadside plantation	Fo, Ti
Rhus parviflora	Tungla	SEAG/FOR	Fu
Shorea robusta	Sal	FOR	Fu, Ti
Terminalia tomentosa	Sain	SIAG	Fu, Fo, Ti
Toona ciliata	Tun	FOR	Fu, Ti

FOR = forest; SIAG = simultaneous agroforestry system; SEAG = sequential agroforestry system; Fi = fibre; fu = fuelwood; Fo = fodder; Ti = timber; Ed = Edible fruits/leaves.

Food, fodder and fuelwood production, consumption, storage and marketing

Total annual fuelwood collection in the village was 223.7 t, of which 15.3% was obtained from simultaneous agroforestry system, 47.5% from sequential agroforestry system and 37.1% from the forests. Total annual fodder consumption in the village was 581 t, of which 21.2% was consumed through grazing and 78.8% through stall feeding. Simultaneous agroforestry system and forests provided 72.4% and 27.6%, respectively, of total fodder used in stall feeding (Table 6).

Fodder, fuelwood, staple food grains and vegetable production in the village was in excess of the local requirements. All the surplus fodder and fuelwood was marketed. About 33% of the food production was stored while 5.5% was marketed. Food products, fodder and fuelwood accounted for 33.38%, 52.95% and 13.67% of total annual income (Rs 1420 capita^{-1} year^{-1}), respectively. Oils and fats (mustard oil and hydrogenated oils) were imported. Net annual income was Rs 1102.30 capita^{-1} year^{-1} (Table 7).

Table 5. Comparative account of energy and monetary inputs and outputs in simultaneous agroforestry, sequential agroforestry and home garden in village Pali, Garhwal Himalaya, India.

Inputs/Outputs	Simultaneous agroforestry		Sequential agroforestry		Home garden	
	Energy (MJ $ha^{-1}yr^{-1}$)	Value (*Rs $ha^{-1}yr^{-1}$)	Energy (MJ $ha^{-1}yr^{-1}$)	Value (*Rs $ha^{-1}yr^{-1}$)	Energy (MJ $ha^{-1}yr^{-1}$)	Value (*Rs $ha^{-1}yr^{-1}$)
Inputs						
Human labour	574	5275	109	1095	204	1755
Draught power	597	600	–	–	121	125
Seeds	3271	608	170	200	47	18
Manure	300825	3184	–	–	26675	1524
Total	305267	9667	279	1295	27047	3422
Outputs						
Foodgrains	36855	9100	5950	7000	–	–
Vegetables	22950	4500	–	–	21000	18200
By products	61600	2640	22400	600	–	–
Fuelwood	11609	1206	17539	1826	–	–
Fodder from trees	30354	4245	–	–	–	–
Grass fodder	29814	3679	–	–	–	–
Leaf litter*	–	–	8332	–	–	–
Total output	193182	25370	54221	9426	21000	18200
Net return	112085	15703	53942	8131	–6047	14778
Output/input ratio	0.63	2.62	194.3	7.28	0.78	5.32

* Monetary value – nil.
US$1 = Rs. 35.00 (1996).

Table 6. Fuelwood and fodder availability from different ecosystems in village Pali, Garhwal, India.

Fuelwood/ fodder ($t\ year^{-1}$)	Ecosystem type			Total
	Simultaneous agroforestry	Sequential agroforestry	Forest	
Fuelwood	34.3 (15.3)	106.3 (47.5)	83.1 (37.1)	223.7
Fodder for stall feeding	331.4 (72.4)	– –	126.4 (27.6)	457.8 (78.8)
Fodder consumed through grazing	–	–	123.2 (100.0)	123.2 (21.1)
Total fodder	331.4 (57.0)	–	249.6 (43.0)	581

Values in parentheses are % of total in a given category.

Table 7. Annual food, fodder and fuelwood production/collection, consumption and export/import from village Pali, Garhwal, India

	Foodgrains and vegetables	Fats/oils	Fuelwood	Fodder
Production/collection	569.1	5.9	628.4	1285.9
Consumption	348.9	14.0	434.4	433.7
Storage	188.5	–	–	–
Export	31.7	–	194.0	852.2
Income through export	474.0	–	194.0	752.0
Import	–	8.2	–	–
Expenditure on import	–	317.7	–	–

Export/import ($kg\ person^{-1}\ year^{-1}$) and expenditure/income through export/import ($Rs\ person^{-1}\ year^{-1}$).

Discussion

Differentiation and spatial patterns of ecosystems in the landscape

Differentiation and spatial patterns of ecosystems in the landscape are determined by the interaction of ecological, policy and human factors. In Garhwal Himalaya, simultaneous agroforestry is the traditional land use of local communities. As per farmers’ perceptions, yield increasing effects of trees on annual agricultural crops in traditional simultaneous agroforestry are less effective than the yield decreasing effects. Proper terracing, drainage, maintenance of protective grass cover on terrace margins and risers, manuring and protection of forest cover around farmland are considered more effective measures for soil conservation and sustainable yields than the role of on farm trees in indigenous knowledge system (Maikhuri et al., 1997; Singh et al., 1997). Reduction in crop yields due to farm trees is reconciled with availability of fodder, fuelwood and other non-timber forest products near homesteads (Khybri et al., 1992).

Most of agroforestry tree species occur as isolated individuals in forest gaps suggesting their early successional adaptive traits (Maikhuri et al., 1997). Occurrence of climax species in farm land is an indicator of recent forest conversion. Trees are traditionally maintained by selective protection of natural regeneration. Relative emphasis on protection of different species largely depends upon the local needs and composition and management of the forests in the landscape. The density and lopping of trees are managed such that crowns of neighboring trees do not overlap. Tree density in simultaneous agroforestry systems in the region is reported in the range of 182 to 419 trees ha^{-1} and species richness from 8 to 90 species (Toky et al., 1989; Sundriyal et al., 1994; Thapa et al., 1995; Semwal and Maikhuri, 1996) compared to nine tree species with total average density of 390 trees/ha observed in the present study. A wide variation in data could be accounted for as due to variation in spatial scale of observation (plot level to a cluster of villages/watershed which means variation in environmental heterogeneity and gradient sampled e.g. elevation covered in above mentioned studies varied from 300 m to 2000 m *amsl.*), variation in methodology (quadrat sampling by some and questionnaire/participatory survey by others) together with huge variation in ecological and socio-economic factors.

A high level of crop diversity in traditional simultaneous agroforestry system is maintained through rotation of crops in small fields in time and space together with coexistence of mono- and mixed cropping practices. Traditional values of diversified production system and emphasis on storage of surplus food production in good climate years derived from the necessity of local production based food security in a difficult terrain faced to environmental risks and uncertainties and the concern for fuller utilization of environmental resources (Goland, 1993). Farmers believe that all agroforestry species have similar effects on all traditional agricultural crops. Scientific evaluations of these perceptions have not been attempted.

Before emergence of organized forestry in 1950s by the government, local communities were the owners as well as managers of forests. Forests were diverse as resources were used only for subsistence by the local communities causing smallscale impacts on natural forest ecosystems. Organized forestry by the government brought in three changes: (a) notification of forest land as government land (b) introduction of silvicultural practices promoting dominance of timber species *Shorea robusta* in lower altitudes and of *Pinus roxburghii*, a species valued for resin as well as timber, in higher altitudes leading to reduction in availability of fodder, fuelwood and other non-timber forest products used by the local communities (c) monopolization of economic benefits from timber and resin by the government. Parallel to this change in forest management, was the growing importance of cash economy in subsistence economy oriented traditional communities (Rao and Saxena, 1996). Three major responses to these changes are apparent in the study village. Firstly, local communities favoured the dominance of fodder trees in private lands. Secondly, they started shifting agriculture because frequent fire promoted dominance of shrub *Rhus parviflora*, a good quality fuelwood species easy to harvest and transport, and pulses could fairly perform under slash-burn conditions giving significant economic returns with low level of inputs. Thirdly, they started setting annual ground fire in *Pinus roxburghii* dominated higher altitude area to improve the quality as well as quantity of palatable grasses. Agriculture and fire by local communities in community and government lands are illicit as per the government forest policy but are widespread features because of ineffective enforcement of law and policy in dissected and inaccessible hilly terrain.

Home gardens in the study area are smaller in size compared to those reported by others (Ramakrishnan, 1992). Trees are not grown perhaps because of small size of home garden in the present case.

Energy and economic efficiency

The scope of energy output/input analysis of this study is limited in scope in that literature values of energy are used. However, the analysis does provide a basis of comparing different land use practices adopted by the farmers. Energy output/input ratios of simultaneous agroforestry systems in the Himalaya are reported in the range of 0.26 to 3.99 (Singh et al., 1997) compared to 0.63 in the present study. Enormous variation in energy efficiency reflected from the data is partly because of huge variation in structure and management within the broad category of 'traditional simultaneous agroforestry system' and partly due to variation in methodology. For example, fodder available from terrace margins and weeds accounted in the present study has been ignored (Ralhan et al., 1991; Singh et al., 1997). Addition of organic wastes and ash, better crop management and saving of labour on travel and transport due to proximity to the home could account for higher energy and economic efficiency of home gardens as compared to simultaneous agroforestry system. The present study shows that farm trees are insufficient to meet the needs of manure, fodder and fuelwood. Crop yields in traditional simultaneous agroforestry system are sustained with energy, organic matter and nutrient inputs derived from the forests and added to the farms in the form of organic manure. The concern for sustainable yield from private farm had been a major factor leading to conservation and sustainable utilization of forest biomass by the indigenous communities.

Higher returns per unit of energy or monetary input from sequential agroforestry system, the shifting agriculture, compared to traditional simultaneous agroforestry are likely to involve enormous ecological costs in terms of run-off and soil erosion in the absence of terracing, manuring and tree cover

(Sen et al., 1997). This land use in its present form thus is unlikely to be sustainable in the long run.

Conclusions

Increasing concern for monetary economy in the subsistence-oriented local communities and timber-centered, organized, forest management practices over a period of time reduced the availability of non-timber forest products so crucial for the livelihood of local communities leading to changes within traditional simultaneous agroforestry system, emergence of land use systems such as shifting agriculture and disturbance of fire in *Pinus roxburghii*-dominated forests. Though agriculture provides higher returns with lower inputs as compared to traditional simultaneous agroforestry, it does not seem to be as desirable as the latter from the environmental and long term sustainability considerations. Expansion of agriculture and degradation of forest cover are common all through the region but nature, rates and factors related to land use-land cover dynamics vary. Comprehensive research programmes are needed to understand the complexities of land use-land cover dynamics, interactions of different ecosystem types in the landscape and the needed interventions for sustainable landscape management in the Himalaya. As agricultural land use practices are influenced by the composition and management of surrounding forests, the present policy of treating agriculture and forests as closed and independent ecological or production systems needs to be replaced by an integrated land use policy.

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