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Status of an indigenous agroforestry system: A case study in Kumaun Himalaya, India

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ABSTRACT

The agro-forestry system is one of the best known indigenous practices for livelihood and sustainable development. In the present study a village Semalkhaliya (Ramnagar block) situated in *bhabar* belt of Kumaun Himalaya was analyzed with the objective to assess the indigenous agroforestry system with energy and economic efficiency of the landscape. This village includes 110 families with a human population of 631. Simultaneous agroforestry system was the main land use system being operated in the village. A total of fifteen tree species and twenty two crop species were reported from the study area. Among tree component, *Mangifera indica, Tectona grandis* and *Populas* sp were the most dominant species. The major cereals grown by the farmers were *Triticum aestivum* and *Oryza sativa.* Most of the surplus food was stored by the villagers for their use and rest is sold for cash. Besides food, the tree species grown in agroforestry based system were used for multipurpose such as fuel, fodder, medicine etc. Homegarden is another land use system which was commonly used by the farmers. In this system seasonal vegetable crops were grown with mixed plantation of fodder and fruit trees. In agroforestry system annual energy input was 81 905 MJ/ha and in home garden annual energy input was 53 913 MJ/ha. In terms of money, highest per ha annual productivity or income was greater in agriculture followed by the home gardens.

Key words: Agroforestry, Economic efficiency, Energy, Homegardens, Policy.

Agroforestry is an integrated approach to land use that is characterized by deliberate maintenance of trees and other woody perennials in fields and pastures. This system is one of the best known traditional practices for livelihood, suitable land management and sustainable development (Kittur and Bargali 2013, Parihaar *et al.* 2014). To maintain the sustainable agricultural production system and to alleviate forest deprivation, it is essential to systematically understand the intensive farming arrangement. For this, we chose to espouse the 'farming arrangement' approach. The basic task of approach is to develop a farming system that can be agreed and maintained by farmers. There is a shortage of empirical evidence on the factors that influence crop improvements (Vibhuti *et al.* 2015).

In Indian Himalaya, more than 90% people live in villages, which are organized as independent socio-ecological systems. Traditionally the village farmers have to maintain close linkages and balances between agriculture, forestry and livestock and these linkages are a basis of land -use patterns. These indigenous agroforestry systems not only support the livelihood through production of food, fodder and fuel wood, but also mitigate the impact of climate change through carbon sequestration (Arora *et al.* 2011, Singh *et al.* 2008a, Bargali and coworkers 2009). Present study describes status and energy and economic efficiency of a traditional village landscape (Semalkhaliya) in Kumaun Himalaya. The two main objectives of the study were: 1. To describe the diversity of plants in traditional agroforestry system. 2. To evaluate economic and energy efficiency of the traditional agroforestry system.

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MATERIALS AND METHODS

The Kumaun Himalaya, spread over a geographical area of 51125 km^2 (77034'to 81002' E longitude and 28043 to 31027' N latitude) comprises five districts of Uttarakhand State of India, viz. Nainital, Bageshwar, Champawat,Udham Singh Nagar, Pithoragarh and Almora. The study village Semalkhaliya is located at a distance of 65 km from Nainital, and 35 km from Corbett National Park Ramnagar. The study site is located in the district Nainital, Kumaun Himalaya at 29°25' to 29°39'N latitude and 78°44' to 79°07'E longitude. The physiographic and demographic status of the village is given in Table 1.

Study site experiences the three distinct seasons, viz. dry summer season (March to mid-June), warm rainy season or monsoon (July to October) and winter season (November to February). The days can be very hot during summer time, with the temperature crossing the 40° C most of the time. During monsoon, the humidity soars up to 98%, making the weather very sultry. During winter the humidity

Table 1 Physiographic and demographic status of the village

Parameter	Village Semalkhaliya
Human Population	631
Live stock population	291
Elevation	345 m
Aspect	NE
Agriculture land (ha)	63.05
Actual cultivated land (ha)	55
Cultivated land/household	57
Irrigated land/household	0.50
Average family size	0.50
Human density/ha cultivated land	0.088
Livestock/household	2.64
Cultivated land/Livestock	0.156

level drops down to about 57%. The night temperature can fall down to 5°C. During the night, a local wind known as 'dadu' blows in the region, lowering the temperature significantly. Soil of the study area is predominantly clay or sandy, and complete mixture of the mineral particle or humus.

The study village consists of 110 family/households. Total population of the Semalkhaliya village is 631 of which 38.51% are adult males, 39.30% adult females and 22.18% children (< 12 years old). Average family size is 0.50.

Total livestock population of the village is 291 of which 18.90% are buffaloes,10.30% cows, 8.93% bullocks, 41.23% goats and 20.61% hen. 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.

The village landscape could be divided into two land cover-land use type: (i) the agrisilviculture system characterized by cultivation of agriculture crop such as wheat, peas, potato, maize, paddy with fuel or fodder tree such as *Grewia optiva,Tectona grandis* and *Populus* sp. (ii) home gardens which involve management of multipurpose trees and shrub in association with annual or perennial agricultural crop and invariably livestock within the compound of individual houses locally known as bara. The village is surrounded by government forest falling under Corbett National Park range. The forest is dominated by *Tectona grandis* and *Shorea robusta.*

The 87 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 a field survey using semistructured interview schedules (Bargali *et al*. 2007, Pandey *et al.* 2011) with adult members or head of the family. Each household was visited at least three times. 20 Households selected randomly out of 87 and were monitored for estimating inputs/outputs to/from agroforestry system, home gardens and the forests. Family head were contacted twice in a month to have advance information on the household activities. Estimates of food, fodder and fuel wood consumption and products supplied to/purchased from the market were derived based on seasonal observations. Durations of sedentary, moderate or heavy works by males and females in various activities (Leach 1976) and bullock power use were noted.

Tree density in agrisilviculture system or in homegardens was measured by placing ten, 10 m × 10 m random quadrats. Standard energy values of various inputs and outputs used for budgeting are given in (Table 2). 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 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, fuel wood, 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 2012–13, the period of study.

RESULTS AND DISCUSSION

Village landscape

The geographical area of the village is 63.05 ha. *Mangifera indica,Tectona grandis* and *Populus* sp. being the most dominant species in the trees and *Triticum aestivium*

Table 2 Energetic values of different inputs and outputs in the agroforestry systems in Himalaya, India (Source: Mitchell 1979).

Category	Energy
Grains	16.2 MJ/kg
Pulses	17.0 MJ/kg
Oilseeds	23.07 MJ/kg
Potato	03.9 MJ/kg
Leafy vegetables	02.8 MJ/kg
Other vegetables	02.4 MJ/kg
Milk	04.2 MJ/kg
Green fodder	03.9 MJ/kg
Hay	14.5 MJ/kg
Straw	13.9 MJ/kg
Fuel wood	19.7 MJ/kg
Farmyard manure/compost	07.3 MJ/kg
Human labour	
Male sedentary work	00.418 MJ/h
Moderate work	00.488 MJ/h
Heavy work	00.679 MJ/h
Human labour	
Female sedentary work	00.331 MJ/h
Moderate work	00.383 MJ/h
Heavy work	00.523 MJ/h
One bullock-day	72.7 MJ/day

Table 3 Trees and shrubs used by the local communities in village Semalkhaliya, Ramnagar, Kumaun Himalaya, India.

Botanical name	Local name	Uses
Acacia catechu	Khair	Fu, Fo, Ti
Adina cardifolia	Haldu	Fu, Ti
Azadirachta indica	Neem	Fu, Ti
Bombax ceiba	Simal	Com, Ed
Dalbergia sissoo	Shisham	Ti
Emblica officinalis	Amla	Ed,Fu
Eucalyptus spp.	Liptis	Fu, Com
Ficus bengalensis	Ber	Ti
Ficus glomerata	Timla	Ti
Ficus relegiosa	Pipal	Fu,Fo
Grewia optiva	Bhimal	Fu, Fo, Fi
Lantana camara	Kuri	Fu
Mallotus phillipensis	Ruina	Fu, Fo, Com
Morus alba	Saitoot	Fo, Ti, Ed
Poplus deltoids	Poplar	Fu, Com
Shorea robusta	Sal	Fu, Ti,Fo
Syzigium cuminii	Jamun	Fu, Ti, Ed
Tectona grandis	Sagwan	FU,Ti

Fi, Fiber; Fu, fuel wood; Fo, fodder; Ti, timber; Ed, Edible fruits/ leaves; Com, Commercial.

and *Oryza sativa* are the most dominant crops in the grains that are cultivated by the local community of the village (Table 3). Area under indigenous agroforestry system of the village was divided into two parts called Mall Sari, the upper part of the village, and Tall Sari, the lower part of the village. Big farmers have at least two plots, one in Mall Sari and the other in Tall Sari.

Agrisilviculture system

The agrisilviculture systems were practiced on land in private ownership. Trees were the permanent features of this land use as timber forest products were utilized. Total average tree density was 710 trees/ha. *Tectona grandis* and *Populus* sp. were the dominant species over there (Table 4).

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. All these crops were grown by all farmers. The sequential sowing and harvesting of some important crops of the Semalkhaliya village are given in Table 5.The cropping patterns were built around two seasons locally referred to as *kharif* (rainy season) and *rabi* (winter season). *Echinochloa frumentacea* (Jhongora), *Zea mays* (Maize), *Glycine max* (Soybean), *Eleusine coracana* (Finger millet), *Sesamum indicum* (Til) and *Phaseolus radiatus* (Beans) were dominant rainy season crops. *Triticum aestivum* (Wheat), *Hordeum vulgare* (Barley) and *Brassica campestris* (Rape seed) were dominant crops of winter season (Table 6).

Table 4 Density of agrisilviculture system trees or home gardens system in village Semalkhaliya, Kumaun, India

Species	Density (trees/ha)	
	Agrislviculture system	Home gardens
Artocarpus integrefolia		120
Populus sp.	660	
Emblica officinalis		70
Litchi chinensis		90
Mangifera indica		160
Musa paradisiaca		90
Psidium guava		50
Prunus persica		60
Tactona grandis	50	
Total	710	640

Table 5 Sequential sowing and harvesting of some important crop of the Semalkhaliya village.

Crop Species	English Name	Local Name	Sowing	Harvesting
Kharif crop				
Oryza Sativa	Paddy	Dhan	June	Nov
Vigna mungo	Blackgram	Urad	Aug.	Dec
Glycine max	Soya	Soyabeen	July	Nov
Glycine soja	Black soya	Bhatt	Aug.	Dec
E. frumentacea	Barnyard millet	Jhungora	June	Sept
Curcuma longa	Turmeric	Haldi	May	Oct
Z. officinalis	Zinger	Adrak	May	Oct
Rabi crop				
T. aestivum	Wheat	Gehu	Oct	May
H. vulgare	Barley	Jau	Oct	May
B. compestris	Mustard	Sarson	Oct	April
P. sativum	Pea	Mater	Oct	April
Allium cepa	Onion	Piyaj	Oct	May
L. esculantum	Tamater	Tomato	Oct	Feb
Zayad crop				
B. rugosa	Mustard	Sarson	May	Aug-Nov

Home garden

Home gardens are a common smallholder agroforestry system in India. The home gardens are commonly called by the Semalkhaliya people as 'bara'. Every family has their own Bara or homegarden where they can grow every kind of the vegetable or spice which they want. They were diverse, containing many vegetable species. Most of the species in home garden produce are fruits, vegetable, spice, oils and medicine. The dominant vegetable and tree species preferred in the home gardens and their primary use are given in the Table 7 and 8.

Table 6 Status of annual crop in the village

Botanical name	Local name	Use
Cropping season kharif (*March–September or summer rainy season*)		
Main crop		
Amaranthus cruentus	Chaulai	Ed
Oryza sativa	Dhan	Ed,Fo, Com
Echinochloa frumentacea	Jhangora	Ed,Fo
Eleusine coracana	Maduwa	Ed,Fo, Com
Glycine max	Soybean	Oil,Ed,Com
Sesamum orientale	Til	Oil, Com
Phaseolus mungo	Urd	Ed, Com
Raphanus sativus	Mula	Ed
Zea mays	Makka	Ed,Fo,Com
Cropping season rabi (*October–March or winter season*)		
Triticum aestivum	Gehun	Ed,Fo,Com
Hordeum vulgare	Jau	Ed,Fo,Com
Lens esculenta	Masur	Ed,Fo,Com
Cicer arietinum	Channa	Ed,Fo,Com
Pisum sativum	Matar	Ed,Fo,Com
Solanum tuberosum	Alu	Ed,Fo,Com
Brassica campestris	Sarson	Ed,Fo,Com, Oil
Orchards		
Mangifera indica	Aam	Ed
Litchi chinensis	Litchi	Ed
Psidium guava	Amrud	Ed
Prunus persica	Aru	Ed
Pyrus communis	Naspati	Ed
Musa paradisiacal	Banana	Ed
Artocarpus integrefolia	Kathal	Ed
Carica papaya	Papita	Ed

Ed, Edible fruits/leaves; Fo, fodder; Com, Commercial.

Table 7 Some common vegetable species grown in homegarden

Botanical name	Local name	Uses
Amaranthus cruentus	Chaulai	Vg
Brassica rugosa	Rai	Vg
Colocasia himalayensis	Pindalu	Vg
Cucurbita maxima	Kaddu	Vg
Curcuma longa	Haldi	Vg
Lagenaria siceraria	Lauki	Vg, Md
Momordica charantia	Karela	Vg, Md
Raphanus sativus	Muli	Vg, Md
Spinacea oleracea	Palak	Vg
Solanum capsicum	Mirch	Vg
Solanum tuberosum	Alu	Vg
Zingiber officinale	Adrak	Vg, Md

Vg, Vegetable; Md, Medicine; Sp, Spice.

Trees and shrubs used by the people

There are many tree/shrub species used by the local people for fuel wood, fodder, fiber, fruits and timber. *Acacia catechu* considered to be the best quality fuel wood, *Grewia optiva* and *Morus alba* are the best quality fodder, *Dalbergia sissoo* and *Azadirachta indica* the best quality wood for house construction and *Shorea robusta* is the best quality wood for agricultural instruments. *Lantana camara* is the only shrub that is used by the people as a fuel wood and burn very easily. Two common species were found abundantly in the agroforestry system or forest, i.e. *Tectona grandis, Eucalyptus, Morus alba, Azadirachta indica* and *Tectona grandis* introduced as roadside plantation (Table 2).

Table 8 Some common tree (Fruits/fodder/other) species grown in homegardens

Botanical name	Local name	Uses
Artocarpus integrefolia	Kathal	Ed
Azadirachta indica	Neem	Fu, Ti
Emblica officinalis	Amla	Ed,Fu
Ficus glomerata	Timla	Ti
Grewia optiva	Bhimal	Fu, Fo, Fi
Litchi chinensis	Litchi	Ed,Fu
Mangifera indica	Aam	Ed, Fu
Morus alba	Saitoot	Fo, Ti, Ed
Musa paradisiacal	Banana	Ed, Fo
Psidium guava	Amrud	Ed, Fu
Tectona grandis	Sagwan	FU,Ti

Fi, Fiber; fu, fuel wood; Fo, fodder; Ti, timber; Ed, edible fruits/leaves; Com, commercial.

In the study sites simultaneous agroforestry is the traditional land use system of local communities. As per farmers' perception yield increasing effects of trees on annual agricultural crops in traditional simultaneous agroforestry are less effective than the yield decreasing effects (Nautiyal and coworkers 1998). Proper tracing, drainage, maintenance of protective grass cover on trace margins and rivers, manuring and protection of forest cover around farm land 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). Reduction of crop yields due to farm trees is reconciled with availability of fodder, fuelwood and other non-timber forest products near farm lands (Singh *et al.* 2008a and b, Bargali *et al.* 2004, Bargali and coworkers 2009, Mishra *et al.* 2010). The density and lopping of trees are managed such that crowns of neighboring trees do not overlap. A wide variation in the tree density in the present agroforestry system (1 350 tree/ha) as compared to Toky *et al.* 1989, Nautiyal coworkers 1998 (182-419 trees/ha) could be due to the variation in ecological and socio-economic factors, while species richness (09 species) was within the range (8-90 species). This may also be due to the use of *Populus* sp. as tree plantation in simultaneous agroforestry system in the study sites. Homegarden are smaller in size compared to those reported by Ramakrishnan (1992) for North Eastern India.

A high level of crop diversity in traditional simultaneous agroforestry is maintained through rotation of crops in small fields in time and space together with coexistence of

Table 10 Fuelwood and fodder availability from different ecosystems in village Semalkhaliya, Kumaun India

Fuelwood/fodder (tonnse/year)	Ecosystem type		Total
	Agroforestry system	Forest	
Fuel wood	114.5 (41.15)	164.25 (59.02)	278.75
Fodder for stall feeding	424.65 (70.15)	180.67 (29.84)	605.32

Values in parentheses are % of total in a given category

energy output/input ratios of simultaneous agroforestry systems in the hills are reported in the range of 0.26- 3.99 (Singh *et al.* 1997, Nautiyal and coworkers 1998) compared to 9.08 for agroforestry and 1.23 for home gardens 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. In the present study fodder available from boundary margins and weeds was not considered. The present study indicates that farm

Table 11 Annual food, fodder and fuelwood production/collection, consumption and export/import (kg/person/year) and expenditure/income through export/import (₹/person/year)

Parameters	Foodgrains	Vegetables	Fats/oils	Fuelwood	Fodder
Production/collection	525.44	7.43	7.92	278.75	1130.76
Consumption	176.96	7.43	19.92	178.35	511.76
Storage	143.09			100.4	
Export	205.39				619.00
Income through export	1465.62				960.2
Import			12.0		
Expenditure on import			1020.00		

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).

Energy and monetary budgets

Total per ha annual energy input was 81 905.79 MJ in agroforestry system and 53 723 MJ in home garden. In both the systems maximum energy input was accounted for manure. Labour input in agroforestry was higher as compared to home garden. Total per ha annual energy output from agroforestry was 744 238.2 MJ and 65 819.52 MJ from homegarden. Total annual fuelwood collection in the village was 278.75 tonnes, of which 41.15% was obtained from simultaneous agroforestry system and 59.02% from the forests. Total annual fodder consumption in the village was 605.32 tonnes, of which 70.15% was obtained from agroforestry system, 29.84% from the forests and total fodder was used in stall feeding (Table 10). Fodder, fuelwood, staple foodgrains and vegetable production in the village was in excess of the local requirements. All the surplus fodder and fuelwood was marketed. About 27.23% of the food production was stored while 39.08% was marketed. Food products, fodder and fuelwood accounted for 26.94%, 57.97% and 14.29% of total annual income (₹ 2 425.82/capita/year), respectively. Oils and fats (mustard oil and refined oil) were imported (Table 11).

The scope of energy output/input analysis of this study is limited in scope and literature values of energy are used. However, the analysis does provide a basis of comparing different land use practices adopted by the farmers. The trees are sufficient to meet the needs of manure, fodder and fuelwood. In traditional agroforestry system crop yields are sustained with energy, organic matter and nutrient inputs derived from the forests, market and introduced to the farms in the form of organic matter (Urea) or manure.

CONCLUSIONS

In the study area, simultaneous agroforestry was the traditional land-use system of local communities. Farmers preferred *Dalbergia sissoo* and *Azadiracta indica* as timber species and *Grewia optiva* and *Morus alba* as fodder species. A high level of crop diversity in traditional simultaneous agroforestry system was maintained by rotation of crop in small field in time and space. Energy output/input ratio of simultaneous agroforestry system was 9.08. The scope of energy output/input analysis of this study was limited in scope in that literature values of energy were used. Addition of organic waste and ash, better crop management and saving of labour on travel and transport due to proximity to home resulted in higher energy and economic efficiency of home garden as compared to simultaneous agroforestry system.

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