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Socio-economic Analysis Based on Energy Input and Output of Mixed Cropping Systems of Bhabhar Region (Shiwalik Range of Kumaun Himalaya, India)

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Abstract

In the present study, the status of energy efficiency and economy of existing agroecosystems in the Shiwalik range of Kumaun Himalaya were assessed. A large number of plant species were cultivated/maintained by the local inhabitants to conserve the diversity in agroecosystems. Agriculture was the main source of economy of the villagers. The agroforestry system provides many ecological services to enhance the socio-economic condition of the farmers. In addition, home garden is another land use system, which is very common in the area. All collected data from agricultural (inputs and outputs) were calculated and converted to energy values by using constants. In the present study, average consumption of annual energy inputs in agroforestry system (103646 MJ/ha) was approximately three times more as compared to home gardens (43056 MJ/ha). Uses of chemical fertilizers and pesticides increased the inputs manifolds. Average annual energy outputs obtained from agroforestry system (434116 MJ/ha) which was seven times more to the home gardens (57008 MJ/ha). Energy output/input ratio in agroforestry varied from 2.26 to 9.06 while in home gardens range speckled between 1.20 and 1.47. In terms of monetary budget, annual return from agroforestry and home garden systems were ₹ 95077/ha and 4201/ha, respectively. From the present study, it can be concluded that agroecosystems provides the good monetary benefits and source of employment to the villagers. The possible benefits of agriculture are raising income and thus improving status of livelihoods in *Bhabhar* region of Kumaun Himalaya.

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Introduction

In the Himalayan province, an ecosystem functioning as a self-governing entity of economic activity and is consisted of agroecosystem, forest ecosystem, households, livestock, and market support[1]. Therefore, it is most important in a village ecosystem to observe the type and level of linkage in various components in order to harness the maximum benefits and proper management of the resource availability[2].

Uttarakhand is primarily an agricultural state and developed as ecological brand equity[3]. This ecological brand owing to the tree stands that helps in several way like leaf litter from the tree enriches the organic carbon ultimately C/N ratio and maintain the soil fertility[4,5]. In the Himalayan Mountains, agriculture is closely linked with animal husbandry and natural forests. There is an urgent need for intensified conservation efforts as well as growing products and generating services in agro-ecosystems[6]. The high energy input is a major problem of an agroecosystems. In the assessment of energy budget, repeat crop failure and addition of inorganic fertilizers added the energy input in an agroecosystem. After the green revolution, the trend of agriculture inputs by chemicals was increased significantly. The farmers use abundant amount of chemical fertilizers, herbicides, pesticides etc in their crop land without taking the considerable level. By this act the crop increase many folds but the net cost of energy input has also increased simultaneously. To overcome this problem, as the agro-system overall is input intensive[7] adaptation of traditional resource management practices such as agroforestry system may potentially provide options for improvement in livelihoods through lowering of energy inputs and simultaneous production of food, fodder, medicines and firewood as well as mitigation impact of climate change[8,9,10,11,12]. The agroforestry is a dynamic, ecologically based natural resource management system that through the integration of trees/woody perennials in farms and rangelands diversifies and sustains production for increased social, economic and environmental benefits[13,14]. In recent years, agroforestry is emerging as the promising land use option to sustain agricultural productivity and livelihoods of farmers[15] along with mitigate the adverse impact of changing climatic conditions[16].

Various studies conducted in the Central Himalayan region revealed that the agriculture practices require massive consumption of forest resources[17,18,19,20,21]. In plain district of the state, agriculture turns up as the major source of the economy and revenue. Therefore, present study is an attempt to analyze the agroecosystems of Kumaun Himalayan *Bhabhar* belt of Uttarakhand state with the objectives to assess the status, agrodiversity, energy and economic efficiency of agroecosystem and their management practices.

Material and Methods

Study Area

The Kumaun Himalayan *Bhabhar* region spread over a geographical area of 51125 km^2 (77^{0}34'to 81^{0}02' E longitude and 28^{0}43 to 31^{0}27' N latitude). The present study was confined only in Nainital district because *Bhabhar* belt is only represented by this district. They constitute the foot of the Himalayas, where the streams descend on to the plains. The Sub-Himalaya geographically corresponds to the Siwalik range (or the Churia range in Nepal) - foothills ranging in elevation from 250-800 m. This zone is made up of 10-km thick succession of sandstone and mudstone shed from the Himalayan mountains, and deposited by rivers, especially since the Miocene (over the past 24 million years)[22]. Total four representative villages (30 families in each village) of *Bhabhar* belt *i.e.,* Padampur (Village 1), Rampur, (Village 2), Fatehpur (Village 3) and Semalkhaliya (Village 4) were selected within 10-45 km radius from Haldwani in Nainital district from *Bhabhar* belt of Kumaun Himalaya.

Climate

The climate was monsoonal sub tropical and characterized by marked seasonality. The year can be divided into three seasons *viz.,* (i) the summer season (April-June): experienced very hot and dry with the temperature reached beyond 42^{o}C, (ii) the rainy season (July-September): where humidity soars up to 95%, make the weather very humid and (iii) the winter season (November-February): when the minimum temperature stoops down to 4^{o}C with the dense fog where humidity level drops down to 57%. February constitute the transitional month between winter-summer and October between rainy-winter seasons.

Soil

Soil samples were collected randomly from the upper soil depth (0-15 cm). Soil samples were thoroughly mixed to form a composite sample for each village. The collected soils were packed separately in plastic bags and brought to the laboratory. The course materials (stones, roots and plant litters) were removed manually. The soil samples were air-dried to analyze the soil physico-chemical properties.

The soil texture was determined through the sieving of soil by different net size (sand 0.02-2.0 mm, silt 0.002-0.02 mm, clay< 0.002 mm). Moisture content was calculated on dry weight basis, water holding capacity (WHC), bulk density (bD) and porosity were estimated[23]. Chemical properties of the soil *i.e.* pH, total organic carbon[24], total nitrogen[25] and phosphorus[26] were determined by the standard methods.

Methods

The information about the live stock, agricultural land, seeds, fertilizer, pesticides, animal dung, human-animal labour, fuel wood, fodder consumption and agricultural input/output of the households were collected through formal discussions with adult members or head of the family. The information was collected through a field survey using semi-structured interview schedules[27,28]. 30 random households, as a representative in each village, were selected for the estimation of inputs/outputs from agroforestry system as well as home gardens. 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 and heavy works by males and females in various activities and bullock power use were noted. All collected data from agricultural (inputs and outputs) were calculated and converted to energy values by using constants[29] (Table 1).Standard energy values of various inputs and outputs used for budgeting were calculated[29]. 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 day 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 by product 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 (The government prices were taken for the calculation of the food grains while region/local price were considered for the byproducts and vegetables) in the villages during the entire study period.

Table 1: Energy coefficients[29] of input and output used for calculation of energy budget

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 hr
Moderate work	00.488 MJ hr
Heavy work	00.679 MJ hr
Human labour	
Female Sedentary work	00.331 MJ hr
Moderate work	00.383 MJ hr
Heavy work	00.523 MJ hr
One bullock-day	72.7 MJ/day

Results and Discussion

Human and Livestock Population

The village populations are the major consumers of the nutrients moving with foods cultivated within an agroecosystem[30]. On an average of 88 families having 544 human populations having 6 family sizes reside in each village.

Since agricultural production is always a prime importance due to food security the agroecosystem was traditional type and livestock play the major share in it[31]. The average live stock population was 198 constituted by 16.96% cow, 16.27% buffaloes, 10% goats, 7.21% bullocks and 49.02% hen (Table 2). Livestock considered as the resources asset, which provides labour, manure, milk, fuel etc. In addition, they also play a crucial role in enhancing social capital or neighborhood of the families by sharing by products. As the farmland systems are fragile and heavily depended on the energy input by naturally or artificially for the production[1]. Here, the livestock play a prominent role in recycling or transferring of nutrients through the forest to the farmland.

Table 2: Physiographic and demographic status of the villages

Parameter	Village 1	Village 2	Village 3	Village 4
	Region: Sub Tropical			
Elevation (m)	424	424	424	345
Human Population	385	438	720	631
Men (%)	45.83	39.42	41.67	38.51
Women (%)	36.67	35.80	38.32	39.30
Children (%)≤12	17.50	24.78	20.01	22.18
Families	65	85	90	110
Average family size	5.92	5.15	8.00	5.70
Live-Stock population	164	104	234	291
Cow (%)	14.80	28.84	13.90	10.30
Buffaloes (%)	6.10	15.38	24.70	18.90
Bullocks (%)	4.90	7.00	8.00	08.93
Goats (%)	-	-	-	41.23
Hen (%)	74.07	48.00	53.40	20.60
Agriculture land (ha)	42.68	56.39	73.23	63.05
Actual cultivated land ha)	35.56	42.62	52.89	55.00

m=Meter, ha=Hectare

Soil

The soils were loam in texture (sand 37-60%, silt 29-34% and clay 11-29%) in all the studied villages. The range of bulk density and water holding capacity were 1.08 (Village 4) to 1.53 g/cm^3 (Village 1) and 32.48 (Village 1) to 45.12% (Village 4), respectively (Table 3). Soil chemical properties (pH, C, N, P etc) are the most important among the factors that determine the nutrients supplying power of the soil[32]. The C and N concentration varied from 0.68 (Village 1) to 1.56% (Village 4) and 0.19 (Village 1) to 0.37 (Village 4), respectively. The range of phosphorus oscillated in between 0.008 (Village 2) and 0.015% (Village 4). The soil carbon(%) was low in village 2 and 3, medium in village 2 and high in village 4. Soil nitrogen (%) was low in village 1 and 3, medium in village 2 and high in village 4. The percentage of phosphorous was recorded low in village 2, medium in village 1 and 3 and high in village 4.

Land Cover/Land Use

The average geographical area of all the four villages was 58.83 ha and average actual cultivated area of the villages was 46.51 ha. Village 3 have the largest agriculture land holding (73.23 ha), which was about 31.11% of the total studied geographic area but village 4 contained largest area in actual cultivated land (55.0 ha) among all. This is due to the heavy commercialization of the agricultural land in the village 3. Agriculture was the characteristic and main economic feature of the villages. Villages were surrounded by the *Shorea robusta forest. Mangifera* *indica, Litchi chinensis, Tectona grandis* and *Populus* sp. being the most dominant tree species in agroforestry system while *Triticum aestivum* and *Oryza sativa* were the most dominant species in grains, which were cultivated by the local community. The agroforestry systems maintain the diversity of plants in both at genetic and species levels, which influenced according to the land use patterns in agroecosystem[33]. In Kumaun Himlayan region, total 5 land use systems, which were commonly practiced in this region[34] while in the present study the village landscape could be divided into 6 land use types:

- Sole cropping system: Herbaceous crops
- Agri-horticulture systems: Herbaceous crops + fruit trees
- Agri-silviculture system: Herbaceous crops + fuel/ fodder/ timber trees
- Agri-horti-silviculture system: Herbaceous crops + fruit trees + fuel or fodder trees
- Agri-Silvi-pastoral system: Herbaceous crops + Trees + grasses
- Home garden: Herbaceous vegetable crops + fuel or fodder trees + multipurpose tree + ornamental plants + shrubs

Table 3: Physico-chemical properties of the soil (0-15 cm) across the sites

Parameters	Sites			
	Village 1	Village 2	Village 3	Village 4
Sand (%)	60.21±0.58	41.01±1.15	51.61±1.88	37.15±0.03
Silt (%)	28.67±0.59	32.59±1.88	30.56±0.69	34.20±0.02
Clay (%)	11.12±0.64	26.32±0.79	17.83±0.53	28.65±0.01
bD (g/cm^3)	1.53±0.01	1.17±0.00	1.32±0.03	1.08±0.01
Porosity (%)	42.48±0.71	56.02±0.44	50.38±0.30	59.40±0.51
Void ratio	1.08±0.01	1.42±0.00	1.26±0.01	1.54±0.01
Moisture (%)	5.53±0.07	12.86±0.09	7.78±0.07	20.37±0.32
WHC (%)	32.48±0.76	43.92±0.56	38.23±0.59	45.12±0.03
Temp (oC)	22.21±0.01	21.20±0.00	21.45±0.05	20.87±0.02
pH	7.2±0.00	7.1±0.00	07.2±0.01	6.5±0.01
C (%)	0.68±0.02	1.03±0.04	0.82±0.04	1.56±0.03
N (%)	0.19±0.00	0.30±0.01	0.23±0.00	0.37±0.00
P (%)	0.011±0.00	0.008±0.00	0.010±0.01	0.015±0.00
C:N	3.58±0.01	3.43±0.03	3.57±0.02	4.22±0.02
SOM	1.17±0.01	1.78±0.04	1.41±0.04	2.69±0.03

bD=Bulk density, WHC=Water holding capacity, Temp=Temperature, C=Carbon, N=Nitrogen, P=Phosphorus, SOM=Soil organic matter

Floristic composition

Overall, total 114 plant species belonging to 46 families were recorded in agroecosystem of the villages including the surrounding area. The vegetation was constructed by the different form of vegetation viz., tree (17 species), shrub (8 species), herb (77 species) and climber (12 species). Out of the total plant species, 68% were cultivated, 27% were wild and 4% were occurred in both cultivated-wild form. The maximum number of species were fall under Fabaceae family (17 species) followed by Poaceae (11 species) and Cucurbitaceae (10 species). Out of 95 genera, the maximum number of species were recorded in genus *Brassica* (*B. compestris*, *B. juncea*, *B. nigra*, *B. oleracea*, *B. rapa*), followed by, *Luffa, Mentha, Solanum* and *Vigna* (3 species in each). The species richness of the present study was quite higher than the reported range (8-97) of the various workers in the Kumaun Himalayan region[19,35].

Cropping Systems

Basically the farming in this region preferred sole and mixed cropping. Under sole cropping only a single herbaceous crop cultivated without intercropping with others while in mixed cropping the farmers sowing the many crops into a same piece of land. Some patterns of mixed cropping, which are commonly adopted by the farmers in the studied area are given:

- Wheat + Pigweed + Pea + Mustard+ Gram
- Wheat + Pigweed + Pea + Radish + Broad bean + Amaranthus
- Wheat +Finger millet + Gram + Sesame
- Paddy + Maize + Soybean + Raghii
- Paddy + Lobia + Black gram + Sugarcane
- Paddy + Pearl Millet + Horse gram + Cucurbits

Crop Husbandry and Agro-Diversity

Diversity is one of the dominant characteristics of the Himalayan agro-ecosystem, which provides specific ecological niche for producing specific food crops. Rice, maize, finger millet and black soya were the dominant rainy crops (*Kharif* crop), sown during June to August and harvested during October to December while wheat, rape seed, gram, pea and potato as winter crops (*Rabi* crop) harvested during February to May. Under *Jayad* crops, seasonal vegetable were cultivated. The vegetables grown during the winter season are considered under *Jayad-rabi* (August- January) and in summer season under *Jayad-kharif* (Feb-May). Kumaun Himalayan region is agriculturally rich with a large number of economically important cereal crops belonging to family Poaceae that serve as a staple food. Total 5 cereal, 2 pseudo-cereal, 2 millet crops, 13 pulse crops, 10 spice crops, 5 oil-yielding crops and 30 species of vegetables were prominent in the region including seasonal and regional vegetables (Table 4). In the present study, total numbers of cultivated crops were listed comparatively low in the earlier study for entire Kumaun Himalayan region[21] and higher as reported by many researchers[14,35,36]. List of some most frequently used improved varieties of different crops and fruit trees are given in table 5.

Table 4: Annual cropping system commonly adopted in the *Bhabhar* belt of Kumaun Himalaya

Botanical name	English	Local name	Family name	Sowing	Harvesting time	Category time
Cereal crops						
Avena sativa L.	Oat	Jai	Poaceae	Oct-Nov	Mar-Apr	R
Hordeum vulgare L.	Barley	Jau	Poaceae	Oct-Nov	Mar-Apr	R
Oryza sativa L.	Rice	Dhan	Poaceae	Jun-Jul	Oct-Nov	K
Triticum aestivum L.	Wheat	Gehu	Poaceae	Oct-Nov	Mar-Apr	R
Zea mays L.	Maize	Makka	Poaceae	May-Jun	Jul-Aug	K
Pseudocereal crops						
Amaranthus spp.	Amaranthus	Chaulai	Amaranthaceae	Nov-Dec	Feb-Mar	R
Fagopyrum esculentum Moench	Buckwheat	Ogal	Polygonaceae	Nov-Dec	Feb-Mar	R
Millet crops						
Eleusine coracana (L.) Gaertn.	Finger millet	Manduwa	Poaceae	Oct-Nov	Mar-Apr	R
Pennisetum glaucum (L.) R.Br.	Pearl Millet	Bajra	Poaceae	Apr-May	Jul-Aug	JK
Pulse Crops						
Cajanus cajan (L.) Millsp.	Pigeon-pea	Arhar	Fabaceae	Jun-Jul	Sep-Oct	K
Cicer arietinum L.	Gram	Chana	Fabaceae	Oct-Nov	Mar-Apr	R
Glycine max (L.)	Soya	Soyabean	Fabaceae	Jun-Jul	Sep-Oct	K

Merr.						
Glycine soja Siebold & Zucc.	Soybean	Bhatt	Fabaceae	Jun-Jul	Sep-Oct	K
Lens culinaris Medikus	Lentil	Masoor	Fabaceae	Jun-Jul	Sep-Oct	K
Macrotyloma uniflorum (Lam.) Verdc.	Horse gram	Gahat	Fabaceae	Apr-May	Sep-Oct	K
Phaseolus lunatus L.	Lobia	Lobia	Fabaceae	Jun-Jul	Sep-Oct	K
Phaseolus vulgaris L.	Kidney bean	Sem	Fabaceae	Oct-Nov	Mar-Apr	R
Pisum sativum L.	Garden Pea	Mater	Fabaceae	Sep-Oct	Dec-Feb	JR
Vicia faba L.	Broad bean	Bakula	Fabaceae	Sep-Oct	Dec-Feb	JR
Vigna mungo (L.) Happer	Black gram	Urad	Fabaceae	Jun-Jul	Oct-Nov	K
Vigna radiata (L.) R. Wilczek	Green gram	Mung	Fabaceae	Jun-Jul	Oct-Nov	K
Vigna unguiculata (L.) Walp.	Cow pea	Lobia	Fabaceae	Jun-Jul	Oct-Nov	K
Spice crops						
Allium sativum L.	Garlic	Lehsun	Liliaceae	Oct-Nov	Mar-Apr	R
Brassica juncea (L.) Czern.	Mustard	Rai	Brassicaceae	Oct-Nov	Mar-Apr	R
Capsium annum L.	Chilly	Mirch	Solonaceae	Oct-Nov	Mar-Apr	R
Cinnamomum tamala Nees.	Bay leaf	Tej patta	Lauraceae	Jun-July	Oct-Nov	R
Cleome viscose L.	Wild/Dog mustard	Jakhiya	Cleomaceae	Aug-Sep	Nov-Dec	JR
Corandrum sativum L.	Coriander	Dhania	Apiaceae	Oct-Nov	Mar-Apr	R
Cuminum cyminum L.	Cumin	Zeera	Apiaceae	Oct-Nov	Feb-Mar	R
Curcuma domestica L.	Turmeric	Haldi	Zingiberaceae	Mar-Apr	Sep-Oct	K
Foeniculum vulgare Mill.	Fennel	Sauf	Apiaceae	Oct-Nov	Mar-Apr	R
Zingiber officinale Ros.	Ginger	Adrak	Zingiberaceae	Mar-Apr	Sep-Oct	K
Oil yielding crops						
Brassica compestris L.	Yellow mustard	Sarson	Brassicaceae	Oct-Nov	Mar-Apr	R
Brassica nigra L.	Mustard black	Rada	Brassicaceae	Oct-Nov	Mar-Apr	R
Glycine max (L.) Merr.	Soya	Soyabean	Fabaceae	Jun-July	Sep-Oct	K
Linum usitatissimum L.	Linseed	Alsi	Linaceae	Oct-Nov	Mar-Apr	R
Sesamum indicum L.	Sesame	Til	Pedaliaceae	Oct-Nov	Mar-Apr	R
Vegetable crops						
Abelmoschus esculentus (L.) Moench	Ladyfinger	Bhindi	Malvaceae	Apr-May	Jun-Aug	K
Allium cepa L.	Onion	Piyanz	Liliaceae	Oct-Nov	Mar-Apr	R
Allium sativum L.	Garlic	Lehsun	Liliaceae	Oct-Nov	Mar-Apr	R
Amaranthus oleracea L.	Amaranth	Chaulai	Amaranthaceae	Oct-Nov	Dec-Jan	JR
Benincasa hispida (Thund) Cogn.	Ash gaurd	Bhuja	Cucurbitaceae	Mar-Apr	Jun-Aug	JK
Brassica juncea (L.) Czern.	Mustard	Rai	Brassicaceae	Oct-Nov	Mar-Apr	R
Brassica oleracea L.	Cabbage	Gobhi	Brassicaceae	Oct-Nov	Dec-Jan	JR
Brassica rapa L.	Turnip	Shaljam	Brassicaceae	Oct-Nov	Dec-Jan	JR
Chenopodium album L.	Pigweed	Bathuwa	Chenopodiaceae	Oct-Nov	Dec-Jan	JR

Colocasia esculenta (L.) Schott	Arum	Arbi	Araceae	Mar-Apr	Nov-Dec	JK
Colocasia himalensis Royle.	Tham	Taru	Araceae	Mar-Apr	Nov-Dec	JR
Cucumis sativus L.	Cucumber	Kheera	Cucurbitaceae	Feb-Mar	May-Jun	JK
Cucurbita maxima Duchesne	Pumpkin	Kaddu	Cucurbitaceae	Mar-Apr	Jun-Aug	JK
Daucus carota L.	Carrot	Gajar	Apiaceae	Oct-Nov	Mar-Apr	R
Ipomoea batatas (L.) Lam.	Sweet Potato	Meetha alu	Convolvulaceae	Oct-Nov	Mar-Apr	R
Lagenaria siceraria Ser.	Bottle ground	Lauki	Cucurbitaceae	Mar-Apr	Jun-Aug	JK
Luffa acutangula (L.) Roxb.	Riged gourd	Torai	Cucurbitaceae	Mar-Apr	Jun-Aug	JK
Luffa aegyptiaca Mill.	Sponge gourd	Ghiya Torai	Cucurbitaceae	Mar-Apr	Jun-Aug	JK
Luffa cylindrica Mill.	Ghia torai	Torai	Cucurbitaceae	Mar-Apr	Jun-Aug	JK
Lycopersicum esculentum L.	Tomato	Tamatar	Solanaceae	Oct-Nov	Dec-Feb	R
Momordica charantia L.	Bitter gourd	Karela	Cucurbitaceae	Mar-Apr	Jun-Aug	JK
Pisum sativum L.	Pea	Matar	Fabaceae	Sep-Oct	Dec-Feb	JR
Raphanus sativus L.	Radish	Muli	Brassicaceae	Oct-Nov	Dec-Feb	JR
Solanum melongena L.	Egg plant	Bengen	Solanaceae	Mar-Apr	Jun-Aug	JK
Solanum tuberosum L.	Potato	Alu	Solanaceae	Oct-Nov	Mar-Apr	JR
Spinacia oleracea L.	Spinach	Palak	Chenopodiaceae	Oct-Nov	Dec-Feb	JR
Trichosanthes anguina L.	Snake gourd	Chichinda,	Cucurbitaceae	Mar-Apr	Jun-Aug	JK
Tricosanthes dioica Roxb.	Pointed gourd	Parval	Cucurbitaceae	Mar-Apr	Jun-Aug	JK
Trigonella foenum-graecum L.	Fenugreek	Methi	Fabaceae	Oct-Nov	Dec-Mar	JR
Vicia faba L.	Broad bean	Bakula	Fabaceae	Oct-Nov	Dec-Mar	JR
Orchards						
Artocarpus heterophyllus Lam.	Jack fruit	Kathal	Moraceae	-	Jul-Aug	JK
Carica papaya L.	Papaya	Papita	Cariaceae	-	Mar-Apr	JR
Citrus limon (L.) Burm.f.	Lime	Nimbu	Rutaceae	-	Dec-Mar	JR
Citrus pseudolimon Tan.	Lemon	Gal gal	Rutaceae	-	Dec-Mar	JR
Litchi chinensis Sonn.	Leechi	Litchi	Sapindaceae	-	Jul-Aug	JK
Mangifera indica L.	Mango	Aam	Anacardiaceae	-	Jul-Aug	JK
Manilkara zapota (L.) P.Royen	Sapodila	Cheeku	Sapotaceae	-	Jul-Aug	JK
Musa paradisiaca L.	Banana	Banana	Musaceae	-	Jul-Aug	JK
Prunus persica (L.) Stokes	Peach	Aru	Rosaceae	-	Jul-Aug	JK
Psidium guajava L.	Gauva	Amrud	Myrtaceae	-	Dec-Mar	JR
Punica granatum L.	Pomegranate	Anar	Lythraceae	-	Dec-Mar	JR

R=Rabi crop, K=Kharif crop, JR=Jayad rabi crop, JK=Jayad kharif crop

Table 5: List of some common cultivated crop varieties of Kumaun Himalayan *Bhabhar* belt

Species	English name	Hindi/Local	Varieties name
Cereal crops	Maize	Makka	Sweta, Kanchan
	Rice	Dhan	Pant Dhaan-10 (PD-10), PD-12, PD-18, Pusa Sugandh-5
	Wheat	Gehu	UP-2526, UP-2565, UP-2572, UP-2684, PBW-343, PBW-550, VL-2684
	Raaghi	Mandwa	VL-Manduwa 149, VL-Manduwa 315, VL-Manduwa 324
Pulse crops	Chickpea	Arhar	PUSA-362, PG-186, PG-114, Suriya
	Lentil	Masoor	PS-06, VL-507, Pant Mung-04, Pant Mung-05
	Pea	Matar	VL-7, VL-10, Arkil, PS-1100, PSM-3
	Soybean	Soya	PS-1347, PS-1225, PS-1092, PS-1241
	Black gram	Urad	PU-40, PU-31, PU-35
Oil Yielding crops	Mustard	Sarson	Pant Pili Sarson-1, Uttara, PT-303
Fodder crops	Barseem	Barsim	Desi Miskavi
	Maize	Makka	African tall, J-1006
Fruit crops	Gooseberry	Aawla	Kanchan, Krishna, NA-6, NA-20
	Stone apple	Bael	NB-5, Pant Aparna, Pusa Urvashi
	Guava	Amrud	Sardar (L-49), Lalit, Shweta, Allahabad Safeda, Pant Prabhat
	Jackfruit	Kathal	-
	Lime	Nimbu	Kagzi, Vikram, Sai Sharbati,
	Lemon	Bada nimbu	Eureka, Kagzi Kalan, Pant Lemon-1
	Litchi	Litchi	Shahi, China, Rose scented, Dehradun, Calcuttia
	Mango	Aam	Bombay Green, Chausa, Dashehari, Langra, Mallika, Amrapali, Pusa Arunima, Pusa Surya
	Papaya	Papita	Pusa Delicious, Pusa Dwarf, Pant-1
	Peach	Aadu	Red June, Snow Queen, Red Heaven, Prabhat, Flora Red, Sharbati
	Pomegranate	Anar	Ganesh, Bhagwa,
	Banana	Kela	Grand Naine
Vegetable crops	Amaranthus	Chaulai	Pusa Kiran, Lal chaulai, Pusa Kirti
	Bitter gourd	Karela	Pusa Vishesh, Pusa Hybrid-2
	Bottle gourd	Lauki	Pusa Hybrid 3, Pusa Summer, Pant Lauki-4 , Pusa Santushti, Pant Sankar Lauki-2, Pant Sankar Lauki-1
	Brinjal	Baingan	Pant Rituraj, Pusa Purple Cluster, Hisar Pragati, Pant Samrat, Pant Brinjal Hybrid1&4.
	Cabbage	Band gobi	Golden Acre , Pusa Ageti, California Wonder
	Capsicum	Shimla	Pusa Deepti, Arka Basant, California wonder, Indra, Tanvi
	Cauliflower	Fool gobi	Pusa Paushja, Pusa Shubra, Pusa Snowball K-1
	Chilli	Mirch	Arka Sweta, Pusa Jwala, Pant C-1
	Cucumber	Kakadi	Parthenocarpic Khira-3, Pusa Sanyog, Pant Khira-1, Pant Sankar Khira-1
	French bean	Bean	Pant Bean -2, Contender, Pant Anupma

Onion	Pyaaz	Pusa White Flat, Pusa Ratnar, Punjab Selection, Bhima Kiran,
Spinach	Palak	Pusa Harit , Pusa Bharati
Pea	Mater	Pant Matar-2, Arkel, Pant Uphar, Pant Sabji Matar-4, Pant Sabji Matar-5
Potato	Alu	Kufri Jyoti, Kufri Himalini, Kufri Surya
Pumpkin	Kaddu	Pusa Vishwas, Azad Pumpkin-1
Radish	Muli	Japanese White, Pusa Reshmi, Pusa Himani, Kashi Sweta
Ridge gourd	Torai	Pusa Nasdar, Pant Torai-1
Tomato	Tamatar	Pusa Ruby, Pusa-120, Pusa Hybrid-2, Pant Bahar, Pant poly house tomato-1
Garlic	Lehsun	Pant Lohit, Yamuna Safed (G-1), (G-50), Yamuna Safed-4 (G-323)
Coriander	Dhania	Pant Haritima, Multicut

Plant Utilization Pattern of Associated Species in Agroecosystems

Scaling up agriculture potential is not much challenging task if provided agricultural extension efforts are directed with suitable site-specific agroforestry model[37] as it supplies the resources in sustainable manner[3]. Agriculture is heavily dependent on energy flows from uncultivated lands, which clearly indicated that this system is closed, self-contained and self-reliant[38]. Total 44 plants, which were associated with the agroecosystms of the villages, were used by the local people to fulfill the daily requirements of fuel, fodder, fiber, fruit, medicine and timber etc (Table 6). These plant species belonging to 37 families in which Lamiaceae contributed the highest number of species (5) followed by Poaceae (4). In tree component, *A. catechu* and *M. indica* considered as the multipurpose trees by providing fuel wood, medicine and timber, *G. optiva* and *F. glomerata* as the best quality fodder, *D. sissoo* as the quality wood for house construction, *Eucalyptus* and *Poplus* sp. were the best quality trees for the commercial purpose. Out of 18 tree spices, 8 species were found exclusively in wild, 6 species in agroforestry system and rest species were common to both wild and agroforestry system. Eleven types of fruit orchards (Table 4) were also found in the studied villages in which *M. indica* and *L. chinensis* were the dominant. Reduction of crop yields due to farm trees is reconciled with availability of fodder, fuelwood and other non-timber forest products near farm lands[10,39,40,41]. Total 8 shrub species were associated with the agroecosystem in which only 2 species (*H. rosa-sinensis* and *S. indicum*) were cultivated and remaining was wild. *L. camara* and *S. cordifolia* were preferably used by the local people particularly in tomato cultivation as the supporting material. These species were also used as quality fuel due to their fast and easily burning properties. Several varieties of multipurpose herbs were also found in the studied villages such as aloe, mint, hemp, holi basil, opium, giloe etc. A total of 25 herb species (wild=15 and cultivated=10) and 3 climber species (wild=2 and common to both wild and agroforestry system=1) were utilized by the villagers for various purpose.

Table 6: Uses of some plant species associated with the agroecosystem

Botanical name	Common name	Hindi name	Family	Habitat	Uses
Acacia catechu (L.f.) Willd.	Cutch tree	Khair	Fabaceae	T/W	Com, Fo, Fu, Med, Ti,
Adina cordifolia (Roxb.) Ridsdale	Yellow Teak	Haldu	Rubiaceae	T/W	Fu, Ti
Aegle marmelos (L.) Corrêa	Stone Apple	Bael	Rutaceae	T/C	Ed, Med
Artocarpus heterophyllus Lam.	Jackfruit	Kathal	Moraceae	T/C	Ed, Fu
Azadirachta indica A. Juss.	Margosa	Neem	Meliaceae	T/W-C	Com, Med

Cinnamomum tamala Nees.	Bay leaf	Thej patta	Lauraceae	T/W-C	Ed, Med, Sp
Dalbergia sisso Roxb	Indian Rosewood	Shisam	Papilionaceae	T/W-C	Fu, Ti
Eucalyptus tereticornis Sm.	Eucalyptus	Eucalyptus	Myrtaceae	T/C	Com
Ficus glomerata Roxb	Cluster-fig	Timla	Moraceae	T/W	Ed, Fo, Re
Grewia optiva J.R.Drumm. ex Burret	Crossberry	Bhimal	Tiliaceae	T/W	Fo, Med
Morus alba L.	Mulberry	Sehtoot	Moraceae	T/C	Ed
Phyllanthus officinalis L.	Emblic	Aawla	Euphorbiaceae	T/C	Ed, Med, Re
Populus deltoides W.Bartram ex Marshall	Popular	Popular	Salicaceae	T/C	Com
Shorea robusta Roth	Sal	Sal	Dipterocarpaceae	T/W	Fu, Ti
Syzygium jambolanum (Syzy)	Jambul	Jamun	Myrtaceae	T/W-C	Ed, Fu
Tamarindus indica L.	Tamarind	Emli	Caesalpiniaceae	T/W	Ed, Med
Tectona grandis L.f.	Teak	Sagon	Verbenaceae	T/W	Fu, Ti
Zizyphus jujube Mill.	Jujube	Ber	Rhamnanaceae	T/W	Ed, Fu
Clerodendrum viscosum Vent.	Glory bower	Bhant	Lamiaceae	S/W	Med
Glycosmis pentaphylla (Retz.) DC	Orangeberry	Putwa	Rutaceae	S/W	Ed, Med,
Hibiscus rosasinensis L.	Hibiscus	Gurhal	Malvaceae	S/C	Med, Or
Lantana camara L.	Lantana	Kuri	Verbenaceae	S/W	Com, Fu
Murraya koenigii (L.)	Curry leaves	Kadi Patta	Rutaceae	S/W	Ed, Med
Rosa sp	Wild rose	Jangli gulab	Rosaceae	S/W	Med, Or
Sesamum indicum L.	Sesame,	Til	Pedaliaceae	S/C	Ed, Med,
Sida cordifolia L	Flannel weed	Jhadu	Malvaceae	S/W	Com, Med
Ageratum conyzoides L.	Whiteweed	Bukila	Asteraceae	H/W	Med
Aloe barbadensis (L.) Burm.f.	Aloe	Ghigwar	Liliaceae	H/C	Med
Boerhavia diffusa L.	Tarvine	Punarnava	Nyctaginaceae	H/W	Med
Cannabis sativa L.	Hemp	Bhang	Cannabaceae	H/W	Med
Commelina benghalensis L.	Spiderwort	Ghaas	Commelinaceae	H/W	Fo, Med
Cymbopogon citrates (DC.) Stapf	Lemon grass	Nimbu ghas	Poaceae	H/C	Med
Cynodon dactylon (L.) Pers	Grass	Dov	Poaceae	H/W	Fo, Med, Re
Cyperus rotundus L.	Grass	Moutha	Poaceae	H/W	Fo, Med
Euphorbia hirta L.	Asthma-plant	Dhudhia	Euphorbiaceae	H/W	Med
Impatiens balsamina L.	Rose balsam	Majhethi	Balsaminaceae	H/W	Or
Ipomoea purpurea (L.) Roth	Morning glory	Subah ki tajgi	Convolvulaceae	H/W	Med
Mentha arvensis L.	Wild mint	Jangli pudina	Lamiaceae	H/C	Ed, Med
Mentha piperita L.	Pipermint	Vilayati pudina	Lamiaceae	H/C	Ed, Med
Mentha spactica L.	Mint	Pudina	Lamiaceae	H/C	Ed, Med
Mimosa pudica L.	Touch me not	Chhui-mui	Mimosaceae	H/W	Med
Musa paradisiaca L.	Banana	Kela	Musaceae	H/C	Ed, Re
Ocimum sanctum L.	Holi basil	Tulsi	Lamiaceae	H/C	Re, Med
Oxalis corniculata L.	Creeping woodsorrel	Khatti mitti	Oxalidaceae	H/W	Med
Papavar somniferum L.	Opium	Poppy	Papaveraceae	H/C	Med
Polygonum nepalensis Meissn.	Smartweed	Jangli palak	Polygonaceae	H/W	Med
Saccharum officinarum L.	Sugar cane	Ganna	Poaceae	H/C	Com, Ed, Re
Solanum nigrum L.	Wonder berry	Makoi	Solanaceae	H/W	Med

Stellaria media (L.) Vill	Chickweed	Ghaas	Caryophyllaceae	H/W	Med
Tagetus erecta L.	Marigold	Genda	Asteraceae	H/C	Med, Or
Trifolium repens L.	Dutch clover	Satfal	Fabaceae	H/W	Med
Cuscuta reflexa Roxb	Dodder	Amar bel	Cuscutaceae	Cl/W	Med
Jasminum officinale L.	Jasmine	Chameli	Oleaceae	Cl/W-C	Med, Or
Tinospora cordifolia (Thunb.) Miers	Giloe	Gurcha	Menispermaceae	Cl/W	Med

C=cultivated, W=wild, W-C=wild cultivated both, Com=commercial, Ed=edible, Fo=fodder, Fu=fuel, Med=medicinal, Or=ornamental, Re=religious, Sp=spices, Ti=timber

Energy Budgets in Agroecosystems

The demand bioenergy is accelerating drastically day by day due to huge increase in population pressure[31]. Average annual energy input consumption in agroforestry system (103646 MJ/ha) was approximately three times more compared to home gardens (43056 MJ/ha). The energy input in term of human and bullock labour is important in the agroecosystem of any region[42]. Among all the studied villages, consumption of human energy input was highest in village 4, which were 276 MJ/ha in agroforestry and 84 MJ/ha in home garden. Draught power consumption (582 MJ/ha in agroforestry system and 218 MJ/ha in home garden) was also highest in the same village. The major contribution of energy input via human and livestock in village 4 was due to the highest cultivated agriculture landholding and livestock population among all. Total seed input (agroforestry + home garden) was highest observed in village 2, which contributed about 36.80% of the total, probably due to the repeated crop failure as reported by the villagers (Table 7). The manure and chemical fertilizers increased the energy inputs in agroforestry systems as well as in home gardens. The consumption of annual energy input in the present study was higher than as reported by many researchers for Kumaun Himalayan region[14,35,36] and less than as reported for Garhwal Himalaya[43]. Average annual energy output from agroforestry was 434117 MJ/ha compared to 57008 MJ/ha in home garden. In a study 27491 MJ/ha gross annual energy output was reported from agroecosystem[35], which was very less compared to the present study due to the small landholdings.

Table 7: Comparative account of energy input and output (MJ/ha) in agroforestry systems of Kumaun Himalayan *Bhabhar* belt

Parameters	Village 1		Village 2		Village 3		Village 4	
	Agrofor System	Home Garden	Agrofor System	Home Garden	Agrofor System	Home Garden	Agrofor System	Home Garden
Input								
Human labour	183	71	156	54	220	67	276	84
Drought power	291	72	436	145	436	144	582	218
Seeds	5164	1202	5875	1781	3440	787	2023	530
Manure	102135	41631	105340	42562	108865	30324	79165	52553
Total input	107773	42976	111807	44542	112960	31324	82045	53385
Out put								
Food grains	87598	526	77679	381	61915	551	267511	1651
Vegetables	-	28504	-	24504	-	19496	-	25925
By products	6439	8122	10348	19154	6745	11177	786	19161
Fuel wood	66807	11345	255871	17374	188252	11728	253494	12297
Grass fodder	82277	2954	74665	3172	73735	3226	222344	6786
Total output	243121	51450	418563	64584	330647	46178	744136	65820
Net return	135348	8474	306755	20042	217687	14854	664970	12097
Output/ input ratio	2.26	1.20	3.74	1.45	2.93	1.47	9.06	1.23

At each studied village output/input ratio in agroforestry varied between 2.25 to 2.74, which was observed the same results (0.26 to 3.99) in another study[44] for Himalaya, apart from village 4 (9.06), which was much greater than the reported range between 0.11 and 2.57 for agroforestry systems[43,45,46] while in other study reported a little bit high range (1.57-4.14) for home garden system[35]. In the present study, the output-input ratio was varied of 2.25 to 9.06 in agroforestry. The agroecosystem studies in Central Himalaya indicated that agriculture in the area can be sustainable if pressure on forestland can be reduced. This could be achieved by reviving the support system and each hectare of agriculture land should be supported by 10-15 ha of forests[38].

Among the cereal and pulse crops (6.69±1.57), the maximum seed output-input ratio (Table 8) was observed in wheat cultivation (11.95), which resulted in maximum benefits in terms of production followed by paddy (10.13). In the vegetable cultivation (8.10±2.23), green/fresh vegetable (11.97) maximized the production compared to tuber crops (4.23). In the fruit production (4.26±2.30), the highest ratio was recorded for jackfruit production (15.78), which resulted in high output (production) due to low input requirement followed by mango cultivation (2.39).

Table 8: Seed input and output (kg/ha) of some major crops cultivated in agroecosystem of *Bhabhar* belt

Parameters	Village 1			Village 2			Village 3			Village 4		
	Input	Out put	Ratio	Input	Out put	Ratio	Input	Out put	Ratio	Input	Out put	Ratio
					Main cereal and pulse crops							
Finger millet	15	60	4	20	50	2.5	12	30	2.5	8	60	7.5
Maize	30	270	9	35	230	6.57	25	200	8	25	200	8
Paddy	65	650	10	70	600	8.57	55	500	9.09	70	900	12.86
Pea	18	40	2.22	20	60	3	15	40	2.67	20	70	3.5
Wheat	90	1250	13.89	150	1500	10	80	600	7.5	110	1800	16.36
Others	20	80	4	25	60	2.4	15	50	3.33	40	120	3
Average of cereal and pulse crops	39.67 ±12.56	391.67 ±195.80	7.19 ±1.84	53.33 ±20.80	416.67 ±233.16	5.51 ±1.36	33.67 ±11.40	236.67 ±103.20	5.52 ±1.22	45.5 ±15.56	525 ±286.31	8.54 ±2.14
					Vegetables crops							
Fresh vegetables	7	120	17.14	10	100	10	8	70	8.75	10	120	12
Tubers	15	60	4	20	75	3.75	12	50	4.17	30	150	5
Average of vegetable crops	11 ±4.00	90 ±30.00	10.57 ±6.57	15 ±5.00	87.5 ±12.50	6.88 ±3.12	10 ±2.00	60 ±10.00	6.46 ±2.29	20 ±10.00	135 ±15.00	8.50± 3.5
					Fruit crops*							
Mango	2000	2750	1.38	2500	4900	1.96	4000	10800	2.7	3200	11250	3.52
Litchi	1000	1200	1.2	1500	2400	1.6	1200	2100	1.75	2000	4800	2.4
Guava	800	1500	1.88	600	750	1.25	500	1000	2	700	2400	3.43
Papaya	800	1250	1.56	700	1250	1.79	200	600	3	400	800	2
Jack fruit	70	1050	15	40	525	13.13	60	1050	17.5	80	1400	17.5
Others	20	25	1.25	30	40	1.33	50	70	1.4	50	90	1.8
Average of fruit crops	781.67 ±295.48	1295.83 ±357.91	3.71 ±2.26	895 ±389.29	1644.17 ±729.21	3.51 ±1.93	1001.67 ±624.93	2603.33 ±1661.86	4.73 ±2.57	1071.67 ±516.66	3456.67 ±1695.87	5.11 ±2.49

*Fruit input is given in terms of fertilizers application

Monetary Budget in Agroecosystem

In terms of monetary budget (Table 9), the total input of the agroecosystem (agroforestry + home garden) was ₹28446/ha, in which agroforestry shared about 81% of the total input and remaining 19% of home garden. Human power (₹11926/ha) followed by manure (₹9200/ha) added the highest input in agroecosystem. The total output of the agroecosystem was estimated ₹127724/ha, in which ₹118135/ha was contributed by the agroforestry systems. Collectively (agroforestry + home garden), the maximum output obtained from the byproducts (fruit, milk, meat etc) i.e., about 60% of the total output followed by food grains. The total output from the agroforestry was recorded of ₹118135/ha.

Table 9: Comparative account of monetary budget ₹ in agroforestry and home garden in studied villages

Parameters	Village 1		Village 2		Village 3		Village 4	
Input	Agrofor. System	Home Garden	Agrofor. System	Home Garden	Agrofor. System	Home Garden	Agrofor. System	Home Garden
Human labour	8750	2000	3904.5	1200	12250	1400	14700	3500
Drought power	1600	500	2400	1000	2400	1200	4800	1500
Seeds	3500	600	4550	400	2380	500	1500	450
Manure	8000	1600	9000	1700	9500	1200	3000	2800
Total Input	21850	4700	19855	4300	26530	4300	24000	8250
Output								
Food grains	25000	900	18000	720	22500	1350	54000	1750
Vegetables	840		660		440		1350	
By products	40850	3600	52570	7200	80790	4560	105180	6400
Fuel wood	4500	600	3000	870	2400	660	15000	750
Grass fodder	10500	1050	8750	1225	7000	980	22500	2450
Total out	80850	6990	82320	10675	112690	7990	196680	12700
Net return	59000	2290	62466	6375	86160	3690	172680	4450
Output/input ratio	3.70	1.49	4.15	2.48	4.25	1.86	8.20	1.54

The total net return was recorded ₹99278/ha in which agroforestry and home garden contributed about ₹95075 and 4201/ha, respectively. The net return from the Kumaun Himalayan homegarden systems was reported ₹15270/ha[35], which was much higher than studied home garden in the present study. The similar results were reported by another study[36], and reported the highest per ha annual productivity or income in agroforestry followed by the home gardens. The total output input ratio indicated that the agroforestry system (5.12) was more beneficial than the home garden (1.78) in *Bhabhar* belt though, home gardens support more plant diversity as compared to other systems[47,48,49].

The correlation interpreted that the energy budget of an agroecosystem depends appreciably upon the soil properties (Table 10). The crop production showed highly positive significant correlated with the silt (r=0.923), feasibility of moisture content (r=0.989), carbon (r=0.992) and nitrogen (r=0.965) of the soil while highly negative significant correlation with soil pH (r=-0.974) because all these soil parameters make the soil productive and enhance the crop production[50,51,52,53,54,55].

Constrains in agriculture

- According to the present scenario, farmers have abandoned their traditional seeds and practices and found themselves dependent on the government and private sector to provide them necessary inputs such as seeds and manure.
- Animal husbandry, once an integral and valued part of agriculture, is relegated to secondary importance as chemical fertilizers replaced

the dung manure, machines replaced draught power and cattle are kept seen only as factories for milk or meat production.

- Farmers prefer a crop if it provides them a good monetary returns though it may involve a great deal of labor. On the other hand, wheat and paddy require very low input cost hence their output-input ratio is higher than other cash crops but the actual amount realized is of course lesser than that of other cash crops. It was observed that paddy is more profitable than wheat because fertilizer requirement of paddy was less as compared to wheat[14].
- After the green revolution the use of chemical fertilizers did catch up fast in Uttarakhand especially in *Tarai* and *Bhabhar* region. The farmers have resorted to the practice of using chemical fertilizers (i.e. mainly urea and DAP) and pesticides in a big way to increase the crop yield and profits. The authors were unable to find anyone household which was not using any chemical fertilizer in their farms. Farmers are not bothered about its harmful impacts because they are getting good monetary returns.

Table 10: Correlation between soil components and the total energy input-output in agriculture of all villages

	Site	Sand	Silt	Clay	bD	Mo	Po	WHC	Temp	pH	C	N	P	Input	Output
Site	1														
Sand	-0.724	1													
Silt	0.773	-0.994**	1												
Clay	0.707	-0.999**	0.990*	1											
bD	-0.787	0.993**	-0.990**	-0.992**	1										
Mo	0.774	-0.930	0.962*	0.918	-0.917	1									
Po	0.787	-0.993**	0.990**	0.992**	-1.000**	0.917	1								
WHC	0.716	-0.995**	0.981*	0.997**	-0.994**	0.892	0.994**	1							
Temp	-0.854	0.967*	-0.969*	-0.964*	0.990**	-0.889	-0.990**	-0.973*	1						
pH	-0.767	0.748	-0.813	-0.726	0.740	-0.938*	-0.740	-0.686	0.724	1					
C	0.812	-0.892	0.935*	0.877*	-0.987**	0.994**	0.987**	0.849*	-0.869	-0.967*	1				
N	0.765	-0.969*	0.988*	0.961*	-0.958*	0.992**	0.958*	0.942*	-0.930*	-0.886	0.974*	1			
P	0.581	-0.261	0.364	0.229	-0.268	0.590	0.268	0.181	-0.282	-0.832	0.669	0.483	1		
Input	-0.833	0.339	-0.434	-0.310	0.397	-0.575	-0.397	-0.294	0.468	0.763	-0.661	-0.498	-0.884	1	
Output	0.822	-0.877	0.923*	0.861	-0.874	0.989*	0.874	0.833	-0.859	-0.974*	0.992**	0.965*	0.693	-0.687	1

*Correlation is significant at 0.05 and ** at 0.01 level, bD=Bulk density, Mo=Moisture, Po=Porosity, WHC=Water holding capacity, Temp=Temperature, C=Carbon, N=Nitrogen, P=Phosphorus

Conclusion

In conclusion, the present study reflects that the farming systems of this region is traditional, sustainable and is seemed quite well. The high level of crop diversity in agroforestry systems were maintained by the farmers through the crop rotation. Agroforestry systems also provide many ecosystem services in a low expenditure with environmental benefits (sequestration of carbon and mitigate the impact of climate change). Therefore, it is recommended from the present study that farmers of the *Bhabhar* Region of Kumaun Himalaya should preferred agroforestry systems to enhance the socio-economic status of their livelihood.

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