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.
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. 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.

Uttarakhand is primarily an agricultural state and developed as ecological brand equity. 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. 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. 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 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. 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. In recent years, agroforestry is emerging as the promising land use option to sustain agricultural productivity and livelihoods of farmers along with mitigate the adverse impact of changing climatic conditions.

Various studies conducted in the Central Himalayan region revealed that the agriculture practices require massive consumption of forest resources. 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 km² (77°34’ to 81°02’ E longitude and 28°43 to 31°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-Himalayas 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). 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°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°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. Chemical properties of the soil i.e. pH, total organic carbon, total nitrogen and phosphorus 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. 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 (Table 1). Standard energy values of various inputs and outputs used for budgeting were calculated.

Table 1: Energy coefficients 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 |
| 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. 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\textsuperscript{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\textsuperscript{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 |
|-------------------------------|-----------|-----------|-----------|-----------|
| 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     |

\textsuperscript{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\textsuperscript{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\textsuperscript{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. In Kumaun Himalayan region, total 5 land use systems, which were commonly practiced in this region 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/cm³)                  | 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 (°C)                   | 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        | 0.72±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 (%)                       | 0.01±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. campestris, 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.
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 + Raghi
- 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 and higher as reported by many researchers.

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 name | Local name | Family name | Sowing time | Harvesting time | Category |
|----------------|-------------|------------|-------------|-------------|----------------|----------|
| 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 |
| Amaranthus spp. | Amaranthus Chaulai | Amaranthaceae | Nov-Dec | Feb-Mar | R |
| Fagopyrum esculentum Moench | Buckwheat | Ogal | Polygonaceae | Nov-Dec | Feb-Mar | R |
| 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 |
| 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 |
| Crop Name                          | Common Name | Family        | Harvest Period       | Source |
|-----------------------------------|-------------|---------------|----------------------|--------|
| **Merr.**                         |             |               |                      |        |
| Glycine soja Siebold & Zucc.      | Soybean     | Fabaceae      | Jun-Jul, Sep-Oct     | K      |
| Lens culinaris Medikus            | Lentil      | Fabaceae      | Jun-Jul, Sep-Oct     | K      |
| Macrotyloma uniflorum (Lam.) Verdc. | Horse gram | Fabaceae      | Apr-May, Sep-Oct     | K      |
| Phaseolus lunatus L.              | Lobia       | Fabaceae      | Jun-Jul, Sep-Oct     | K      |
| Phaseolus vulgaris L.             | Kidney bean | Fabaceae      | Oct-Nov, Mar-Apr     | R      |
| Pisum sativum L.                  | Garden pea  | Fabaceae      | Sep-Oct, Dec-Feb     | JR     |
| Vicia faba L.                     | Broad bean  | Fabaceae      | Sep-Oct, Dec-Feb     | JR     |
| Vigna mungo (L.) Happer           | Black gram  | Fabaceae      | Jun-Jul, Oct-Nov     | K      |
| Vigna radiata (L.) R. Wilczek      | Green gram  | Fabaceae      | Jun-Jul, Oct-Nov     | K      |
| Vigna unguiculata (L.) Walp.       | Cow pea     | Fabaceae      | Jun-Jul, Oct-Nov     | K      |
| **Spice crops**                   |             |               |                      |        |
| Allium sativum L.                 | Garlic      | Liliaceae     | Oct-Nov, Mar-Apr     | R      |
| Brassica juncea (L.) Czern.       | Mustard     | Brassicaceae  | Oct-Nov, Mar-Apr     | R      |
| Capsium annum L.                  | Chilly      | Solonaceae    | Oct-Nov, Mar-Apr     | R      |
| Cinnamomum tamala Nees.           | Bay leaf    | Lauraceae     | Jun-Jul, Oct-Nov     | R      |
| Cleome viscosa L.                 | Wild/Dog mustard | Cleomaceae | Aug-Sep, Nov-Dec     | JR     |
| Coriandrum sativum L.             | Coriander   | Apiaceae      | Oct-Nov, Mar-Apr     | R      |
| Coriandrum sativum L.             | Coriander   | Apiaceae      | Oct-Nov, Mar-Apr     | R      |
| Curcuma domestica L.              | Turmeric    | Zingiberaceae | Mar-Apr, Sep-Oct     | K      |
| Foeniculum vulgare Mill.          | Fennel      | Apiaceae      | Oct-Nov, Mar-Apr     | R      |
| Zingiber officinale Ros.          | Ginger      | Zingiberaceae | Mar-Apr, Sep-Oct     | K      |
| **Oil yielding crops**            |             |               |                      |        |
| Brassica compestris L.            | Yellow mustard | Brassicaceae | Oct-Nov, Mar-Apr     | R      |
| Brassica nigra L.                 | Mustard black | Brassicaceae | Oct-Nov, Mar-Apr     | R      |
| Glycine max (L.) Merr.            | Soya        | Fabaceae      | Jun-Jul, Sep-Oct     | K      |
| Linum usitatissimum L.            | Linseed     | Linaceae      | Oct-Nov, Mar-Apr     | R      |
| Sesamum indicum L.                | Sesame      | Pedaliaceae   | Oct-Nov, Mar-Apr     | R      |
| **Vegetable crops**               |             |               |                      |        |
| Abelmoschus esculentus (L.)       | Ladyfinger  | Malvaceae     | Apr-May, Jun-Aug     | K      |
| Moench                            |             |               |                      |        |
| Allium cepa L.                    | Onion       | Liliaceae     | Oct-Nov, Mar-Apr     | R      |
| Allium sativum L.                 | Garlic      | Liliaceae     | Oct-Nov, Mar-Apr     | R      |
| Amaranthus oleracea L.            | Amaranth    | Amaranthaceae | Oct-Nov, Dec-Jan     | JR     |
| Benincasa hispida (Thund) Cogn.   | Ash gaud    | Cucurbitaceae | Mar-Apr, Jun-Aug     | JK     |
| Brassica juncea (L.) Czern.       | Mustard     | Brassicaceae  | Oct-Nov, Mar-Apr     | R      |
| Brassica oleracea L.              | Cabbage     | Brassicaceae  | Oct-Nov, Dec-Jan     | JR     |
| Brassica rapa L.                  | Turnip      | Brassicaceae  | Oct-Nov, Dec-Jan     | JR     |
| Chenopodium album L.              | Pigweed     | Chenopodiaceae | Oct-Nov, Dec-Jan     | JR     |
| Plant Name                        | Common Name         | Family             | Season 1  | Season 2  | Season 3  | Season 4  | Region |
|----------------------------------|---------------------|--------------------|-----------|-----------|-----------|-----------|--------|
| *Colocasia esculenta* (L.)       | Arum                | Araceae            | Mar-Apr   | Nov-Dec   | _         | _         | _      |
| Schott                           | **Tham**            | Araceae            | Mar-Apr   | Nov-Dec   | _         | _         | _      |
| *Colocasia himalensis* Royle.    | Cucumber            | Cucurbitaceae      | Feb-Mar   | May-Jun   | _         | _         | _      |
| *Cucumis sativus* L.             | Kheera              | Cucurbitaceae      | _         | _         | _         | _         | _      |
| Duchesne                         | **Pumpkin**         | Cucurbitaceae      | Mar-Apr   | _         | _         | _         | _      |
| *Daucus carota* L.               | Carrot              | Apiaceae           | Oct-Nov   | _         | _         | _         | _      |
| *Ipomoea batatas* (L.) Lam.      | Bottle gourd        | Convolvulaceae     | Oct-Nov   | _         | _         | _         | _      |
| Lam.                             | **Musa paradisiaca* L. | Musaceae            | _         | _         | _         | _         | _      |
| *Lagenaria siceraria* Ser.       | Lauki               | Cucurbitaceae      | Mar-Apr   | Jun-Aug   | _         | _         | _      |
| R.                               | **Luffa acutangula* (L.) | Cucurbitaceae      | Mar-Apr   | Jun-Aug   | _         | _         | _      |
| *Luffa cylindrica* Mill.         | Ghia torai          | Cucurbitaceae      | Mar-Apr   | Jun-Aug   | _         | _         | _      |
| *Lycopersicum esculentum* L.     | Tomato              | Solanaceae         | Oct-Nov   | Dec-Feb   | _         | _         | _      |
| Lam.                             | **Momordica charantia* L. | Cucurbitaceae      | Mar-Apr   | Jun-Aug   | _         | _         | _      |
| *Pisum sativum* L.               | Bitter gourd        | Cucurbitaceae      | Mar-Apr   | _         | _         | _         | _      |
| R.                               | **Raphanus sativus* L. | Brassicaceae       | Oct-Nov   | Dec-Feb   | _         | _         | _      |
| *Solanum melongena* L.           | Egg plant           | Solanaceae         | Mar-Apr   | Jun-Aug   | _         | _         | _      |
| R.                               | **Solanum tuberosum* L. | Solanaceae         | Oct-Nov   | Mar-Apr   | _         | _         | _      |
| *Spinacia oleracea* L.           | Spinach             | Chenopodiaceae     | Oct-Nov   | Dec-Feb   | _         | _         | _      |
| *Trichosanthes anguina* L.       | Snake gourd         | Cucurbitaceae      | Mar-Apr   | Jun-Aug   | _         | _         | _      |
| *Trichosanthes dioica* Roxb.     | Pointed gourd       | Cucurbitaceae      | Mar-Apr   | Jun-Aug   | _         | _         | _      |
| *Vicia faba* L.                  | Broad bean          | Fabaceae           | Oct-Nov   | Dec-Mar   | _         | _         | _      |
| R.                               | **Artocarpus heterophyllus* Lam. | Moraceae            | _         | _         | _         | _         | _      |
| *Carica papaya* L.               | Papaya              | Cariacae           | _         | _         | _         | _         | _      |
| R.                               | **Citrus limon* (L.) | Rutaceae           | _         | _         | _         | _         | _      |
| *Citrus pseudolimon* Tan. Burm.f.| Lemon               | Rutaceae           | _         | _         | _         | _         | _      |
| *Litchi chinensis* Sonn.         | Litchi              | Sapindaceae        | _         | _         | _         | _         | _      |
| *Mangifera indica* L.            | Mango               | Anacardiaceae      | _         | _         | _         | _         | _      |
| R.                               | **Manilkara zapota* (L.) | Sapotaceae         | _         | _         | _         | _         | _      |
| *Psidium guajava* L.             | Gauva               | Myrtaceae          | _         | _         | _         | _         | _      |
| P. Royen                         | **Prunus persica* (L.) | Rosaceae           | _         | _         | _         | _         | _      |
| *Stokes*                         | Pineapple           | Myrtaceae          | _         | _         | _         | _         | _      |
| *V punica granatum* L.           | Pomegranate         | Lythraceae         | _         | _         | _         | _         | _      |

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 name | 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      |
| Pulses crops             | Chickpea     | Arhar            | PUSA-362, PG-186, PG-114, Suriya                    |
|                          | Lentil       | Matar            | PS-06, VL-507, Pant Mung-04, Pant Mung-05          |
|                          | Pea          | Matar            | VL-7, VL-10, Arki, 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, Mallik, 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,                                    |
| Vegetable crops          | Amaranthus   | Chaulai          | Pusa Kiran, Lal chaulai, Pusa Kirti                 |
|                          | Bitter gourd | Karela           | Pusa Vishes, Pusa Hybrid-2                          |
|                          | Bottle gourd | Lauki            | Pusa Hybrid 3, Pusa Summer, Pant Lauki-4, Pusa Santoshti, Pusa Sankar Lauki-2, Pant Sankar Lauki-1 |
|                          | Brinjal      | Baingan          | Pant Riturai, Pusa Purple Cluster, Hisar Pragati, Pant Samrat, Pant Brinjal Hybrid1&4. |
|                          | Cabbage      | Band gobi        | Golden Acre, Pusa Aget, 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 Uihar, 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 as it supplies the resources in sustainable manner. Agriculture is heavily dependent on energy flows from uncultivated lands, which clearly indicated that this system is closed, self-contained and self-reliant. Total 44 plants, which were associated with the agroecosytems 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 species, 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. 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 | Haldhu | 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 |
| Scientific Name                  | Common Name          | Family          | Type/Use |
|---------------------------------|----------------------|-----------------|----------|
| Cinnamomum tamala Nees.         | Bay leaf             | Lauraceae       | T/W-C    | Ed, Med, Sp |
| Dalbergia sisso Roxb            | Indian Rosewood      | Papilionaceae   | T/W-C    | Fu, Ti     |
| Eucalyptus tereticornis Sm.     | Eucalyptus           | Myrtaceae       | T/C      | Com        |
| Ficus glomerata Roxb            | Cluster-fig          | Moraceae        | T/W      | Ed, Fo, Re |
| Grewia optiva J.R.Drumm. ex Burret | Crossberry          | Tiliaceae       | T/W      | Fo, Med    |
| Morus alba L.                   | Mulberry             | Moraceae        | T/C      | Ed         |
| Phyllanthus officinalis L.      | Emblic               | Euphorbiaceae   | T/C      | Ed, Med, Re|
| Populus deltoides W.Bartram ex Marshall | Popular            | Salicaceae     | T/C      | Com        |
| Shorea robusta Roth             | Sal                  | Dipterocarpaceae| T/W      | Fu, Ti     |
| Syzygium jambolanum (Syzy)      | Jambul               | Myrtaceae       | T/W-C    | Ed, Fu     |
| Tamarindus indica L.            | Tamarind             | Caesalpiniaceae | T/W      | Ed, Med    |
| Tectona grandis L.f.            | Teak                 | Verbenaceae     | T/W      | Fu, Ti     |
| Zizyphus jujube Mill.           | Jujube               | Rhamnaceae      | T/W      | Ed, Fu     |
| Clerodendrum viscosum Vent.     | Glory bower          | Lamiaceae       | S/W      | Med        |
| Glycosmis pentaphylla (Retz.) DC| Orangeberry          | Rutaceae        | S/W      | Ed, Med    |
| Hibiscus rosa-sinensis L.       | Hibiscus             | Malvaceae       | S/C      | Med, Or    |
| Lantana camara L.               | Lantana              | Verbenaceae     | S/W      | Com, Fu    |
| Murraya koenigii (L.)           | Curry leaves         | Rutaceae        | S/W      | Ed, Med    |
| Rosa sp                         | Wild rose            | Rosaceae        | S/W      | Med, Or    |
| Sesamum indicum L.              | Sesame,              | Pedaliaceae     | S/C      | Ed, Med    |
| Sida cordifolia L.              | Flannel weed         | Malvaceae       | S/W      | Com, Med   |
| Ageratum conyzoides L.          | Whiteweed            | Asteraceae      | H/W      | Med        |
| Aloe barbadensis (L.) Burm.f.    | Aloe                 | Liliaceae       | H/C      | Med        |
| Boerhavia diffusa L.            | Tarvine              | Nyctaginaceae   | H/W      | Med        |
| Cannabis sativa L.              | Hemp                 | Cannabaceae     | H/W      | Med        |
| Commelina benghalensis L.       | Spiderwort           | Commelinaceae   | H/W      | Fo, Med    |
| Cymbopogon citrates (DC.) Stapf | Lemon grass          | Poaceae         | H/C      | Med        |
| Cynodon dactylon (L.) Pers      | Grass                | Poaceae         | H/W      | Fo, Med, Re|
| Cyperus rotundus L.             | Grass                | Poaceae         | H/W      | Fo, Med    |
| Euphorbia hirta L.              | Asthma-plant         | Euphorbiaceae   | H/W      | Med        |
| Impatien balsamina L.           | Rose balsam          | Balsaminaceae   | H/W      | Or         |
| Ipomoea purpurea (L.) Roth      | Morning glory        | Convolvulaceae  | H/W      | Med        |
| Mentha arvensis L.              | Wild mint            | Lamiaceae       | H/C      | Ed, Med    |
| Mentha piperita L.              | Pipermint            | Lamiaceae       | H/C      | Ed, Med    |
| Mentha spactica L.              | Mint                 | Lamiaceae       | H/C      | Ed, Med    |
| Mimosa pudica L.                | Touch me not         | Mimosaceae      | H/W      | Med        |
| Musa paradisica L.              | Banana               | Musaceae        | H/C      | Ed, Re     |
| Ocimum sanctum L.               | Holi basil           | Lamiaceae       | H/C      | Re, Med    |
| Oxalis corniculata L.           | Creeping woodsorrel  | Oxalidaceae     | H/W      | Med        |
| Papaver somniferum L.           | Opium                | Papaveraceae    | H/C      | Med        |
| Polygonon nepalensis Meissn.    | Smartweed            | Polygonaceae    | H/W      | Med        |
| Saccharum officinarum L.        | Sugar cane           | Poaceae         | H/C      | Com, Ed, Re|
| Solanum nigrum L.               | Wonder berry         | Solanaceae      | H/W      | Med        |
Energy Budgets in Agroecosystems

The demand for bioenergy is accelerating drastically day by day due to huge increase in population pressure\(^\text{31}\). Average annual energy input consumption in agroforestry system (103,646 MJ/ha) was approximately three times more compared to home gardens (43,056 MJ/ha). The energy input in term of human and bullock labour is important in the agroecosystem of any region\(^\text{42}\). 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\(^\text{14,35,36}\) and less than as reported for Garhwal Himalaya\(^\text{43}\). Average annual energy output from agroforestry was 43,4117 MJ/ha compared to 57,008 MJ/ha in home garden. In a study 27,491 MJ/ha gross annual energy output was reported from agroecosystem\(^\text{35}\), 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   | Home      | Agrofor   | Home      | Agrofor   | Home      | Agrofor   | Home      |
|                     | System    | Garden    | System    | Garden    | System    | Garden    | System    | 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              | 102,135   | 41,631    | 105,340   | 42,562    | 108,865   | 30,324    | 79,165    | 52,553    |
| Total input         | 107,773   | 42,976    | 111,807   | 44,542    | 112,960   | 31,324    | 82,045    | 53,385    |
| Out put             |           |           |           |           |           |           |           |           |
| Food grains         | 87,958    | 526       | 77,679    | 381       | 61,195    | 551       | 267,511   | 1651      |
| Vegetables          | -         | 28,504    | -         | 24,504    | -         | 19,496    | -         | 25,925    |
| By products         | 6439      | 8122      | 10,348    | 19,154    | 6745      | 11,777    | 786       | 19,161    |
| Fuel wood           | 66,807    | 11,345    | 25,587    | 17,374    | 18,825    | 11,728    | 25,349    | 12,297    |
| Grass fodder        | 82,277    | 2954      | 74,665    | 31,72    | 73,735    | 3226      | 22,344    | 6786      |
| Total output        | 243,121   | 51,450    | 41,8563   | 64,854    | 330,647   | 46,178    | 74,4136   | 65,820    |
| Net return          | 135,348   | 84,74     | 30,6755   | 20,042    | 217,687   | 14,854    | 66,4970   | 12,097    |
| 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\textsuperscript{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\textsuperscript{43,45,46} while in other study reported a little bit high range (1.57-4.14) for home garden system\textsuperscript{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\textsuperscript{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  | Output | Ratio | Input  | Output | Ratio | Input  | Output | Ratio | Input  | Output | 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** | ±12.56 | ±195.80 | ±1.84 | ±20.80 | ±233.16 | ±1.36 | ±11.40 | ±103.20 | ±1.22 | ±15.56 | ±286.31 | ±2.14 |
| **Vegetable crops**         |        |        |       |        |        |       |        |        |       |        |        |       |
| Fresh vegetables            | 7      | 120    | 17.14 | 10     | 100    | 10    | 8      | 70     | 10    | 120   | 12     |       |
| Tubers                      | 15     | 60     | 4     | 20     | 75     | 3.75  | 12     | 50     | 4.17  | 30    | 150    | 5     |
| Average of vegetable crops  | ±4.00  | ±30.00 | ±6.57 | ±5.00  | ±12.50 | ±3.12 | ±2.00  | ±10.00 | ±2.29 | ±10.00 | ±15.00 | 3.5   |
| **Fruit crops**             |        |        |       |        |        |       |        |        |       |        |        |       |
| Mango                       | 2000   | 2750   | 1.38  | 2500   | 4900   | 1.96  | 4000   | 10800  | 2.7   | 3200  | 11250  | 3.52  |
| Litchi                      | 1000   | 1200   | 1.1   | 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 | 1295.83 | 3.71  | 895    | 1644.17 | 3.51  | 1001.67 | 2603.33 | 4.73  | 1071.67 | 3456.67 | 5.11  |
| fruit crops                 | ±295.48 | ±357.91 | ±2.26 | ±389.29 | ±729.21 | ±1.93 | ±624.93 | ±1661.86 | ±2.57 | ±516.66 | ±1695.87 | ±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/ha35, which was much higher than studied home garden in the present study. The similar results were reported by another study36, 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 systems47,48,49.

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 production50,51,52,53,54,55.

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. 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|       |       |       |       |       |      |      |      |      |      |      |       |        |
| 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 |

*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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