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Agro-biodiversity and traditional agriculture practices in mountainous Kedarnath Valley, Garhwal Himalaya, India

Abstract

Traditional agriculture practice is the main occupation of people of the mountainous Kedarnath Valley. It is also source of income of majority of the families in Kedarnath Valley. The present study was focused on the collection of agriculture and horticulture data through field visits and various methods including questionnaire, personal interviews, direct interaction with the villagers and group discussion. A wide verity of cereals, millets, vegetables, pulses and fruits has been recorded from the Kedarnath Valley. Altogether, 14 plant species belonging to 13 genera and 6 families from cereals and millets crops, 36 plant species belonging to 28 genera and 13 families from vegetable crops, 12 plant species belonging to 8 genera and one family from pulses and 18 plant species belonging to 8 genera and 6 families from fruits have been recorded. Main agriculture crops in the Valley are paddy, finger millet, *barnyard millet, maize, wheat, barley, amaranatha, and vegetables, all types of pulses, oilseeds and fruits. Among vegetables, potato, carrot, onion, tomato, all types of leaf vegetables, pumpkin, brinzal, pea, ladyfinger, radish, garlic, ginger and* bitter gourd*. are grown widely. All varieties of fruits are also grown in the Valley. The main fruits are orange, malta (orange), plum, vilayati and local peach, apricot, lemon, mango and pear.* According to traditionally accepted criteria, agriculture land in the region is identified as irrigated locally known as *sera* or *Gangarh* and rainfed locally known as *Ukhar* or *danda*. The present study aims at discussing agro-biodiversity and traditional agriculture practices including cropping patterns harvesting seasons, production of crops, key problems of agriculture and suggesting some important measures for improving traditional farming system, which can promote sustainability, in terms food security and livelihood security.

Keywords: kedarnath valley, traditional agriculture practices, agro-biodiversity

Volume 4 Issue 2 - 2020

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Received: October 20, 2019 | **Published:** March 18, 2020

Introduction

Traditional agricultural practice is the most important occupation of the residents for their livelihood of the mountainous Kedarnath Valley. Local inhabitants are engaged in the production of cereal crops and livestock farming. In the Kedarnath Valley, horticultural practice is also carried out but its contribution in terms of land cover and productivity is very meagre. The farming system in the Valley has been very old, which is based upon the centuries old practices and carried out mostly on the narrow patches of the terraced fields. The main cereal crops are wheat, barley, paddy, millets, pulses and vegetables. The economic viability of these crops is insufficient even to meet the food requirement of the population, but these crops are appropriate for this ecologically fragile ecosystem. The scope for further development and modernization of agriculture practices is not viable due to the fragile ecosystem and precipitous slope. Therefore, the young generation has migrated to the cities of plains in search of higher education, private jobs, business and recruitment in National Army. Diversifying and increasing the livelihood options, other than biomass based production, will definitely increase the food security and livelihood security of the people of Kedarnath Valley.

The Indian Himalaya represents 18% of the India's land area. The Indian Himalaya occupies a special place in the mountain ecosystems of the world. This Valley is not only important from the point of view of climate and as a provider of life giving water to a large part of the Indian subcontinent; but it also harbours a rich variety of flora, permanent feature of agricultural base, human communities and cultural diversity.[1] Dispersed small settlements and terraced agricultural fields carved out of the hill slopes for increasing crops, with many versatile tree species growing predominantly on the boundaries of rainfed terraces, are typical features in the temperate area of Kedarnath Valley.

Agriculture is the mainstay of Kedarnath Valley economy. Majority of the population in this Valley lives in rural areas and depends primarily on agriculture and livestock based activities for their sustenance. The agricultural production system is restricted up to an altitude of 3,000 m asl as the high-altitude villages have a very harsh climate and a short agriculture season. Agriculture totally depends on monsoon. The climatic and geographic differentiations isolate the region from the rest of the world. Potato and kidney beans are the main crops of the highlands, which are grown between altitude of 1,700 and 2,400 m asl.[2,3]

Pande et al.,[4] studied agro-biodiversity of Kumaun Himalaya, India. Sharma et al.,[5] worked on cropping pattern and agricultural productivity of Pindar River basin, Garhwal Himalaya. Maikhuri et al.,[6] contributed on organic farming in Uttarakhand Himalaya, India. Sati[7] worked on systems of agriculture farming in the Uttarakhand Himalaya, India.

However, no base line data on agro-biodiversity and traditional agriculture practices in Kedarnath Valley are available. Kedarnath Valley is globally important for the presence of major Hindu Shrine of Kedarnath Temple dedicated to Lord Shiva. It is also very important for its altitudinal and temperature gradients. Therefore, an attempt has been made to present base line data on the agro-biodiversity and traditional agriculture practices of the Kedarnath Valley

Materials and methods

Study area

The Kedarnath Valley is located between the coordinates of latitude 30^{0}25'0" to 30^{0}45'0" N and longitude 78^{0}55'0" to 79^{0}20'0" E of Ukhimath tehshil in the Rudraprayag district of Garhwal Himalaya, Uttarakhand. The survey was conducted from lower altitude of 864 m above m.s.l to alpine meadow of Kedarnath-Tunganath (3,680-4,000 m above m.s.l). This study was carried out in 17 villages (Chandrapuri, Bhiri, Ukhimath, Sari, Karokhi, Ransi, Gaundar, Kabiltha, Kalimath, Guptkash, Narayanloti, Tarsali, Barasu, Sersi, Triyuginarayan, Tausi and Gaurikund) of Kedarnath Valley of Ukhimath tehshil (Figure 1). The Kedarnath Valley is in the district of Rudraprayag with an area of 1,248 km^2 including 248 villages with a total population of 87,024 including 42,614 males and 44,410 females.[8] The forest area of the Kedarnath Valley is rich in the species of Deodar (*Cedrus deodara*), Kail (*Pinus walichiana*), Oak (*Qurcus incana*, *Quercus leucotricophora*). Buransh (*Rhododendron arboretum)*, Thuner (*Taxus baccata),* Cheer *(Pinus rbullocksburghii*), Akhrot (*Junlans regia*) in the higher reaches. Kedarnath Valley is very rich in edible plant resources. Kedarnath Valley is also famous for alpine grasslands (*Bugyals)*. There are many beautifully carpeted rich *bugyals* (grasslands) near Kedarnath and Tunganath temples.

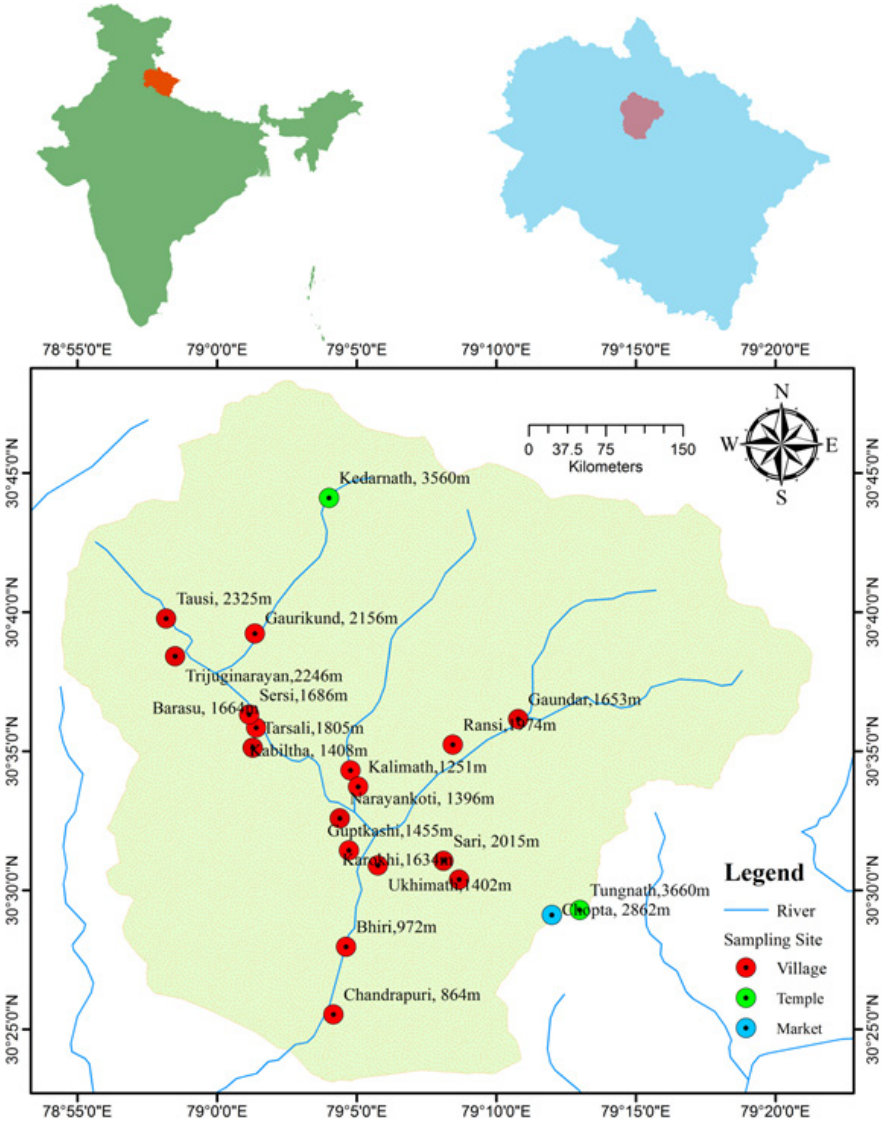

Figure 1 Location map of the study area: the Kedarnath valley.

Citation: Prasad C, Sharma RC. Agro-biodiversity and traditional agriculture practices in mountainous Kedarnath Valley, Garhwal Himalaya, India. *Biodiversity Int J.* 2020;4(2):90–101. DOI: 10.15406/bij.2020.04.00168

Methodology

The present investigation was carried out in seventeen villages of Kedarnath Valley. These villages were selected from Kedarnath Valley with a view obtain comprehensive information on traditional knowledge related with the crop diversity, agriculture practices and their management practices. The study was based on primary and secondary sources of data and analyses of these data. An in – depth survey was carried out in selected villages in the region to identify the priorities and perception of local farmers. Questionnaire, individual interviews and group discussion methods were used for the collection of data. A complete structural questionnaire was made at household level for each selected village, covering 410 households and personal interviews with local knowledgeable people. Farmers were interviewed to obtain information on traditional knowledge system. Individual contacts were made and questions were asked about traditional system in the village. Representation of women among the farmers was also ensured.

Results

Crop pattern in Kedarnath valley

The traditional agriculture of Kedarnath Valley exhibits a diversity in crop composition and crop rotation due to variations in temperature and altitude. The present study was conducted on the agriculture and horticulture practices including cropping and harvesting seasons (Tables 1a–1d). According to traditionally accepted criteria of agriculture land in the area, it is recognized as either irrigated, locally known as *Sera* or *Gangarh* or rainfed locally known as *Ukhar* or *danda* in Kedarnath Valley. Based on the location of the land, rainfed land is further divided into two types, below the village or lower part known as *Mullasari* and above the village or upper part, known as *Mallasari.*

Sera and *Ukhar* are the traditionally accepted categories of agricultural land in Kedarnath Valley. Generally four types of crops are grown within twelve months (November to October). These crops are:

a) Kharif Crops (April to October)

b) Rabi Crops (November to April)

c) Jayad Crops (April to October)

d) Mixed Crops (vegetables)

Jayad Crops like *Sagora* (Kitchen garden), waste land, side of cultivated land fields in the vicinity of homes are used for this purpose. The mixed crops are mainly vegetables. Mostly there are marginal farmers in the Valley whose average agriculture land represents about 0.135±0.04 to 0.471±0.242 ha/household. The average agriculture land holding is the highest in Gaurikund and lowest in Gaundar village.

Table 1a Agriculture crop (*Rabi* and *Kharif*) diversity of Kedarnath valley

Rabi Agriculture Crops				
Scientific name	**Name**	**Family**	**Sowing time**	**Harvesting time**
Brassica campestris L.	Mustard (*Pili sarson*)	Brassicaceae	September - October	May - June
Brassica nigra L.	Black mustard (*Sarson*)	Brassicaceae	September - October	May - June
Hordeum vulgare L.	Barley (*Jyo*)	Poaceae	September - October	May - June
Triticum aestivum L.	Wheat (*Genhu*)	Poaceae	September - October	May - June
Kharif agriculture crops				
Amaranaths paniculatus L.	Prickly Amaranth (*Cholai*)	Amaranathaceae	June - July	September - October
Arachis hypogaea L.	Groundnut (*Mungfali*)	Papilioniaceae	June - July	September - October
Echinochloa frumentacea Link	Barnyard Millet (*Jhangora*)	Poaceae	June - July	September - October
Eleusine coracana (L.) Gaertner	Finger Millet (*Manduwa*, *Koda*)	Poaceae	June - July	September - October
Foeniculum vulgare Mill.	Fennel (*Saunf*)	Umbelliferae	June - July	September - October
Oryza sativa L.	Rice (*Dhan*, *Chawal*)	Poaceae	June - July	September - October
Saccharum officinarum L	Sugarcane (*Ganna*)	Poaceae	June - July	September - October
Sesamum indicum L.	Sesame (*Til*)	Pediliaceae	June - July	September - October
Setaria italica (L.) P. Beauv.	Foxtail Millet (*Kauni*)	Poaceae	June - July	September - October
Zea mays L.	Maize (*Makka*)	Poaceae	June - July	September - October

Table 1b Vegetable crops diversity in Kedarnath valley

Scientific Name	Name	Family	Seedling Time	Harvesting Time
Abelmoschus esculentus (L.) Moench	Lady Finger *(Bhindi)*	*Malvaceae*	April - May	August- September
Allium sativum L.	*Garlic (Lahsun)*	*Liliaceae*	October - November	May-June
Allium sepa L.	Onion *(Pyaj)*	*Liliaceae*	October - November	May-June
*Allium spp.*L.	*Garlic (Lahsun)*	*Liliaceae*	October - November	May-June
Brassica juncea (L.) Czern.	Mustard Green (*Rai)*	*Poaceae*	March- April	June- July
Brassica oleracea L.	Cauliflower *(Phool Gobhi)*	*Brassicaceae*	March- April	July - August
Brassica oleraceavar caulorapa L.	Cabbage *(Band Gobhi)*	*Brassicaceae*	March- April	July - August
Brassica rapa L.	Turnip *(Shaljam)*	*Brassicaceae*	March- April	June- July
Brassica spp. L.	Mustard Green (*Hathi Kan Rai)*	*Poaceae*	March- April	June- July
Capsicum annuum L.	Red Pepper *(Mirch)*	*Solanaceac*	March- April	August- September
Capsicum annuum L.	*Cilli (Hari Mircha)*	*Solanaceac*	March- April	July - August
Capsicum annuum L.	Bell Papper *(Shimla Mirch)*	*Solanaceac*	March- April	July - August
Chenopodium album L.	Pigweed *(Bathwa)*	*Chenopodiaceae*	March- April	June- July
Colocasia esculenta (L.) Schott	Colocasia roots *(Arbi Pindalu)*	Araceae	May-June	November-December
Coriandrum sativum L.	*Coriander (Dhaniyan)*	*Apiaceae*	April-May	June- September
Cucumis sativus L.	Cucumber *(Kheera)*	*Cucurbitaceae*	March- April	July - August
Cucumis utilissimus L.	Cucumber *(Kakari)*	*Cucurbitaceae*	March- April	July - August
Cucurbita maximal Duchesne	Pumpkin *(Kaddu)*	*Cucurbitaceae*	March- April	July - August
Curcuma domestica L.	Turmeric *(Haldi)*	*Zingiberaecae*	March- April	June –February
Cyclanthera pedata (L.) Schrader	Kankoda	*Cucurbitaceae*	March- April	September - December
Cyclanthera spp. (L.) Schrader	*Bada Kankoda*	*Cucurbitaceae*	March- April	September - December
Daucus carota L.	Carrot *(Gajar)*	*Umbelliferaece*	March- April	June- July
Lagenaria siceraria (Molina) Standl.	Bottle Gourd *(Lonky)*	*Cucurbitaceae*	April-May	July-October
Luffa aegyptiaca Mill.	Ridge Gourd (*Ghia Torai)*	*Cucurbitaceae*	March- April	July - August
Lycopersicon esculentum L.	Tomato *(Tmater)*	*Solanaceac*	March- April	July - August
Mentha arvensis L.	Mint *(Podina)*	*Lamiaceae*	April - May	June- July
Momordica charantia L.	Bitter Gourd *(Karela)*	*Cucurbitaceae*	March- April	July - August
Pisum sativum L.	Pea *(Matar)*	*Papilioniaceae*	March- April	July - August
Raphanus sativus (L.) Domin	Radish *(Muli)*	*Poaceae*	March- April	June- July
Secale cereal L.	Mustard Green *(Rai)*	*Poaceae*	March- April	June- July
Solanum melongena L.	Egg Plant *(Bengan)*	*Solanaceac*	March- April	July - August
Solanum tuberosum L.	Potato *(Aaloo)*	*Solanaceac*	February-March	June- July
Spinacia oleracea L.	Spinach *(Palak)*	*Chenopodiaceae*	October - November	March - April
Trichosanthes anguina L.	Snake Gourd *(Chichinda)*	*Cucurbitaceae*	April-May	July- September
Trigonella foenumgraecum L.	Fenugreek leaves (*Methi)*	*Papilioniaceae*	December - January	April - May
Zingiber officinale Roscoe	Zinger *(Adarak)*	*Zingiberaecae*	April-May	November-December

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Table 1c Pulse diversity in Kedarnath valley

Pulses				
Scientific name	**Name**	**Family**	**Seedling time**	**Harvesting time**
Cajanus cajan (L.) Millsp.	*Taur*	Fabaceae	May - June	October - November
Dolichos lablab (L.) Sweet	Hyachinth Bean *(Seme)*	Fabaceae	June - July	October - November
Dolichos spp. (L.) Sweet	Nepali bean	Fabaceae	March - April	June - July
Glycine max (L.) Merrill	Soyabean *(Bhatt)*	Fabaceae	May - June	October - November
Glycine soja Siebold & Zucc.	*Kala Bhat*	Fabaceae	May - June	October - November
Lens culinaris Medikus	Lentil *(Masur)*	Fabaceae	October- November	April - May
Macrotyloma uniflorum (Lam.) Verdc.	*Gahet*	Fabaceae	May - June	October - November
Phaseolus vulgaris L.	Kideney Bean *(Sem bilayati, Razma)*	Fabaceae	April- may	July-August
Pisum sativum L.	*Mater*	Fabaceae	October- November	April - May
Vigna mungo (L.) Hepper	Black Gram *(Urad)*	Fabaceae	May - June	October - November
Vigna umbellate (Thunb.) Ohwi & H. Ohashi	*Reyans*	Fabaceae	April- May	October - November
Vigna umbellata (Thunb.)	*Cow Pea (Lobiya, Sonta)*	Fabaceae	May - June	October - November

Table 1d Fruits diversity in Kedarnath valley

Scientific name	**Common Name**	**Family**	**Flowering time**	**Harvesting Time**
Citrus aurantifolia (Christm.) Swingle	Lime (*Kaghzi*, *Nimbu*)	Rutaceae	April -May	November - December
Citrus aurantium L 1753	Orange (Narangi)	Rutaceae	April -May	November - December
Citrus hystrix DC	Zamir	Rutaceae	April -May	November - December
Citrus limon (L.) Osbeck	Lemon (*Pahadi Nimbu*)	Rutaceae	April -May	November - December
Citrus sinensis (L.) Osbeck	Orange (Malta)	Rutaceae	April -May	November - December
Citrus spp. (L.) Osbeck	Leman	Rutaceae	April -May	November - December
Mengifera indica L.	Mango (*Aam*)	Anacardiaceae	March-April	July-August
Musa paradisiacal L.	Banana*(Kela)*	Musaceae	January-February	June-July
Prunus amygdalus (Mill.) D.A.Webb	Almond (*Badam*)	Rosaceae	April -May	June - July
Prunus armeniaca L.	Apricot (*Chuli*)	Rosaceae	April -May	July - August
Prunus domestica L.	Plum	Rosaceae	April -May	June - July
Prunus persica (L.) Batsch 1801	Peach (*Aaru*)	Rosaceae	April -May	June - July
Prunus spp. (L.) Batsch 1801	Peach (*Vilayti Aaru*)	Rosaceae	April -May	June - July
Psidium guajava L.	Guava (*Amrud*)	Myrtaceae	April-May	July-September
Punica granatum L.	Pomegranate (*Aanar*)	Punicaceae	Junr-July	August-September
Pyrus melus Miller, 1768	Apple *(Seb)*	Rosaceae	April -May	August - September
Pyrus pyrifolia (Burm.) Nak,	Pear (*Naspati*)	Rosaceae	March-April	July-August
Syzygium cumin (L.) Skeels	Jambolan *(Jammun*)	Myrtaceae	April- May	June-July

The cropping pattern in Kedarnath Valley is divided into two major parts: *Rabi* (October - April) and *Kharif* (April-October). Wheat, Barley, Mustard, Lintels and Peas are the major crops of *Rabi* season; while *Kharif* season includes crops of Paddy, Finger millet, Barnyard millet, Foxtail millet, Maize and pulses. Generally three crops are grown in two years in rainfed area; while in irrigated land, two crops are grown in a year.

All across the Kedarnath Valley, the agricultural activities are performed by humen and bullock power. The role of women folk is so important that they are considered to be the back bone of the hill agriculture. These women folks perform operations ranging from field preparation, sowing, weeding, harvesting to threshing. The role of men folk is however confined to ploughing and maintenance work on agricultural fields. It has been observed that weeding (particularly during *Kharif* season) extracts about half of the total humen labour. Bullock is used in ploughing and rarely in thrashing activities of certain crops.

Crop productivity

The present study on agro-resources of Kedarnath Valley revealed that 14 plant species belonging to 13 genera and 6 families are of *Rabi* and *Kharif* crops. However, 36 plant species belonging to 28 genera and 13 families are of vegetables. 12 plant species belonging to 8 genera and one family are of pulses. 18 plant species belonging to 8 genera and 6 are families of fruits plants in the Kedarnath Valley (Figures 2&3).

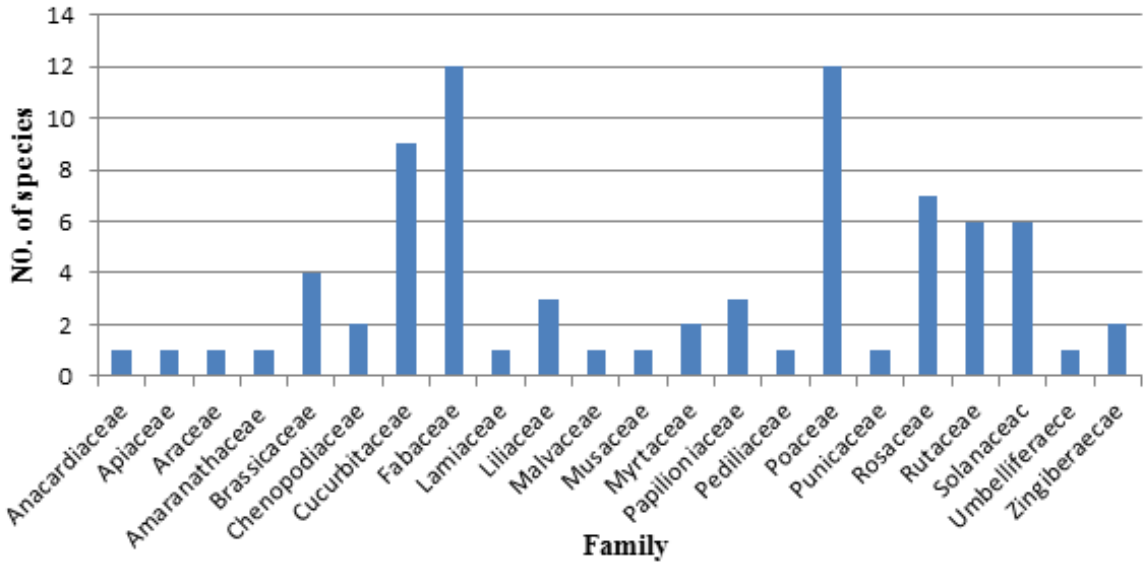

Figure 2 Number of plant species belonging to different families.

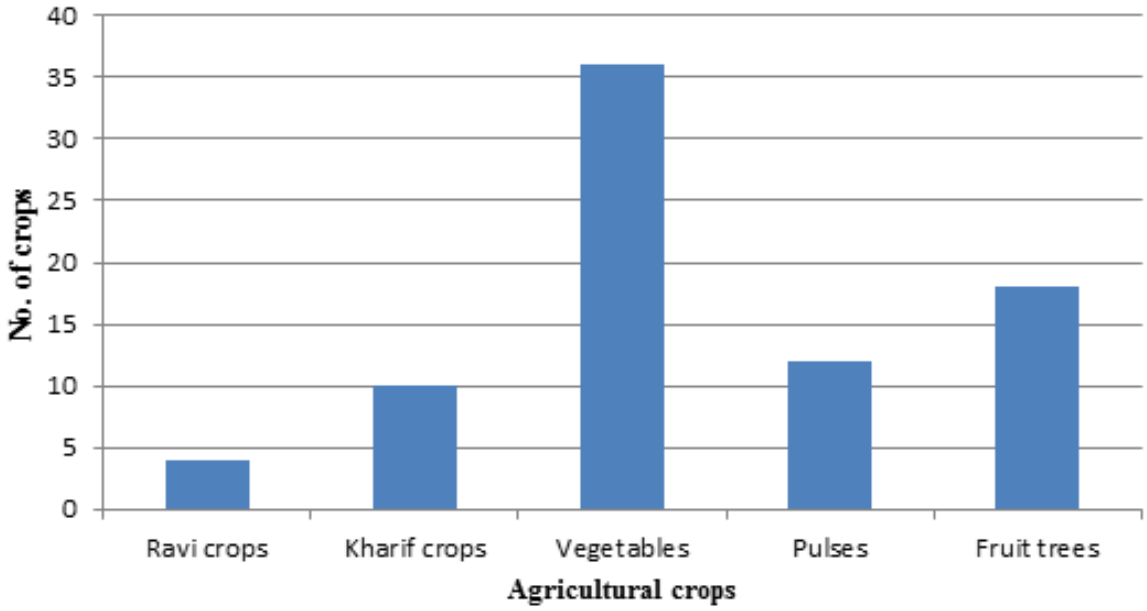

Figure 3 Utilization of plant species.

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Rabi and Kharif crops

The average yield of Wheat (*Triticum aestivum*) was recorded to be maximum (87.857±2.337 kg/household) in Bhiri villages and minimum (52.222±7.321 kg/household) in Sersi village. The yield of Barley (*Hordeum vulgare*) was maximum (74.706±50.388 kg/household) in Gaurikund village and minimum (43±5.712 kg/household) in Gaundar village. The productivity of Mustard (*Brassica campestris*) was maximum (50±9.574 kg/household) in Karokhi village and minimum (11.471±2.348 kg/household) in Gaurikund village. The yield of *Barnyard millet* (*Jangora*) (*Echinochloa frumentacea*) was maximum (122.353±60.67 kg/household) in Gaurikund village and minimum (55±7.071 kg/household) in Sersi village. Productivity of Finger Millet (*Manduwa*) (*Eleusine coracana*) was highest (125.294.386 kg/household) in Gaurikund village and minimum (52.222±7.321 kg/household) in Sersi village. The productivity of Sesame (*Til*) (*Sesamum indicum*) was maximum (12.577±2.194 kg/household) in Chandrapuri and minimum (6.462±1.664 kg/household) in Gaurikund. However, Garukund, Tausi, Trijuginarayan, Sersi, Barasu, Tarsali, Narayankoti, Guptkasi, Kalimath and Kabiltha have not seen cultivating Til crop. The productivity of Maize (*Zea mays*) was food to be maximum (23.269±3.726 kg/household) in Tausi village and minimum (7.462±2.213 kg/household) in Chandrapuri. The productivity of Rice, Paddy (*Oryza sativa*) was maximum (111.786±29.821 kg/household) in Bhiri and minimum (17.7±4.83 kg/household) in Tarsali. The productivity of *Prickly amaranth* (*Cholay*) (*Amaranaths paniculatus*) was maximum in Gaurikund villages (130±89.022 kg/household) and minimum in Chandrapuri villages (14.423±4.319kg/household). The productivity of *Kauni* (*Setaria italica*) was maximum (11.823±3.395 kg/household) in Bhiri and minimum (5.263±1.147 kg/household) in Karokhi. However, Gaurikund, Tausi, Trijuginarayan, Sersi, Barasu, Tarsali, Narayankoti, Guptkashi, Kalimath and Kabiltha do not cultivate *Kauni* crop (Table 2).

Vegetables

Farmers of Kedarnath Valley also grow a variety of vegetables in their fields. The most commonly grown vegetables in Kedarnath Valley are: Zinger (*Zingiber officinale*), Potato (*Solanum tuberosum*), Bitter Gourd (*Karela*) (*Momordica charantia*), Cucumber (*Pahadi kakari*) (*Cucumis utilissimus*), Pumpkin (*Cucurbita mexima*), Tomato (*Lycopersicon esculentum*), Ridge Gourd (*Giya torai*) (*Luffa aegyptiaca*) and Eggplant, Began (*Solanum melongena*) (Figure 4).

The average yield of Zinger (*Zingiber officinale*) was recorded to be maximum (12.15±4.99 kg/household) in Gaundar and minimum (2.17±2.40 kg/household) in Kabiltha. However, Gaurikund, Tausi, Trijuginarayan, Sersi, Barsu villages do not cultivate Zinger crop. The yield of Potato (*Solanum tuberosum*) was maximum (85.94±11.17 kg/household) in Trijuginarayan and minimum (7.5±8.66 kg/household) in Kabiltha. The productivity of Bitter Gourd (*Karela*) (*Momordica charantia*) was maximum (12.63±2.81 kg/household) in Chandrapuri and minimum (4.71±1.49 kg/household) in Narayankoti. The yield of Cucumber (*Pahadi kakari*) (*Cucumis utilissimus*) was maximum (29.38±8.54 kg/household) in Tarsali and minimum (4.65±1.01 kg/household) in Chandrapuri. Productivity of Pumpkin (*Cucurbita mexima*) was maximum (27.81±6.32 kg/household) in Tarsali and minimum (6.15±1.01 kg/household) in Chandrapuri The productivity of Cucumber (*Cucumis sativus*) was maximum (10.38±3.26 kg/household) in Chandrapuri and minimum (6.462±1.664 kg/household) in Guptkashi. The productivity of Cabbage (*Brassica oleraceavar*) was maximum (81.92±17.44 kg/household) in Narayankoti villages and minimum (6.46±1.10 kg/household) in Bhiri. The productivity of Cauliflower (*Brassica oleracea*) was maximum (40.38±8.11 kg/household) in Narayankoti and minimum (5.92±1.27 kg/household) in Bhiri. The productivity of Tomato (*Lycopersicon esculentum*) was maximum (20.77±3.92 kg/household) in Narayankoti and minimum (3.03±0.72 kg/household) in Chandrapuri. The productivity of Ridge Gourd (*Giya torai*) (*Luffa aegyptiaca*) was maximum (16.35±4.14 kg/household) in Narayankoti and minimum (1.56±1.78 kg/household) in Kabiltha. The yield of Spinach (*Spinacia oleracea*) was maximum (18.51±2.32houshold/bunch) in Trijuginarayan and minimum (3.16±4.19 bunch/household) in Kabiltha. The productivity of Onion (*Allium sepa*) was maximum (18.25±2.48 kg/household) in Bhiri and minimum (5.10±1.85 kg/household) in Karokhi. The yield of Mint (*Mentha arvensis*) was maximum (20.88±5.92 bunch/household) in Gaurikund and minimum (0.89±1.05 bunch/household) in Kabiltha. Productivity of Egg plant, *Began* (*Solanum melongena*) was maximum (13.08±3.19 kg/household) in Narayankoti and minimum (4.96±0.87 kg/household) in Chandrapuri. The productivity of Pigweed, (*bathwa*) (*Solanum melongena*) was maximum (38.13±7.50 househole/bunch) in Tarsali and minimum (2.58±2.77 bunch/household) in Kabiltha. The productivity of Lady Finger (*Abelmoschus esculentus*) was maximum (9.08±2.64 kg/household) in Gaundar and minimum (5.66±1.67 kg/household) in Ransi. The productivity of Red Paper (*Capsicum annuum*) was maximum (6.80±1.36 kg/household) in Gaundar and minimum (5.15±0.96 kg/household) in Chandrapuri. The productivity of Pea (*Pisum sativum*) was maximum (51.35±10.84 kg/household) in Trijuginarayan and minimum (4.61±0.94 kg/household) in Chandrapuri. The productivity of Radish (*Raphanus sativus*) was maximum (55.00±13.66 kg/household) in Tarsali and minimum (2.82±3.10 kg/household) in Kabiltha. The yield of Mustard Green (*Rai*) (*Brassica juncea*) was maximum (287.50±120.42 bunch/household) in Tarsali and minimum (3.16±4.19 bunch/household) in Kabiltha. The yield of Garlic (*Allium sativum*) was maximum (17.60±5.89 kg/household) in Gaurikund and minimum (2.47±2.55 kg/household) in Kabiltha. Productivity of Turnip *(Brassica rapa)* was maximum in Tarsali villages (12.50±5.00 kg/household) and minimum (4.37±2.39 kg/household) in Guptkashi. The productivity of Turmeric *(Curcuma domestica)* was maximum (14.42±1.45 kg/household) in Narayankoti and minimum (2.88±3.33 kg/household) in Kabiltha. The productivity of Fenugreek Leaves (*Methi)* (*Trigonella foenumgraecum*) was maximum (11.35±3.10 bunch/household) in Narayankoti and minimum (3.10±1.19 bunch/household) in Guptkashi. The productivity of *Kankoda* (*Cyclanthera pedata*) was maximum (52.50±15.28 kg/household) in Tarsali and minimum (4.97±6.17 kg/household) in Kabiltha. The productivity of *Bada Kankoda (Cyclanthera spp.)* was maximum (20.31±5.31 kg/household) in Tarsali and minimum (6.35±1.87 kg/household) in Narayankoti. The productivity of Chilii (*Capsicum annuum*) was maximum (12.25±3.89 kg/household) in Tarsali villages and minimum (1.22±1.61 kg/household) in Kabiltha. The productivity of Capsicum (*Simla mirch*) (*Capsicum annuum*) was maximum (15.7±5.26 kg/household) in Sersi villages and minimum (1.2±1.53 kg/household) in Kabiltha. The productivity of Coriander *(Coriandrum sativum)* was maximum (58.13±19.40 bunch/household) in Tarsali and minimum (4.57±1.28 bunch/household) in Chandrapuri. The productivity of Colocasia roots *(pindalu)* (*Colocasia esculenta*) was maximum (20±6.61 kg/household) in Gaurikund and minimum (1.04±1.31 kg/household) in Kabiltha. The productivity of *Beans* (*Dolichos lablab*) was maximum (41.25±12.71 kg/household) in Tarsali and minimum (2.72±3.43 kg/household) in Kabiltha. The productivity of Bottle Gourd (*louki*) was maximum (13.71±2.91 kg/household) in Bhiri and minimum (6.00±1.31 kg/household) in Tarsali. However, three

new crops were reported from Tausi, Trijuginarayan, Sersi, Barasu, Tarsali, Narayankoti and Ransi Village. *Hathi Kan Rai* new crop has been reported from Tarsali village. It's leaf shape is bigger than other normal *Rai*. Second crop is *Bada Kankoda*, which is collected in Tausi, Trijuginarayan, Sersi, Barasu, Tarsali, Narayankoti and Ransi. It is also big size in comparison to normal *Kankoda*. Third crop is Garlic, its leaves and roots are bigger than normal Garlic. Now days, some of the families sell their vegetables in the nearby market. The average annual income generated from vegetables was maximum in village Narayankoti (Rs.21,730.77±5,280.59/ annum) followed by Tarsali (Rs.13,625.00±3,304.04/annum), Sersi (Rs.10,611.11±12,710.06/annum), Barasu (Rs.6,500.00±3,696.85/ annum), Ransi (Rs.5,400.00±1,443.37/annum), Guandar (Rs.4,850±1,469.87/annum) and minimum in village Trijuginarayan (Rs.3,743.243±1,018.04/annum) (Tables 3a&3b).

Pulses

The wide varieties of pulses are cultivated in Kedarnath Valley. Most of them are cultivated organically (Figure 4). The important pulses grown in the Kedarnath Valley are *Masur* (*Lens culinaris*), Hyachmth Bean (*Sem*) (*Dolichos lab lab*), Kidney Bean, *Razma* (*Phaseolus vulgaris*), Black Gram (*Vigna mungo*), *Soyabean* (*Glycine max*), *Gahet* (*Macrotyloma uniflorum*), *Kala Bhatt* (*Glycine soja*), *Taur* (*Cajanus cajan*) and *Lobiya* (*Vigna umbellata*). The average yield of *Masur* (*Lens culinaris*) was estimated to be maximum (11.17±2.71 kg/household) in Sarifollowed by Karokhi (10.28±2.89 kg/household), Ransi (6.16±2.08 kg/household) and minimum (4.4±1.57 kg/household) in Gaundar. The yield of Hyachmth Bean (*Sem*) (*Dolichos lablab*) was maximum (16.95±5.58 kg/household) in Sari and minimum (8.44±1.91/ kg/household) in Guptkashi. However, Bhiri and Chandrapuri villages do not cultivate *Sem*. The productivity of Kidney Been, *Razma* (*Phaseolus vulgaris*) was maximum (20.50±3.94 kg/household) in Gaundar and minimum (9.95±3.33 kg/household) in Kalimath. However, Bhiri and Chandrapuri people do not cultivate Kidney Bean. The yield of Black Gram (*Vigna mungo*) was maximum (11.92±2.81 kg/household) in Bhiri followed by Chandrapuri (11.84±2.78 kg/household), Karokhi (7.16±2.24 kg/household), Sari (5.95±1.94 kg/household), Ransi (4.2±1.26 kg/household) and minimum (2.75±0.97 kg/household) in Gaundar. However, other villages are not cultivating Black Gram. Productivity of *Soyabean* (*Glycine max*) was maximum in Chandrapuri (27.70±2.55 kg/household) and minimum (9.72±1.40 kg/household) in Karokhi The productivity of *Gahet* (*Macrotyloma uniflorum*) was maximum (10.50±2.657 kg/household) in Chandrapuri followed by Bhiri (10.25±2.78 kg/household), Sari (6.34±1.61 kg/ household), Karokhi (6.28±1.40 kg/household), Ransi (5.04±1.57 kg/household) and minimum (3.35±1.14 kg/household) in Gaundar. However, other villages do not cultivate *Gahet*. The productivity of *Rayans* (*Vigna umbellata*) was maximum (13.077±4.09 kg/ household) in Chandrapuri followed by Bhiri (13.03±4.15 kg/ household), Trsali (5.47±1.19 kg/household), Barasu (6.17±1.37 kg/household) and minimum (3.05±1.08 kg/household) in Sersi. However, other villages do not cultivate *Reyans*. The productivity of *Kala Bhatt* (*Glycine soja*) was maximum (23.00±1.10 kg/household) in Gaundar and minimum (6.50±1.55 kg/household) in Tarsali. The productivity of *Taur* (*Cajanus cajan*) was maximum (25.00±6.48 kg/ household) in Chandrapuri and minimum (4.91±1.72 kg/household) in Trijuginarayan. The productivity of *Lobiya* (*Vigna umbellata*) was maximum (12.05±2.80/ kg/household) in Kalimath and minimum (5.16±0.34 kg/household) in Karokhi. However, Ukhimath, Bhiri and Chandrapuri are not cultivating *Lobiya* (Table 4).

Fruits cultivation

Horticulture sector may contribute to the rural economy of the Kedarnath Valley. It offers much desired opportunity for diversification and increased employment options in the Valley, where scope of expansion of conventional agriculture is rather restricted due to weired topography and majority of scattered and marginal holdings. Horticulture expansion can become an effective tool for accelerating development in the area through enhancing the income of farmers outside the subsistence level. For acceleration of horticulture, the area under horticulture fruit trees can be increased by the utilization of cultivable wastelands and the land belonging to truant landowners. Apple, banana, Almond, Guava, Pomegranate, *Orange, Malta (Orange), Plum, Vilayati and Local Peach, Apricot, Lemon, Mango and pear* are the important horticulture fruit trees of the Kedarnath Valley (Figure 4). Many minor fruits are also grown in the area. Value addition of citrus and other fruits provide a significant income to the deprived households. The average production of *Malta* (*Citrus sinensis*) was estimated to be maximum (290.77±86.76 kg/ household) in Tarsali followed by Sersi (275±66.97 kg/household), Barsau (268.06±88.76 kg/household) and minimum (255.77±90.91 kg/household) in Narayankoti. The yield of *Aaru* (*Prunus armeniaca*) was maximum (90±14.14 kg/household) in Tarsali followed by Narayankoti (57.69±14.23 kg/household) and minimum (50±6.32kg/ household) in Sersi. The Plum (*Prunus domestica*) is cultivated (60±20 kg/household) in Tarsali only. Presently, about 19% of families of villages sell these *Malta, Aadu* and Plum (Figure 5), at the rate of *Malta* (Rs. 10kg/household), *Aadu* (Rs. 20 kg/household) and Plum (Rs. 20 kg/household). They earn an average of Rs. 1,380.56±426.16/ annum to Rs.1,909.62±788.29/annum. The annual income generation from fruits was highest (Rs.1,909.62±788.29/annum) in Narayankoti followed by Sersi (Rs.1,733.33±602.93/annum), Tarsali (Rs.1,573.07±663.20/annum) and minimum (Rs.1,380.56±426.16/ annum) in Barasu (Table 5). Some families do not sell their fruits in the market and their families have these fruits for self-consumption only due to low production.

Table 5 Production (Kg/household) of fruits in Kedarnath valley

Household	*Citrus sinensis (Malta)* kg/ household	*Prunus persica (Bilayati aaru)* kg/household	*Prunus domestica (Plum)* kg/household	Annual Income Rs/annum
Sersi	275±66.97	50±6.32	-	1733.33±602.93
Barasu	268.06±88.76	-	-	1380.56±426.16
Tarsali	290.63±86.06	90±14.14	60±20	1573.077±663.204
Narayankoti	255.77±90.91	57.69±14.23	-	1909.62±788.29

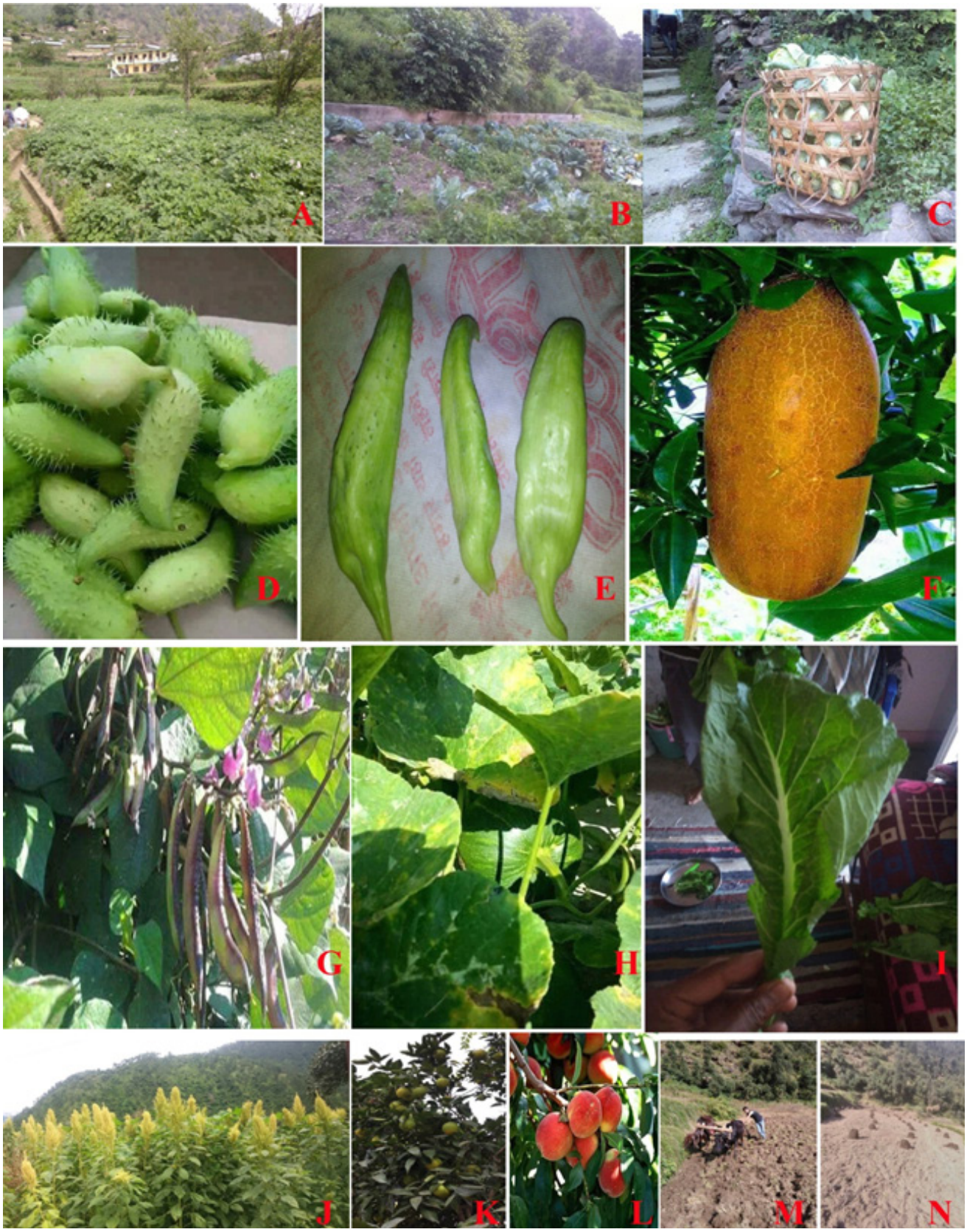

Figure 4 A. *Solanum tuberosum*, B, C. *Brassica oleraceavar caulorapa*, D. *Cyclanthera pedata*, E. *Cyclanthera spp.*, F. *Cucumis utilissimus*, G. *Dolichos lablab* , H. *Cucurbita mexima(kadu)*, I. *Brassica spp.*, J. *Amaranaths paniculatus*, K. *Citrus sinensis*, L. *Prunus spp.* M. Field Ploughing, N. Cow dung.

Citation: Prasad C, Sharma RC. Agro-biodiversity and traditional agriculture practices in mountainous Kedarnath Valley, Garhwal Himalaya, India. *Biodiversity Int J.* 2020;4(2):90–101. DOI: 10.15406/bij.2020.04.00168

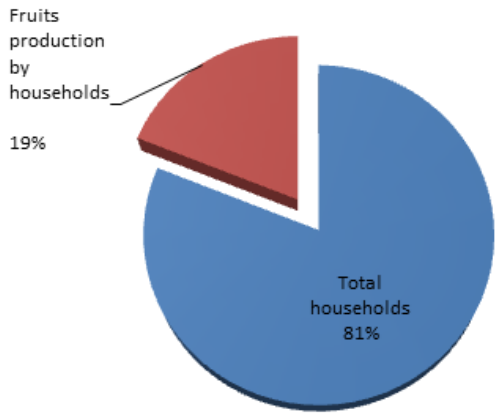

Figure 5 Fruits production by households in Kedarnath valley.

Soil fertility

Various traditional methods are practiced in the Kedarnath Valley in order to maintain the fertility of agriculture soil after each crop harvest. Decomposed animal dung, bedding leaves, urine and leftover feed) are the most important and common techniques practiced for maintaining the soil fertility throughout the Valley. In this regard, the crops grown in the irrigated land are given more priority by the farmers than rainfed crops. As far as the quality of manure is concerned, it primarily depends on the type of bedding leaves (organic resources), quantity of dung and the state of decomposition at the time of its practices, which enables the agriculture soil to recuperate after successive crop harvests after fallowing of the land for certain period. Mixed cropping particularly raising leguminous crops with cereals and millets are practiced. Leguminous pods are harvested after maturity and the entire plants are ploughed and covered by the soil for converting into manure.

There is a specific traditional practice for enhancing the soil fertility of the agricultural fields in the Kedarnath Valley. This practice is locally known as '*Goat'*. Under this system, cattle herders are requested to get their hundreds of goats and sheeps to stay in the fallow land for a week or so. Thus, the dung and the urine of the cattle are mixed with the soil, contributing to the enhancement of fertility. After this, these goats and sheeps are shifted to another piece of fallow land for staying for another week or so. This traditional system is very popular in the Kedarnath Valley.

Irrigation

The sources of irrigation in Kedarnath Valley are mainly springs, *gads, gadheras* and rivers. The spring water, which, flows through the *gads* and *gadheras*, is taken to the fields through small irrigation channels known as *Guhls* or *Kuhls* developed by the community or the Minor Irrigation Department of the state government. Farmers also make small dug out ponds (*dhab)* in Kedarnath Valley for harvesting rain water. This stored rain water is used for irrigation during lean period.

Integrated farming

The main characteristics of the agriculture of Kedarnath Valley are the integrated farming or agropastoralism. Integrated mountain agriculture includes crop cultivation and rearing of cattle simultaneously. The livestock converts leaves from the forest into manure for cropland and also provides draught power for ploughing land. The farmers in Kedarnath Valley rear cows, bullocks, buffaloes, sheep and goats, horses and mules.

India has already established its leadership in different sectors of information and communication technology and engineering but the present challenge is how to sustain the economic prosperity, particularly in remote rural areas. Therefore, rural development in the country requires priority, because more than 65% of the population is still living in villages and over 85% of the rural people are dependent on agriculture for their livelihood. (Figure 4).[9]

Crop yield is very low in hills as compared to that in plains.[10] The hilly areas are comparatively infertile land with poor irrigation facilities, difficulties in using modern technology, and little use of modern inputs and this is because of both their unsuitability and non-availability.

Discussion

The crop biodiversity contributes in a variety of ways in maintaining agroecosystem stability and resilience.[11] The Garhwal Himalaya is well known as a repository of many crop species, vegetables and pulses.[12] The abrupt seasonal variability, unscientific change in the cropping patterns and change in the food habits of the inhabitants have contributed to the decline of natural agro-resources base in the Kedarnath Valley. However, the traditional crops are well adapted in the local environmental conditions and possess the inherent qualities to withstand the sudden outbreak of diseases, pests and natural hazards.

Farmers in Kedarnath Valley use manure (leaf litter mixed with livestock excreta) acceptable worldwide. Croplands with low productivity and depleted soil organic carbon do exist, more so in the foothill region.[13] In the high hills, low productivity and depleted agricultural soils are an outcome more of casual cultivation (due to labour shortage arising from outmigration and increasing tendency of viewing farming-based livelihoods as inferior to the secondary/ tertiary sector based ones) over the past few decades rather than any inherent biophysical stresses.[14,15]

Sharma et al.,[16] studied cropping pattern and agricultural productivity of Pindar River basin, Garhwal Himalaya. Many other workers also contributed on the system of agriculture faming, organic farming, hill agriculture, challenges and opportunity of agro biodiversity and agroforestry mapping from the different parts of the Uttarakhand.[4,6,7,16–19]

Mixed crop-livestock systems may have the potential to maintain an ecosystem's healthy functioning and enable it to absorb not only the shocks to the natural resource base.[20,21] In the Garhwal region, the farming community has responded to the changing consumption patterns of consumers by diversifying its production towards high-value food commodities. Experiences from many developing countries have revealed about the changing production at the farm level due to altering dietary patterns.[22,23] As economies grow, there is a gradual movement out of subsistence food-crop production to a diversified market-oriented production system.

Divers of degradation and depletion of agriculture

Inability of farming to satisfy the needs such as quality education, health and comforts

Small and fragmented land holdings, low crop yields due to water and nutrient stresses, lack of policies protecting farmers from

exploitation and uncertainty in the monetary market, lack of policies promoting local crop storage, value-addition and marketing capacity, Lack of quality social infrastructure (health, education and comforts) around rural areas are the drivers of agriculture depletion.

Wild animal damaging agriculture and horticulture

Wild animals are the biggest threat to agriculture and horticulture farming in Kedarnath Valley. The wild boar, bear, deer, sola, monkey, languor and nilgai damage to agricultural crops and fruit plants every year, which directly affects the local people and their livelihood.

Lack of effective innovations enabling reduction in labor and time inputs in farming

Limited local innovation capacity, neglect of hill specificities in conventional agricultural research and development programmers, are some of impediments in poor development of hill agriculture.

Inability to realize the potential benefits from traditional farming

Weakening of traditional institutions, damaging crops and livestock by wildlife restricted access to areas rich in high quality leaf litter (a constituent of manure) and fodder, low inputs in traditional organic farming, the supply of food grains at subsidized price, and secured income from employment in government schemes are also some of the drivers for poor development hill farming.

Sustainable development of agriculture in Kedarnath Valley

The agro-biodiversity is very rich in Kedarnath Valley. Due to high altitudinal and temperature gradients and varied climate conditions, desired agriculture production is not achieved. The above said drivers also contribute for the poor development of agriculture in this important Valley. The following suggestions are given for the sustainable development of agriculture in Kedarnath Valley:

- Traditional crops and practices should be maintained in the Kedarnath Valley. Any intervention or changes in these crops can lead to ecological imbalance.
- In Kedarnath Valley, wild animals cause great damage to crops. The government should make such policies, which can prevent wild animals from damaging agriculture, and increase agriculture production.
- The Valley is highly landslide prone region. The landslide zones should be planted by fodder and fruit tress which are economically viable and environmentally sound.
- The agroforestry should be promoted in the Valley, thereby preventing landslides in agricultural land.
- In the Valley, along with agriculture, tea plantation, herbal culture and floriculture should be encouraged, which can help in improving the livelihood of the farmers.
- Cash crops including vegetables, pulses and oilseeds can be produced in a bigger way keeping in view the climate and terrain of the Valley.
- Seeds of the traditional crops should be conserved in the gene bank and research center of the state.
- The people of the Valley should be encouraged for the promotion of traditional crops which are most suitable and adapted to the environment of the Valley.

Conclusion

It has been concluded from the present study that the agriculture along with the horticulture sector is considered as a major source of earning in the villages in the Kedarnath Valley. The present study revealed that the scope of cultivation of fruits, off-season vegetables, medicinal plants and collection of non-timber based forest products are very vast. It is recommended that the most promotion of these activities will definitely give a base for sustainable livelihood of the people in the area. The present study revealed a rich agro-biodiversity in Kedarnath Valley including 14 species belonging to 13 genera and 6 families of cereals and millets 36 species belonging to 28 genera and 13 families of vegetables, 12 species belonging to 8 genera and 1 family of pulses and 18 species belonging to 8 genera and 6 families of fruits in Kedarnath Valley. Main agriculture crops were paddy, finger millet, barnyard millet, maize, wheat, barley, amaranatha, common vegetables and all types of traditional pulses and fruits. Among vegetables, potato, carrot, onion, tomato, all types of leaf vegetables, pumpkin, brinzal, pea, ladyfinger, radish, garlic, ginger and karela were grown widely. All varieties of fruits are grown in the Valley. The main fruits grown are orange, malta, plum, vilayati and local aaru, chuli, lemon, mango and naspati. Agriculture alongwith horticulture sector plays a vital role in economy of the Valley. Agriculture crops and horticulture fruits are supplementing the nourishment of the people in the Kedarnath Valley.

Acknowledgments

Authors are thankful for the local people of the Kedarnath Valley for sharing their valuable knowledge and help in data collection. One of the authors (Chandi Prasad) thankfully acknowledges the University Grants Commission, New Delhi and H.N.B. Garhwal University (A Central University) for providing University fellowship for undertaking the present work.

Conflicts of interest

No conflict of interest was reported by the authors.

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