Nature Environment and Pollution Technology
An International Quarterly Scientific Journal

p-ISSN: 0972-6268
(Print copies up to 2016)
e-ISSN: 2395-3454

Vol. 20 | No.3 | pp. 923-939 | 2021

Original Research Paper

https://doi.org/10.46488/NEPT.2021.v20i03.002

Open Access Journal

Ethnobotanical Study and Plant Diversity in the Forest of Kedarnath Valley, Garhwal Himalaya, India

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Nat. Env. & Poll. Tech.
Website: www.neptjournal.com

Received: 28-07-2020
Revised: 14-09-2021
Accepted: 15-10-2020

Key Words:
Forest resources
Kedarnath valley
Dominant species
Total basal area

ABSTRACT

The present study was carried out in the forest of Kedarnath valley in Garhwal Himalaya. The aim of the study was to access the diversity status and ecological status. The study was conducted following the stratified sampling techniques by placing quadrates (1m×1m) for herbs, (5m×5m) for shrubs, and (10m×10m) size for trees in the forest area. A total number of 221 plant species were recorded during the floristic survey in the project area. Plant diversity of the project area encompasses 49 species of trees, 28 species of shrubs, and 144 species of herbs. Important value index, the Shannon diversity index, and total basal area species were recorded. The tree density in the present study was highest in the Kedarnath valley which ranged from 0.3 to 8.5 no./ha. Shrub density in the present study varied from 0.4 to 13.5 no./ha, whereas herb density ranged between 0.2 to 22.4 no.ha^{-1}. Total basal cover (TBC) for trees showed a range of 9.542 to 0.075 m^2.ha^{-1}, and the Shannon diversity index ($\overline{H}$) for tree species was recorded from a minimum of 0.976 to a maximum of 3.048. The horrific disaster in the Kedarnath valley in 2013 caused a lot of damage to the bugyals (High altitude grass) and forests of the valley. About 500 species of vesicular medicinal plants, fodder plants, and other important plant species were washed away (Botanical Survey of India 2015). The current study is a pioneer in the aspect and can be helpful in making district forest plans, protocols, and implementation of forest policy to protect the forest by local people.

INTRODUCTION

Forest plays a vital role in the sustenance of the Himalayan ecosystem. The mountain people are directly dependent on forest resources for food, firewood, fodder, and timber. Mountain forests are rich in biodiversity and are distributed according to different elevations and slopes. Forest also plays an important role in providing habitat for wildlife. The Kedarnath valley is an important upper stretch of the Ganga River system in the Uttarakhand Himalaya. Characterized by rugged, rough, and precipitous slopes, the entire valley is very prone to landslides, mass wasting, landslips, and slope failures.

The climate and vegetation of Uttarakhand vary greatly with different altitudes, from a glacier at a high altitude of 7,817 m asl. to a subtropical forest at lower altitudes. The high altitude region is covered by ice and bare rock. The annual rainfall is 1,550 mm and the average annual temperature ranges between -8°C to 25°C. The human population density of the state is 189 persons per km^2, which is lower than the national average of 382 persons per km^2 (Census 2011). According to the 19th Livestock Census (2012), 4.79 million livestock population has been reported in Uttarakhand. The climate is subtropical in the south and temperate in the north. The climate remains cool in the middle zone of the state (Srivastava & Singh 2005). The state represents one of the four high diversity states of the Indian Himalayan region with about 4,248 species of Angiosperms and 18 species in Gymnosperms (Srivastava & Singh 2005).

The Uttarakhand area has been a major site plant exploration since 1796 when Thomas Hardwicke collected plants from the Alaknanda Valley of Garhwal Himalaya. By the beginning of the 21st century, a large number of plant collectors have explored the area and a great deal of information was available about the flowering plants of this area. Based on these collections, floristic reports, and their own collections, Uniyal et al. (2007) compiled a checklist of flowering plants of Uttarakhand as baseline data for writing the flora of Uttarakhand. This valuable document suggests the presence of nearly 4,700 species of flowering plants, including 32 species of Gymnosperms and a few cultivated species. Kimothi et al. (1989) studied some medicinal plants of the Gopeshwar-Tungnath region of Uttar Pradesh. Negi et al. (2008) worked on the inventory of species richness of Panchayat forests and adjoining reserve forests in three dis-

tricts of Garhwal Himalaya, India. Kumar (2009) identified major religious plants of Rudraprayag district (Garhwal), Uttarakhand (India). Semwal et al. (2010) studied medicinal plants used by local Vaidyas in Ukhimath block, Uttarakhand, India. Ballabha et al. (2013) studied community structure and plant diversity of community-based religious conserved forest of Garhwal Himalaya, India. Pala et al. (2016) worked on community structure and plant diversity of community-based religious conserved forest of Garhwal Himalaya, India. Nautiyal et al. (2017) studied the exploration of some important fodder plants of the Joshimath area of the Chamoli district of Garhwal, Uttarakhand. Singh et al. (2017) studied ethnomedicinal plants used by local inhabitants of Jakholi block, Rudraprayag district, western Himalaya, India. Prasad and Sharma (2018) studied wild edible plant resources of Kedarnath valley, Garhwal Himalaya, Uttarakhand.

The state of Uttarakhand is an important part of the Himalayas. Uttarakhand covers an area of 1.63% of the geographical area of India. The forest cover of Uttarakhand is 24, 295 km^2 which is 45.43% of the state's geographical area. In the term of forest canopy density classes, the state has 4,969 km^2 under very dense forest, 12,884 km^2 under moderately dense forest; and 6, 442 km^2 under open forest (FSI 2017). The forest in Uttarakhand is divided into sixteen types (FSI 2017), which are characterized by Northern Tropical Dry Deciduous Forests (Dry Sal-bearing Forest and Dry Plain Forest), Himalayan Sub-tropical Pine Forests (Himalayan Chir-pine and Sub-tropical Scrubs and Euphorbia Scrub), Himalayan Moist Temperate Forests (Lower Western Himalayan Temperate and Upper West Himalayan Temperate Forests), Himalayan Dry Temperate Forest (Dry Temperate Coniferous and West Himalayan Dry Juniper Forest), Sub-alpine Forests (West Himalayan Birch/Fir Forest and Pastures) and Moist and Dry Alpine Scrub Forests.

MATERIALS AND METHODS

Study Area

The Kedarnath valley is located between the coordinates of latitude 300‘25°” to 300‘45°” N and longitude 780‘55°” to 790‘20°” E of Ukhimath tehsil in the Rudraprayag district of Garhwal Himalaya, Uttarakhand. The survey was done from a lower altitude of 864 m above m.s.l to the alpine meadow of Kedarnath-Tunganath (3,680-4,000 m above m.s.l). This study was carried out in nine study sites of Kedarnath valley of Ukhimath tehsil (Fig. 1), their locations, geographical coordinates, and elevations have been presented in Table 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 (Census of India 2011).

Data Collection

Information regarding the plant biodiversity, economically important plants, fruits and fodder plants and medicinal plants were collected. Field visits were made for the collection of plants and also to collect information on the biodiversity of the area. Plants were identified by the villagers, and scientific validation of these plants was made by the Himalayan Herbarium, Department of Botany and High Altitude Plant Physiology Research Center (HAPPRC), H.N.B. Garhwal University (A Central University), Srinagar-Garhwal. Relevant uses of these plants were also collected from different literature.

Plant biodiversity analysis was carried out during the study period when the majority of the plants were at the peak of their growth. In every study site, 10 transects of 10 m × 10 m (100 sq m) size was randomly laid to study tree species and 10 quadrates of 5m × 5m (25sq m) size were randomly laid to study shrub species. The herbaceous species was studied by laying 10 quadrats of 1m × 1m (1sq m) size randomly in each study site.

Quantitative Analysis

The important quantitative analysis such as density, frequency, and abundance of tree species, shrubs and herbs species were determined as per Gates (1949), Curtis and Mc-Intosh (1950), Misra and Puri (1954), Curtis (1951), Phillips (1959), Misra (1969), Mullar-Dombois and Ellenberg (1974).

Density:

$$\text{Density} = \frac{\text{Total number of individuals of a species in all quadrats}}{\text{Total number of quadrats studied}}$$

(b) Frequency (%):

$$\text{Frequency (\%)} = \frac{\text{Number of quadrats in which the species occurred} \times 100}{\text{Total number of quadrats studied}}$$

(c) Abundance:

$$\text{Abundance} = \frac{\text{Total number of individuals of a species in all quadrats}}{\text{Total number of quadrats in which the species occurred}}$$

Basal Area

The basal area is the area of a given section of land that is occupied by the cross-section of tree trunks and stems at the base. The basal area per tree is the cross-sectional area of a tree at breast height. The term is used in forest manage-

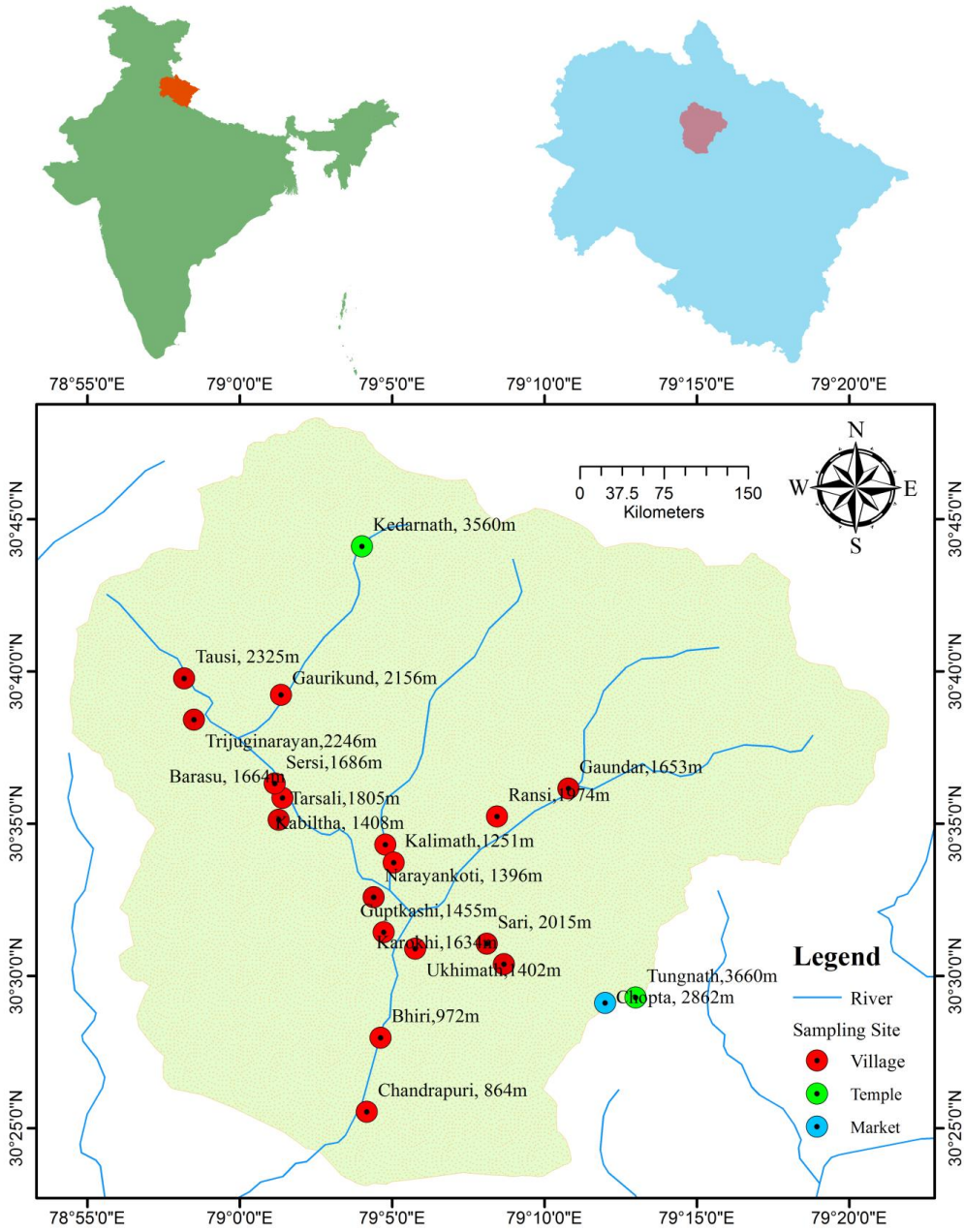

Fig. 1: Location map of the study area: The Kedarnath valley.

ment and forest ecology (Phillips 1959) as:

$$\text{Mean of the circumference (c)} = \frac{\text{Sum of all cbh (circumference)}}{\text{Total number of species}}$$

$$\text{Mean Basal area} = \frac{C^2}{4\pi}$$

$$\text{Total Basal area} = \text{Mean Basal area} \times \text{Density}$$

Where, cbh = Circumference at breast height, C = sum of cbh value of all individuals of a tree species within each plot and $\pi = 3.14$.

Importance Value Index

This index is used to determine the overall importance of

each species in the community structure. In calculating this index, the percentage values of the relative frequency, relative density, and relative dominance are summed up together and this value is designated as the Importance Value Index or IVI of the species (Curtis 1959).

(a) Relative density:

$$\text{Relative Density} = \frac{\text{Number of individual of the species} \times 100}{\text{Number of individual of all the species}}$$

(b) Relative frequency:

$$\text{Relative Frequency} = \frac{\text{Number of occurrence of the species} \times 100}{\text{Number of occurrence of all the species}}$$

(c) Relative dominance:

$$\text{Relative Dominance} = \frac{\text{Total basal area of the species} \times 100}{\text{Total basal area of all the species}}$$

The total basal area was calculated from the sum of the total diameter of immerging stems. In trees, poles, and saplings, the basal area was measured at breast height (1.5m) and by using the formula πr^2; but in the case of herbaceous vegetation it was measured on the ground level by using calipers.

Species diversity indices (Shannon Wiener Index) of general diversity ($\overline{H}$) was computed using the following formula:

$$\text{Shannon Wiener Diversity Index } (\overline{H}) = -\sum_{l-1}^{s}\left(\frac{n_i}{N}\right)\log_2\left(\frac{n_i}{N}\right)$$

Where, $\overline{H}$ = Shannon Wiener index of diversity; n_i = total no. of individuals of a species; and N= total no of individuals of all species.

RESULTS

The Kedarnath valley is very rich in terms of forest resources. Kedarnath valley is a highly elevated alpine meadow (*bugyal*) with a rich diversity of herbs, shrubs, and trees. Pine forest is common in mid-altitude, while in the upper reaches, temperate conifers forest, mainly Oak, *Rhododendron*, Devadar, Kafal are abundant. Many plant species of fodders, medicinal and fruit-bearing plants are common in this Valley. This study on the forest resources was carried out in nine sites of Kedarnath valley (Table 1).

The Kedarnath valley is blessed with the Himalayan Dry Temperate Forests, Dry Temperate Coniferous Forest and West Himalayan Birch/Fir Forests, Sub-Alpine Pasture, Himalayan Chir-Pine Forest, Himalayan Moist Temperate Forest, West Himalayan Sub-Alpine Birch/Fire Forest, and Alpine Forest.

The Forest cover of the study area has been presented in Table 2, and Karokhi has the largest forest cover area wise followed by Sari, Ransi, Ukhimath, Kabiltha, and Tungnath and Barasu have the lowest forest cover (Revenue report of the Village, Tehsil Ukhimath, R-57, 2016-17).

PLANT BIODIVERSITY

The terrestrial ecological survey for various aspects of the Kedarnath valley was conducted for a period of three years (2015 to 2018). The altitude in the villages of Kedarnath valley ranged from 864 m to 4,260 m asl. The major forest type of the valley was a mountain forest. A total number of 221 plant species were collected during the present study in the Kedarnath valley. Plant diversity in the valley encompasses 49 tree species, 28 shrub species, and 144 herb species. An

Table 1: Study sites, their location, geographical coordinates, and elevations of the study area.

Study Site	Location	Latitude	Longitude	Altitude (m above m.s.l.)
S_1	Chandrapuri	30°25'29.72''N	79° 04'17.68''E	864
S_2	Kalimath	30°33'43.66''N	79°05'03.29''E	1,251
S_3	Gaundar	30°36'09.76''N	79° 10'47.29''E	1,653
S_4	Tarsali	30°35'07.94''N	79°01'16.97''E	1,805
S_5	Sari	30°31'03.75''N	79°08'06.71''E	2,015
S_6	Gaurikund	30°39'13.42''N	79°01'26.82''E	2,156
S_7	Trijuginarayan	30°38'25.55''N	78°58'30.01''E	2,246
S_8	Kedarnath	30°44'07.38''N	79°04'00.57''E	3,560
S_9	Tungnath	30°29'17.54''N	79°12'59.84''E	3,660

inventory of plant species, their local names, family, and ethnobotanical uses have been presented in Table 3.

Study Site S_1

The study site S_1 was Chandrapuri village at the left bank of Mandakini River (864 m above m.s.l). This site has some scattered trees with few shrubs and plenty of herbs. The density, frequency, abundance, and Importance Value Index (IVI) of the trees, shrubs, and herbs at S_1 have been presented in Table 4 and Table 5. Ecological analysis revealed the dominant tree species were *Grewia optiva* (IVI: 20.700), *Banhinia variegata* (IVI: 19.286), *Pinus roxburghii* (IVI: 16.921), and *Toona ciliata* (IVI: 16.303) at S_1. The dominant shrub species were *Girardnia diversifolia* (IVI: 30.774), *Adhaoda zeylanica* (IVI: 27.831), *Lantana camara* (IVI: 27.631), and *Urtica dioica* (IVI: 23.440). The dominant herb species were *Galinsoga parviflora* (IVI: 14.549), *Euphurbia chamaesyce* (IVI: 12.127), *Reinwardtia indica* (IVI: 11.902), and *Ganatanthus pumilus* (IVI: 11.798).

Study Site S_2

The study site S_2 was Kalimath (1,251 m asl.) at the right bank of the Kali Ganga and left bank of the Mandakini River. The density, frequency, abundance, and Importance Value Index (IVI) of the trees, shrubs, and herbs have been presented in Table 4 and Table 5. Ecological analysis revealed the dominant tree species were *Quercus liucotrichophora* (IVI: 26.805), *Alnus nepalensis* (IVI: 24.373), *Pyrus pashia* (IVI: 20.456), and *Pinus roxburghii* (IVI: 17.741). However, the dominant shrub species were *Solanum viarum* (IVI: 31.703), *Girardnia diversifolia* (IVI: 28.478), and *Berberis aristata* (IVI: 24.146). The dominant herb species were *Pilea umbrosa* (IVI: 10.690), *Laportea ovalifolia* (IVI: 9.412) and *Eulaliopsis binata* (IVI: 9.311).

Study Site S_3

The study site S_3 (1,653 m asl.) was the Gaundar village at the right bank of the Madmaheswar Ganga. The density, frequency, abundance, and importance value index (IVI) of the trees, shrubs, and herbs have been presented in Table 4 and Table 5. Ecological analysis revealed the dominant tree species were *Quercus liucotrichophora* (IVI: 40.799), *Alnus nepalensis* (IVI: 30.639), and *Myrica esculenta* (IVI: 24.402). However, the dominant shrub species were *Sarcococca saligna* (IVI: 30.712), *Adhatoda vasica* (IVI: 30.402),

Table 2: Forest cover of Ukhiamth Tehsil in 2016-17 (Area in ha).

S.No.	Name of villages	Altitude (m. above m.s.l.)	Geographical area (ha)	Forest Cover (ha)
	Chandrapuri	864	20.157	4.655
	Bhiri	972	63.282	13.419
	Kalimath	1,251	98.389	39.329
	Narayankoti	1,396	29.408	9.876
	Ukhimath	1,402	214.977	85.989
	Kabiltha	1,408	49.105	22.404
	Guptakashi	1,455	195.875	80.207
	Karokhi	1,634	386.831	304.698
	Gaundar	1,653	60.215	7.966
	Sersi	1,686	85.96	16.86
	Barasu	1,664	129.003	0.09
	Tarsali	1,805	25.71	6.04
	Ransi	1,974	253.634	118.833
	Sari	2,015	286	254.702
	Gaurikund	2,156	55.119	25.8
	Trijuginarayan	2,246	419.426	29.66
	Tausi	2,325	50.044	2.64
	Chopta	2,862	3.62	2.845
	Kedarnath	3,568	14.36	-
	Tungnath	3,660	1.636	1.045

Sources: Revenue Report of villages, Tehsil Ukhimath, R-57, 2016-17

and *Girardnia diversifolia* (IVI: 28.320). The dominant herb species were *Bidens pilosa* (IVI: 14.015), *Agrimonia pilusa* (IVI: 12.262), and *Euphurbia chamaesyce* (IVI: 11.681).

Study Site S_4

The study site S_4 (1,805 m a.s.l) was the Tarsali village, located at the right bank of the Mandakini River. The density, frequency, abundance, and Importance Value Index (IVI) of the trees, shrubs, and herbs have been presented in Table 4 and Table 5. Ecological analysis revealed the dominant tree species were *Quercus liucotrichophora* (IVI: 43.294), *Rhododendron arboreum* (IVI: 28.921), and *Neolitsea sericea* (IVI: 19.164). However, the dominant shrub species were *Sarcococca saligna* (IVI: 51.337), *Girardnia diversifolia*

Table 3: Inventory of plant species, their local names, and ethnobotanical uses in the study area of Kedarnath valley

S.No.	Name of Species	Local Name	Family	Ethnobotanical Uses
Trees				
1.	*Abies spectabilis* (D.Don) Spach		Pinaceae	Timber, Fuel
2.	Aesculus indica (Wall.ex Camb.) Hook	Pangar	Sapindaceae	Medicinal, Wild edible, Fuel
3.	*Alnus nepalensis* D.Don	Utis	Betulaceae	Timber, Fuel
4.	*Banhinia variegata* L.	Kachnar	Caesalpinaceae	Medicinal, Wild edible, Fuel
5.	*Betula alnoides* Buch. -Ham.ex D.Don	Saur, sore	Betulaceae	Timber, Fuel, Fodder
6.	*Cedrus deodara* (Roxb.) G.Don	Deodara	Pinaceae	Timber, Fuel
7.	*Celtis australis* L.	Khadik	Cannabaceae	Fodder, Fuel
8.	*Cinnamomum Spp.* Schaeff.		Lauraceae	Fodder, edible, Fuel
9.	*Cotoneaster affinis* Lindl.	Ruins	Rosaceae	Fuel, Agriculture tool
10.	*Debregeasia longifolia* (Burm.F.) Wedd.	Syanru	Urticaceae	Fodder, edible, Fuel
11.	*Emblica officinalis* Gaertn.	Aonla	Euphorbiaceae	Medicinal, edible, Fuel
12.	*Ficus auriculata* Lour.	Timla	Moraceae	Fodder, fruit edible
13.	*Ficus palmata* Forsk.	Bedu	Moraceae	Fodder, fruit edible, medicinal
14.	*Ficus religiosa* L.	Peepal	Moraceae	Medicinal, Fuel
15.	*Ficus semicordata* Bunch.-ham.ex J. E.Smith	Khannu	Moraceae	Medicinal, Wild edible, Fuel
16.	*Fraxinus americana* L.	Anga	Oleaceae	Fuel, Timber
17.	*Grewia optiva* Drummond ex Burrt	Bhimal	Tiliaceae	Fuel, Fodder
18.	*Hippophae salicifolia* D.Don		Elaeagnaceae	Medicinal, Wild edible, Fuel
19.	Holmskiodia sanguinea	Khagsoo	Verbinaceae	Fuel, Fodder
20.	*Juglans regia* L.	*Akhrot*	Juglandaceae	Medicinal, Wild edible, Fish poison, Fuel
21.	*Lyonia ovalifolia* (Wall.) Prude	Anyar	Ericaceae	Fuel, Fish Poison, Medicinal, Fodder
22.	*Mangifera indica* L.	Aam	Anacardiaceae	Fruit edible, woodwork
23.	*Morus alba* L.	Sahtoot	Moraceae	Fruit edible woodwork, sericulture
24.	*Myrica esculenta* Buch. -Ham.ex D.Don	Kafal	Myricaceae	Medicinal, Wild edible, Fish poison, Fuel
25.	*Neolitesa serobiculata* (Meisn.) Gamble	Gadmweda	Lauraceae	Fuel
26.	*Neolitsea sericea* (Blume) Koidz.	(Mweda, chirad)	Lauraceae	Fuel
27.	*Neolitsea Spp.* (Bent. & Hook.F.) Merr.	Lampatiya	Lauraceae	Fuel, Timber
28.	*Phoenix humilis* Royle.	Khajoor	Arecaceae	Medicinal, Wild edible, Fuel
29.	*Pinus roxburghii* Sarjent	Kulain	Pinaceae	Wood for construction, resin, medicinal, timber
30.	*Prunus cerasoides* D.Don	Panya	Rosaceae	Medicinal, Wild edible, Fuel, Timber
31.	*Prunus cornuta* (Wall. ex Royle)	Himalayan bird cherry, padus	Rosaceae	Medicinal, Wild edible, Fuel, Timber

Table cont....

S.No.	Name of Species	Local Name	Family	Ethnobotanical Uses
32.	*Pyrus pashia* Buch. -Ham.ex D.Don	Mol	Rosaceae	Fodder, Fuel, Medicinal, Wild edible
33.	*Quercus floribunda* Lindley.ex Rehder	Moru	Fabuceae	Fodder, Fuel
34.	*Quercus liucotrichophora* A.Camus	Banj	Fagaceae	Fodder, Fuel
35.	*Quercus semecarpifolia* Sm.	Karsu	Fagaceae	Fodder, Fuel
36.	*Quercus Spp.* L.	Harinj, Green oke	Fagaceae	Fodder, Fuel
37.	*Rhododendron arboreum* Sm.	Burans	Ericaceae	Medicinal, Wild edible, Fuel, Timber
38.	*Rhododendron barbatum* W*allich ex G. Don*		Ericaceae	Medicinal, Wild edible, Fuel, Timber
39.	*Rhus sandwicensis* A.Gray	Titret	Anacardiaceae	Fuel, Fodder
40.	*Rosa sericea* Lindl.		Rosaceae	Medicinal, Fuel
41.	*Sapindus mukorossi* Gaertner	Reetha	Sapindaceae	Medicinal, Fuel, Timber
42.	*Symplocos panniculata (*Thunb.) Miq	Lodha	Symplocaceae	Fodder. Fuel
43.	*Syzygium cumiini* (L.) Skeels	Jamun	Myrataceae	Medicinal, Wild edible, Fuel, Timber
44.	*Taxcus baccata* L.	Thuner	Taxaceae	Medicinal, Timber, fuel
45.	*Taxus wallichiana* Zucc.		Taxaceae	Medicinal, Timber, fuel
46.	*Toona ciliata* Roem.	Toon	Meliaceae	Timber and wood work, social forestry
47.	*Ulmus wallichiana* Planch.	Pamani,mairu	Urticaceae	Fodder, Fuel
48.	*Viburmum mullaha* Buch. -Ham.ex D.Don	Malyo	Caprifoliaceae	Fodder, Fuel, Medicinal, Wild edible
49.	Zanthoxylum armatum DC	Timaru	Rutaceae	Fodder, Fuel, Medicinal
Shrubs				
1.	*Ageratina adenophora* (Spreng.) King & H.Rob.	Basinga	Acanthaceae	Medicinal
2.	Arismia tortosum			Medicinal
3.	*Berberis aristata* Roxb.ex.DC.	Kirmor	Berberidaceae	Wild edible, Medicinal, Fuel
4.	*Berberis jaeschkeana* DC.		Berberidaceae	Wild edible, Medicinal, Fuel
5.	*Boehmeria platyphylla* D.Don	Khagsa	Urticaceae	Fodder, Fuel
6.	*Caesalipinia decapetala* (Roth) Alston	Kingari,kunju	Caesalpiniaceae	Fodder, Medicinal, Fuel
7.	*Cannabis sativa* Linn.	Bhang	Cannabinaceae	Bark fibers for ropes, sacs, and rough clothes, seeds as condiment, intoxicating
8.	*Cotoneaster microphyllus* Wall. ex Lindl.		Malaceae	Wild edible, Medicinal, Fuel
9.	*Desmodium concimum* DC.	Sakina	Fabaceae	Fodder, Fuel
10.	*Desmodium elegans* DC.	Chamlai	Fabaceae, Papilion-aceae	Fodder, Fuel
11.	Echinops cornigenus	Kandara	Asterceae	Medicinal, Edible
12.	*Elueagnus parvifolia* Wall.ex Royal	Giwain	Elueagnaceae	Wild edible, Medicinal, Fuel
13.	*Girardnia diversifolia* (Link) Friis	Jhir kandali	Urticaceae	Fodder, Medicinal
14.	*Lantana camara* L.	Gajar ghass	Verbenaceae	Fuel, furniture, Medicinal, Weed
15.	*Lonicera x bella* Zabel	Ghugti	Carprifoliaceae	Fuel
16.	*Prisepia utilis* Royle	Bhenkul	Rosaceae	Medicinal, Fuel
17.	*Pyracantha crenulata* (D.Don) M.Roem.	Ghingaru	Rosaceae	Soil binder, fruit edible, Medicinal, Fuel
18.	*Rhododendron barbatum* W*allich ex G. Don*		Ericaceae	Medicinal, Wild edible, Fuel, Timber
19.	*Rhododendron campanulatum* D.Don	Burans	Ericaceae	Medicinal, Wild edible, Fuel, Timber
20.	*Rosa spp.* L.		Rosaceae	Medicinal, Fuel

Table cont....

S.No.	Name of Species	Local Name	Family	Ethnobotanical Uses
21.	*Rubus ellipticus* Sm.	Hinsalu	Rosaceae	Fruit edible
22.	*Rubus niveus* Thunb.	Kali hisar	Rosaceae	Fruit edible
23.	*Sarcococca saligna* (D.Don)	Geru, paliyala	Buxaceae	Medicinal, Fuel
24.	*Sinarumdinaria anceps* (Mittf.) Chao & Renvoize.Sqn.	Ringal	Poaceae	Fuel
25.	*Smilax aspera* L.	Kukardara	Smilacaceae	Medicinal
26.	*Solanum viarum* Dunal		Solanaceae	Medicinal
27.	*Urtica dioica* L.	Kandali	Urticaceae	Edible, Medicinal
28.	*Viburnum spp.* L.		Adoxaceae	Medicinal
Herbs				
1.	*Abies pindrow* (Royle ex D.Don) Royle		Pinaceae	Medicinal, Edible
2.	Abrus precatorius L.	Ratti	Fabaceae	Medicinal
3.	*Acomastylis elata* (Wall.ex G.Don) F.Bolle		Rosaceae	Medicinal
4.	Agrimonia pilusa Ledebour	Lisukuri	Rosaceae	Fodder
5.	*Ampelocissus latifolia* Planch.		Araliaceae	Fodder, Medicinal
6.	*Anaphalis beddomei* Hook.F.		Asteraceae	Medicinal
7.	*Anaphalis contorta* (D.Don) Hook.f.		Asteraceae	Medicinal
8.	*Anaphalis royleana* DC		Asteraceae	Medicinal
9.	*Anaphalis spp.* DC.		Asteraceae	Medicinal
10.	*Anaphalis spp.*DC.		Asteraceae	Medicinal
11.	*Androsace lanuginosa* Wall.		Primulaceae	Medicinal
12.	*Anemone obtusiloba* D.Don, Prode. Fl.		Ranunculaceae	Medicinal
13.	*Anemone patens* L.		Rosaceae	Medicinal
14.	*Anemone spp* L.		Ranunculaceae	Medicinal
15.	*Anemone vitifolia* Buch.-Ham. ex DC.		Ranuculaceae	Medicinal
16.	*Animone obtusiloba* D.Don		Renunculaceae	Medicinal
17.	*Arisaema flavam* (Foessk.) Schott		Araceae	Medicinal
18.	*Arisaema intermedium* BL.	Akash laguli	Convolvulaceae	Medicinal
19.	*Arisaemia tortosum* (Wall.) Schott		Araceae	Medicinal
20.	Arisuema totuosum (Wall.) Schot	Bell type	Vitaceae	Medicinal
21.	*Aster spp*. L.		Asteraceae	Medicinal
22.	*Bauhinia vahlii* Wight & Arn.	Bagmungari	Araceae	Medicinal
23.	*Bergenia ciliata* (Haworth) Stern.	Silpara	Saxifragaceae	Medicinal
24.	*Bidens pilosa* L.	Kumar	Astoraceae	Medicinal, Fodder
25.	*Bistorta macrophylla* (D.Don) Sojak		Polygonaceae	Medicinal
26.	*Bistorta vaccinifolia* Wall. ex Meisn.)		Polygonaceae	Medicinal
27.	*Boehmeria grandis(*Hook. & Arn.) A. Heller	Foortya	Urticaceae	Fodder
28.	*Boehmeria nivea* (L.) Gaudich.		Urticaceae	Medicinal
29.	Boenninghausenia albiflora	Upniya ghass	Rutaceae	Fodder, Medicinal
30.	*Bupleurum fruticosum* L.		Apiaceae	Fodder
31.	*Carax hirta* L.		Cyperaceae	Fodder
32.	*Carex spp.* L.		Cyperaceae	Fodder

Table cont....

S.No.	Name of Species	Local Name	Family	Ethnobotanical Uses
33.	*Centella asiatica* L.	Brahmi	Apiaceae	Medicinal
34.	*Chenopodium album* L.	Bathua	Chenopodiaceae	Edible, Fodder, Medicinal
35.	*Citrullus colocynthis* (L.) Schrader		Rutaceae	Medicinal
36.	*Clematis montana* Buch.-Ham. ex DC.		Ranunculaceae	Medicinal
37.	*Corydalis cornuta* Royal		Papaveraceae	Medicinal
38.	*Crepidium acminatum* (D.Don) Szlach.	Jeevak	Orchidaceae	Medicinal
39.	*Cuscuta reflexa* Roxb.	Dudhi	Euphorbiaceae	Medicinal
40.	*Cyananthus lobatus* Wall. ex Benth		Campanulaceae	Medicinal
41.	*Cyathula tomentosa* (Roth) Moq.	Lichkura	Amarnathaceae	Fodder, Medicinal
42.	*Cymbopogon citratus* (DC.) Stapf	Lemongrass	Poaceae	Fodder, Medicinal
43.	*Cynodon dactylon* (L.) Pers.	Doob	Poaceae	Medicinal, Fodder
44.	*Cynoglossum zeylanicum* L.		Boraginaceae	Medicinal
45.	*Cyperus odoratus* L.	Ghass	Cyperaceae, Poaceae	Fodder
46.	*Danthonia cachmiriana* L.		Poaceae	Fodder
47.	*Danthonia spp.* DC.		Poaceae	Fodder
48.	*Daphne papyracea* Wall.	Kandara	Asteraceae	Fodder
49.	*Digitaria ciliaris (Retz.)* Koeler	Menaru	Poaceae	Fodder
50.	*Dioscorea belophylla* (Prain) Haines Syn.	Tedu	Deoscoreaceae	Edible, Medicinal
51.	*Dioscorea Spp.* L.		Dioscoreaceae	Edible
52.	*Diplazium caudatum* (Cav.) Jermy	Farn	Athyriacae	Medicinal
53.	*Diplazium esculentum* (Retz.) SW.	Lingra	Dryopteridaceae, Athyriaceae	Edible, Medicinal
54.	*Diplazium melanochlamys* (Hook.) T.Moore	Una, fern	Athyriacae	Fodder, Medicinal
55.	*Diplazium splendens* Ching	Meen	Araceae	Medicinal
56.	Diplazium spp.	Bis lingara	Dryopteridaceae, Athyriaceae	Medicinal
57.	*Dryopteris filixmas* (L.) Schott	Fern	Dryopteridaceae	Medicinal, Fodder
58.	*Dryopteris filix* -mas		Dryopteridaceae	Medicinal
59.	*Dubyaea hispida* (D.Don) DC.		Asteraceae	Medicinal
60.	*Duchesnea indica* (Andrcos) Th.Wolf	Bhina kafal	Rosaceae	Edible, Medicinal
61.	*Echinops cornigenus* Roxb.	Meda	Asparagaceae	Medicinal
62.	*Epilobium hirsutum* L.		Onagraceae	Medicinal
63.	*Eulaliopsis binata* (Retz.) C.E. Hubb.	Ban pindalu	Araceae	Medicinal. Edible
64.	*Euphorbia spp.*L.		Euphorbiaceae	Medicinal
65.	*Euphurbia chamaesyce* L.	Ban-haldi	Zingiberaceae	Fodder, Medicinal
66.	*Evolvulus alsinoides* (L.) L.	Sankpushpi	Convolvulaceae	Medicinal
67.	*Fagopyrum esculentum* (L.) Moench.	Konlya, ougal	Polygonaceae	Fodder, Medicinal, Edible
68.	*Festuca spp.* L.	Grass	Poaceae	Fodder
69.	*Fragaria rubicola* L.		Rosaceae	Medicinal
70.	*Fumaria indica* (haussk.) Pugsl.	Pit-papra	Liliaceae	Medicinal
71.	*Galinsoga parviflora* Cav.	Khor type	Poaceae	Fodder
72.	*Ganatanthus pumilus* (D.Don) Engl. & Krause	Badelu grass	Asteraceae	Fodder, Medicinal

Table cont....

S.No.	Name of Species	Local Name	Family	Ethnobotanical Uses
73.	*Gaultheria trichophylla* Royle		Ericaceae	Medicinal
74.	*Geum elatum* Wall. Ex G.Don		Rosaceae	Medicinal
75.	*Gleichenia spp.* Sm.		Gleicheniaceae	Medicinal
76.	*Hedra nepalensis* K.Koch	Ivi	Polygonaceae	Medicinal
77.	*Hedychium spicatum* Buch.-Ham.	Phiyunli	Liliaceae	Medicinal
78.	*Heracleum maximum* Bartr.		Asteraceae	Medicinal
79.	*Impatiens scabrida* DC.		Balsaminaceae	Medicinal
80.	*Impatiens sulcata* Wall.	Majuro	Balsaminaceae	Medicinal
81.	*Ischaemum rugosum* Salisb.		Poaceae	Medicinal, Fodder
82.	*Juniperus squamata* Buch.-Ham. ex D.Don		Cupressaceae	Medicinal
83.	*Laportea ovalifolia* Schum. (Thonn.) Chew	Malcharu	Nasselxaxter	Fodder
84.	*Lathyrus spp.* L.	Kurfalya	fabaceae	Edible, Fodder, Medicinal
85.	*Lonicera obovata* Royle		Carprifolvaxter	Medicinal
86.	*Oplismenus hirtellus* (L.) P.Beauv.	Menaru, basket grass	Poaceae	Fodder
87.	*Oxalis corniculata* L.	Bhilmori	Oxalidaceae	Edible, Fodder, Medicinal
88.	*Oxora coccinea* L.		Rubiaceae	Medicinal
89.	*Oxyria digyna* (L) Hill		Polygonaceae	Medicinal
90.	*Paeonia emodi* Royal	Dhanduru	Paeoniaceae	Edible, Medicinal
91.	*Parthenocissus semicordata* (Wall) Planch.		Vitaceae	Medicinal
92.	*Persicaria amplexicaulis* (D. Don) Ronse Decraene		Polygonaceae	Medicinal
93.	*Pilea umbrosa* Wall.ex Bl.	Chaolu	Urticaceae	Fodder
94.	*Plantago brachyphylla* Edgew. ex Decne		Plantaginaceae	Medicinal
95.	*Plantago deprassa* Willd.	Luhurya, symlya	Planttaginaceae	Medicinal
96.	*Plantago spp.* L.		Plantaginaceae	Medicinal
97.	*Podophyllum hexandrum* Royle	Ban kakdi	Podophyllaceae	Edible, Medicinal, Fodder
98.	*Polygonatum verticillatam* (L.) All.	Malu	Caesalpiniaceae	Medicinal
99.	*Polygonum capitatum* (Buch.-Ham. Ex D.Don) H.Gross		Renunculaceae	Medicinal
100.	*Polygonum filicaule* Wall. ex Meissn		Polygonaceae	Medicinal
101.	*Polygonum spp.* L.		Polygonaceae	Medicinal
102.	*Polygonum polystachyum* Wall. ex Meissn		Polygonaceae	Medicinal
103.	*Poteatilla spp.* L.		Rosaceae	Medicinal
104.	*Potentilla atrosangunea* G.LOOD.ex D.Don		Rosaceae	Medicinal
105.	*Potentilla fulgens* L.		Rosaceae	Medicinal
106.	*Potentilla fulgens* Wall. Ex HK.F.	Bajaradanti	Rosaceae	Medicinal
107.	*Potentilla spp.* L.		Rosaceae	Medicinal
108.	*Potentilla polyphylla* Wall. ex Lehm.		Rosaceae	Medicinal
109.	*Potentilla polyphylla* Wall. ex Lehm		Rosaceae	Medicinal
110.	*Primula spp* L.		Primulaceae	Medicinal
111.	*Prunella vulgaris* L.		Lamiaceae	Medicinal

Table cont....

S.No.	Name of Species	Local Name	Family	Ethnobotanical Uses
112.	*Ranunculus hirtellus* Royle		Ranunculaceae	Medicinal
113.	*Ranunculus repens* L.		Apiaceae	Medicinal
114.	*Reinwardtia indica* Dum.	Bugla	Asterceae	Medicinal
115.	*Rhododendron anthopogon* D.Don	Burans	Ericaceae	Medicinal, Wild edible, Fuel, Timber
116.	*Rubia manjith* Roxb.ex Fleming	Lichkuri, indian madder	Rubiaceaae	Medicinal, Fodder
117.	*Rumex hastatus* D.Don	Almora	Polygonaceae	Edible, Fodder, Medicinal
118.	*Rumex nepalensis* Speeng.		Polygonaceae	Medicinal
119.	*Saccharum officinarum* L.		Poaceae	Medicinal
120.	*Salix lindleyana* Wallich ex Ander.		Salicaceae	Medicinal
121.	*Salix spp* L.		Salicaceae	Medicinal
122.	*Salvia nubicola* Wall. ex Sweet		Lamiaceae	Medicinal
123.	*Saxifraga parnassifolia* D.Don		Saxifragaceae	Medicinal
124.	*Scrophularia californica* Cham. & Schldl.		Scrophulariaceae	Medicinal
125.	*Sedum spp* L.		Crassulaceae	Medicinal
126.	*Selenium cuneifokiaa* DC.		Asteraceae	Medicinal
127.	*Senecio spp* L.		Asteraceae	Medicinal
128.	*Sibbaldia cuneata* Hornem.ex Kuntze		Rosaceae	Medicinal
129.	*Smilax aspera* L.		Smilacaceae	Medicinal
130.	*Solanum nigrum* L.		Solanaceae	Fodder, Medicinal
131.	*Sweritia chirayia* (Roxb. Ex Fleming) Karsten	Chiraita	Gentianaceae	Medicinal
132.	*Tanacetum longifolium* Wall. ex DC.		Asteraceae	Medicinal
133.	*Taraxacum officinale* (L.) Weber ex F.H. Wigg		Asteraceae	Medicinal
134.	*Taraxacum officinale* (L.) Weber ex F.H.Wigg		Asteraceae	Medicinal
135.	*Tetratigma spp.* Merr.& Chun	Bell-type	Vitaceae	Edible, Medicinal
136.	Tetratigma pubinerve		Thymelaeaceae	Medicinal
137.	*Tetratigma serrulatum* (Roxb.) Planch.		Vitaceae	Medicinal
138.	*Teucrium quadnfarium* Buch -Ham.		Lamiaceae	Medicinal
139.	*Trichosanthes tricuspidata* Lour.	Ilaru	Cucurbiaceae	Medicinal
140.	Trychidium royle			Medicinal
141.	*Urtica dioica* L.		Urticaceae	Fodder
142.	*Valeriana herdwikaii* Wall.		Caprifoliaceae	Medicinal
143.	Viburnum grandiflorum Wall.		Adoxaceae	Medicinal
144.	*Viola biflora* L.	Bana-ksha	Violaceae	Medicinal

(IVI: 35.807), and *Berberis aristata* (IVI: 22.769). The dominant herb species were *Oplismenus hirtellus* (IVI: 21.957), *Cyperus odoratus* (IVI: 18.375), and *Ischaemum rugosum* (IVI: 15.377).

Study Site S_5

The study site S_5 (2,015m a.s.l) was the Sari village, located at the left bank of the Mandakini River. The density, frequency, abundance, and Importance Value Index (IVI) of the trees, shrubs, and herbs have been presented in Table 4 and Table 5. Ecological analysis revealed the dominant tree species were *Quercus liucotrichophora* (IVI: 25.677), *Alnus nepalensis* (IVI: 21.965), and *Aesculus indica* (IVI: 21.701). However, the dominant shrub species were *Girardnia diversifolia* (IVI: 40.998), *Sarcococca saligna* (IVI: 27.752), and *Urtica dioica* (IVI: 25.216). The dominant herb species were *Pilea umbrosa* (IVI: 20.192), *Cymbopogon citratus* (IVI: 16.016), and *Cymbopogon citratus* (IVI: 16.016).

Table 4: Dominance of tree, shrub, and herb species and Total Basal Area (TBA) of plant species in the study area of Kedarnath valley

S.N.	Village Name	Dominance of tree species	Dominance of shrub species	Dominance of herb tree species	TBA
1.	Chandrapuri	*Grewia optiva*	*Girardnia diversifolia*	*Galinsoga parviflora*	*Banhinia variegata*
2.	Kalimath	*Quercus liucotrichophora*	*Solanum viarum*	*Pilea umbrosa*	*Quercus leucotrichophora*
3.	Gaundar	*Quercus liucotrichophora*	*Sarcococca saligna*	*Bidens pilosa*	*Quercus leucotrichophora*
4.	Tarsali	*Quercus liucotrichophora*	*Sarcococca saligna*	*Oplismenus hirtellus*	*Quercus leucotrichophora*
5.	Sari	*Quercus liucotrichophora*	*Girardnia diversifolia*	*Pilea umbrosa*	*Quercus leucotrichophora*
6.	Gaurikund	*Quercus liucotrichophora*	*Echinops cornigenus*	*Oplismenus hirtellus*	*Quercus leucotrichophora*
7.	Trijuginarayan	*Quercus liucotrichophora*	*Sarcococca saligna*	*Agrimonia pilusa*	*Quercus leucotrichophora*
8.	Kedarnath	*Taxus wallichiana*	*Berberis jaeschkeana*	*Trychidium royle*	*Taxus wallichiana*
9.	Tungnath	*Abies spectabilis*	*Rhododendron campanulatum*	*Carax hirta*	*Rhododendron barbatum*

Study Site S_6

The study site S_6 (2,156 m a.s.l) was the Gaurikund village, located at the right bank of the Mandakini River. The density, frequency, abundance, and Importance Value Index (IVI) of the trees, shrubs, and herbs have been presented in Table 4 and Table 5. Ecological analysis revealed the dominant tree species were *Quercus liucotrichophora* (IVI: 38.35), *Neolitsea sericea* (IVI: 35.87), and *Betula alnoides* (IVI: 24.25). However, the dominant shrub species were *Echinops cornigenus* (IVI: 52.24), *Girardnia diversifolia* (IVI: 35.31), and *Sarcococca saligna* (IVI: 26.49). The dominant herb species were *Oplismenus hirtellus* (IVI: 18.55), *Cymbopogon citratus* (IVI: 17.25), and *Diplazium esculentum* (IVI: 16.59).

Study Site S_7

The study site S7 (2,246 m a.s.l) was the Trijuginarayan village, located at the right bank of the Mandakini River. The density, frequency, abundance, and Importance Value Index (IVI) of the trees, shrubs, and herbs have been presented in Table 4 and Table 5. Ecological analysis revealed the dominant tree species were *Quercus liucotrichophora* (IVI: 48.10), *Rhododendron arboreum* (IVI: 28.37), and *Neolitsea sericea* (IVI: 25.40). However, the dominant shrub species were *Sarcococca saligna* (IVI: 33.43), *Girardnia diversifolia* (IVI: 24.12), and *Cannabis sativa* (IVI: 18.25). The dominant herb species were *Agrimonia pilusa* (IVI: 22.48), *Bidens pilosa* (IVI: 14.48), and *Diplazium esculentum* (IVI: 14.27).

Table 5: Different ecological and diversity parameters in the study area of Kedarnath valley.

Parameters	Chandrapuri	Kalimath	Gaundar	Tarsali	Sari	Gaurikund	Trijuginarayan	Kedarnath	Tungnath
Tree density (ind.100 m^{-2})	38.4	100.7	37.9	81	46	54.3	49.4	6.8	15.5
Shrub density (ind.25 m^{-2})	81.5	95	122.9	46.8	65	36.9	49.1	15	11.8
Herb density (ind.m^{-2})	200	323.4	248.7	202.8	198.9	197.6	125.5	229.7	147
TBC (m^2ha^{-1})	21.828	57.364	20.417	33.606	34.086	43.704	38.28	21.475	-
Tree IVI	300.001	299.995	300.002	299.989	300.004	299.83	299.99	300	299.98
Shrub IVI	299.998	300.002	299.999	300.006	299.999	300.01	231.55	300.01	300
Herb IVI	300.002	300.001	300.001	300	299.997	299.99	300.01	299.99	300.02
Shannon Index (Tree) ($\overline{H}$)	3.028	3.048	2.901	3.001	2.918	2.753	2.636	1.737	-
Shannon Index (Shrub) ($\overline{H}$)	2.788	2.696	2.629	2.492	2.594	2.404	2.047	0.192	-
Shannon Index (Herb) ($\overline{H}$)	3.613	3.787	3.531	3.305	3.156	3.367	3.317	3.712	3.115

IVI=Importance Value Index; TBA=Total Basal Area; $\overline{H}$=Diversity Index

Study Site S_8

The study site S_8 (3,568m a.s.l) was the Kedarnath, located at the right bank of the Mandakini River. The density, frequency, abundance, and Importance Value Index (IVI) of the trees, shrubs, and herbs have been presented in Table 4 and Table 5. Ecological analysis revealed the dominant herb species were *Trychidium royle* (IVI: 17.38), *Danthonia spp.* (IVI: 12.00) and *Anaphalis spp.* (IVI: 11.16). However, the dominant shrub species were *Berberis jaeschkeana* (IVI: 35.81), *Rosa spp.* (IVI: 21.38), and *Arismia tortosum* (IVI: 15.39). The dominant tree species were *Taxus wallichiana* (IVI: 66.82), *Abies spectabilis* (IVI: 63.44), and *Rhododendron barbatum* (IVI: 50.12).

Study site S_9

The study site S_9 (3,660 m a.s.l) was the Tungnath, located at the left bank of the Mandakini River. The density, frequency, abundance, and Importance Value Index (IVI) of the trees, shrubs, and herbs have been presented in Table 4 and Table 5. Ecological analysis revealed the dominant herb species were *Carax hirta* (IVI: 26.23), *Potentilla fulgens* (IVI: 20.98), and *Rhododendron anthopogon* (IVI: 19.27). However, the dominant shrub species were *Rhododendron campanulatum.* The dominant tree species were *Abies spectabilis.*

Total basal area (TBA)

In the Chandrapuri forest area, the total basal area was higher for *Banhinia variegata* (1.978 m^2ha^{-1}), possibly due to a higher density of trees (Table 4 and Table 5). In the Kalimath forest area, the total basal area was higher for *Quercus liucotrichophora* (7.688 m^2ha^{-1}), possibly due to a higher density of trees (Table 4 and Table 5). In the Gaundar forest area, the total basal area was higher for *Quercus liucotrichophora* (4.864 m^2ha^{-1}), possibly due to a higher density of trees (Table 4 and Table 5). In the Tarsali forest area, the total basal area was higher for *Quercus liucotrichophora* (9.542 m^2ha^{-1}), possibly due to a higher density of trees (Table 4 and Table 5). In the Sari forest area, the total basal area was higher for *Quercus liucotrichophora* (4.242 m^2ha^{-1}), possibly due to a higher density of trees (Table 4 and Table 5). In the Gaurikhund forest area, the total basal area was higher for *Quercus liucotrichophora* (7.319 $m^2.ha^{-1}$), possibly due to a higher density of trees (Table 4 and Table 5). In the Trijuginarayan forest area, the total basal area was higher for *Quercus liucotrichophora* (8.89 $m^2.ha^{-1}$), possibly due to a higher density of trees (Table 4 and Table 5). In the Kedarnath forest area, the total basal area was higher for *Taxus wallichiana* (4.654 $m^2.ha^{-1}$), possibly due to a higher density of trees (Table 4 and Table 5). In the Tungnath forest area, the total basal area was higher for *Rhododendron barbatum* (20.59 $m^2.ha^{-1}$), possibly due to a higher density of trees (Table 4 and Table 5).

Diversity Index

The species diversity index (Shannon-Wiener) can be regarded as a measure of environmental quality and points to the well-being of any ecosystem. The plant species diversity indices for site S1 to S9 have been presented in Table 5. For site S_1, it was 3.028 for trees, 2.788 for shrubs, and 3.613 for herbs. However, for site S_2, it was found to be 3.048 for trees, 2.696 for shrubs, and 3.787 for herbs. For site S_3, it was 2.901 for trees, 2.629 for shrubs, and 3.531 for herbs. For site S_4, it was 3.001 for trees, 2.492 for shrubs, and 3.305 for herbs. For site S_5, it was 2.918 for trees, 2.594 for shrubs, and 3.1564 for herbs. For site S_6, it was 2.753 for trees, 2.404 for shrubs, and 3.367 for herbs. For site S_7, it was 2.636 for trees, 2.047 for shrubs, and 3.317 for herbs. For site S_8, it was 1.737 for trees, 0.192 for shrubs, and 3.712 for herbs. For site S_9 it was 3.115 for herbs. This pointed out the dominance of herbs and trees at sites S_1, S_2, and S_4, and the dominance of herbs at sites S_3, S_5, S_7, S_8, and S_9. The dominance of both herbs and shrubs is only at site S_6. The dominant tree species was *Abies* spectabilis, whereas, the dominant shrub species was *Rhododendron campanulatum.*

IMPACTS OF ECODISASTER 2013 ON FOREST AREA OF KEDARNATH VALLEY

During the study, it was discovered that during the Kedarnath eco-disaster in Kedarnath valley in June 2013, there was a lot of damage to the forest in the riverbank of the Mandakini River due to flash floods and landslides. The flood plain of the Mandakini River was totally destroyed in which several important medicinal plants flowering plants and ornamental plant species were washed. In this disaster, about 500 valuable plant communities were affected. Even in the lower areas of Kedarnath, the nearby forest area of Mandakini River was damaged. Most of the forest was damaged in Jangalchhati, Rambara, Bhimbali, Gaurikund, Sonprayag, and Sitapur, in which medicinal plants, fodder plants, and wild edible plants were completely destroyed. In this disaster, landslides and flash floods that occurred in Kali gad, Madhmaheswar gad, and Kakara gad destroyed forest, in which, many fuel and fodder plants forest area was damaged.

Rawat et al. (2016) studied the biomass estimation during 2012 by sampling at ten random plots laid at open and dense forest sites. The biomass obtained from that study had shown that 242.24 $ton.ha^{-1}$ to 322.97 $ton.ha^{-1}$ for the Mixed Forest. The total washed-out area from the forest was nearly an average of 92.44 (Open and Dense Forest). This showed that nearly 22392.66 to 29855.35 tons of biomass from the total

area was lost. The disturbance in dense mixed forest (33.16 ha) and open mixed forest (59.28 ha) was recorded by Rawat et al. (2016) (Fig. 2). Over 500 plant species have suffered losses varying from minor to significant. Considering heavy riverbank cutting, multiple landslides event, and deposition of sediments in the Kedarnath pastoral area, the impact on vegetation is comparatively higher in meadows (BSI 2015).

It will take many thousands of years for regeneration in natural conditions for vegetation growth and productivity. To an ecosystem, the biomass and thus carbon sequestration process are directly linked. Loss in biomass from the available species extinction is a greater loss for the ecological cycle from the present area.

Ethnobotanical Plants and Their Use

Kedarnath valley is very rich in terms of the presence of medicinal plants, Edible plants, Fodder plants, Timber trees and fuelwood, and economically important plants. Local people of the Kedarnath valley use these plants for the cure of several diseases, as fodder, timber, and fuelwood (Table 3). A large number of these species are harvested in the wild, particularly for food, medicinal purposes, and for sale (Prasad & Sharma 2018).

DISCUSSION

Species richness in a forest depends on climatic, edaphic, and biotic factors (Ayappan & Parthasarathy 2001). A total of 221 plant species were recorded in Kedarnath valley. The species diversity of Kedarnath valley was found in the following order Herbs (144)> Trees (49) >Shrubs (28). Semwal et al. (1999) reported a total of 81 plant species including 20 tree species, 24 shrubs species, and 37 herbs species in the forests of Jardhar in Garhwal Himalaya. Kharkwal et al. (2005) carried out a study in the pine forest at different altitudes of Central Himalaya and reported a total of 56 species comprising 51 genera and 28 families, which is lower than the present study. The tree density in the present study was highest in the Kedarnath valley which ranged from 0.3 to 8.5no./ha. Sinha and Maikhuri (1998) also reported almost the same density in core and interactive zones of the Haryali sacred forest of Garhwal Himalaya. Chandrashekara & Sankar (1998) reported a stem density of the iringole sacred grove in Kerala. These values were within the values reported by Saxena and Singh (1982), Bargali et al. (1988), Pangtey et al. (1989), and Bhandari et al. (1997) for various forests of Garhwal Himalaya. Shrub density in the present study varied from 0.4 to 13.5no./ha, whereas herb density ranged between 0.2 to 22.4no./ha. These values are comparable to the reported values of Kumar et al. (2009), Uniyal et al. (2010) for a forest in Garhwal Himalaya. A/F ratio is used to interpret the distribution pattern of species. Odum (1971) stated that clumped (contagious) distribution is the commonest pattern in nature, and random distribution is found only in a uniform environment and the regular distribution occurs where severe competition between the individuals exists (Panchal & Pandey 2004). Pala et al. (2011) have reported trees, shrubs, and herbs density of 6.88 trees 100 m^{-2}, 12.8 shrubs 25 $m^{-2,}$ and 16.34 herbs m^{-2} respectively in Chanderbadni sacred forest of Garhwal Himalaya.

Total basal cover (TBC) for trees showed a range of 9.542 to 0.075 $m^2.ha^{-1}$ from the Kedarnath valley forest. The variations in the TBC in different study sites may be due to variations in the number and size of tree species in different sites. The present study values are supported by Pande et al. (2001), who observed TBC ranged from between 56.42-126 $m^2.ha^{-1}$ in a forest in Garhwal Himalaya. Vidyasagaran et al. (2005) reported the average TBC value of 25.79 $m^2.ha^{-1}$ in sacred groves of the Thrissur district of Kerala. Sinha and Maikhuri (1998) also reported TBC values of 47.59 to 26.87 $m^2.ha^{-1}$ in the core and interactive zones of the Hariyali sacred forest from Garhwal Himalaya. Sacred forests mostly show reduced forest loss than unprotected areas and higher plant species richness, canopy heights, and stem diameters (Campbell 2004). Rawat (2005) also reported TBC values between 3.74-80.36 m^2/ha for temperate forests in Garhwal Himalaya. Tripathi and Singh (2009) reported that basal area is an important indicator of tree stocking, which reflects stand volume or biomass and recorded 24.84 $m^2.ha^{-1}$ basal areas of trees in a riverine forest of Katernia ghat Wildlife Sanctuary.

Shannon diversity index ($\overline{H}$) for tree species was recorded from a minimum of 0.976 to a maximum of 3.048 in Kedarnath valley. The values of the present study were higher than the values (1.44-2.27) calculated by Looy et al. (2003) on the effect of river embankment and forest fragmentation on plant species and composition of flood plain forests in the Meuse valley, Belgium. The values of the present study were higher than the values (0.8-1.4) reported by Pala et al. (2011) in the forests along the river Ganga in the Himalayas. Shannon Wiener diversity index ($\overline{H}$) for shrub species was recorded from lowest (0.192) to highest (2.788) in the Kedarnath valley. Ram et al. (2004) reported shrub diversity from 2.6 to 3.8 for different forest types in Kumaun Himalaya. Shannon Wiener's diversity index ($\overline{H}$) for herb species was recorded from minimum (3.115) to maximum (3.787) in Kedarnath valley. The values of the present study were within the values reported for different forests by many workers (Singh & Singh, 1986, Pande et al. 2002). The values of the present study are also within the reported values (3.24 to 4.03) given by Kharkwal et al. (2005).

Several workers (Greig-Smith 1957, Singh & Yadav 1974) have reported contagious distribution in natural veg-

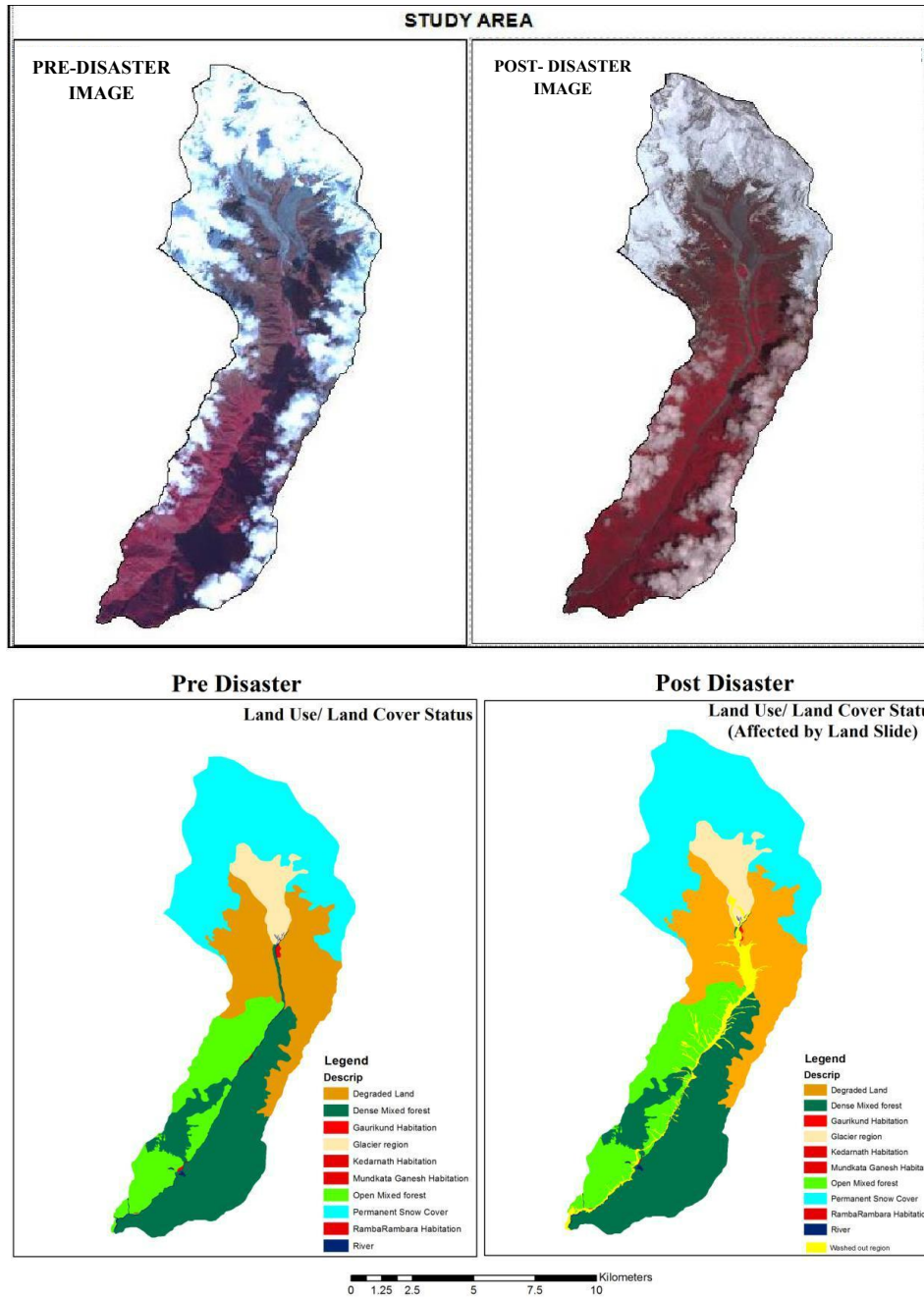

Fig. 2: Satellite imageries: Landuse landcover status of the study area pre and post-disaster of Kedarnath valley.

etation. However, shrubs and herbs were found distributed contagiously in all study sites. The regular distribution pattern was entirely absent. Mishra and Laloo (2005) and Upadhaya et al. (2004) also reported a contagious pattern of distribution for subtropical forests of North-east India. Other studies conducted within Garhwal Himalaya (Bhandari et al. 1998, Pande et al. 2002) have also shown a contagious pattern of Vegetational distribution in different forest types. Rawat et al. (2018) studied tree species richness, dominance, and regeneration status in western Ramganga valley. Bhatt et al. (2020) worked on God's tree: A culturally coded strategy for conservation in Chamoli District. Tiwari et al. (2020) also worked on weed floristic composition and diversity in paddy fields of Mandakini valley.

CONCLUSION

The current study documented that the Kedarnath valley is blessed with mainly eight types of forests that include the Himalayan Dry Temperate Forests, Dry Temperate Coniferous Forest, West Himalayan Birch/Fir Forests, Sub-alpine Pasture, Himalayan Chir-Pine Forest, Himalayan Moist Temperate Forest, West Himalayan Sub-Alpine Birch/Fire Forest, and Alpine Forest. The largest forest cover was found in Karokhi followed by Sari, Ransi, Ukhimath, Kabiltha, whereas, the lowest forest cover was recorded in Tungnath and Barasu. A total number of 221 plant species were collected and documented from the Kedarnath valley. Plant diversity in the valley encompasses 49 species of trees, 28 species of shrubs, and 144 species of herbs. The tree density in the current study was recorded highest in the Kedarnath valley which ranged from 0.3 to 8.5 no.ha^{-1}Shrub density in the present study varied from 0.4 to 13.5 no.ha^{-1}, whereas herb density ranged between 0.2 to 22.4 no.ha^{-1}. Total basal cover (TBC) for trees showed a range from 9.542 to 0.075 m^2/ha, Total basal cover (TBC) for trees showed a range of 9.542 to 0.075 m^2.ha^{-1}, and the Shannon diversity index ($\overline{H}$) for tree species was recorded from a minimum of 0.976 to a maximum of 3.048.

The Kedarnath valley consisted of patchy vegetation including many economically important plants such as medicinal herbs, timber trees wild edible plants, fodder, and fuelwood. During the Kedarnath eco-disaster that occurred in June 2013, huge damage to the forest in the riverbank of the Mandakini River was recorded due to flash floods and landslides. It was estimated that nearly 500 valuable plant species were affected by this eco-disaster.

ACKNOWLEDGEMENTS

The authors are thankful to the local people of the Kedarnath valley and VDO of tehsil Ukhimath to share their valuable knowledge, data and help in data collection. One of the authors (Chandi Prasad) thankfully acknowledges the H.N.B. Garhwal University (A Central University) for providing support during the research.

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