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

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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 m².ha⁻¹, and the Shannon diversity index (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 km², which is lower than the national average of 382 persons per km² (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-
tracts 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 Joshiama 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 km² which is 45.43% of the state’s geographical area. In the term of forest canopy density classes, the state has 4,969 km² under very dense forest, 12,884 km² under moderately dense forest; and 6, 442 km² 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 30°25’20’’ to 30°45’20’’ N and longitude 78°55’20’’ to 79°20’20’’ 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 km² 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:

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

Frequency (%):

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

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-
Mean of the circumference ($c$) = \[
\text{Sum of all cbh (circumference)} \div \text{Total number of species}
\]

Mean Basal area = \[
\frac{C^2}{4\pi}
\]

Total Basal area = Mean Basal area × 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

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

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

**(b) Relative frequency:**

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

**(c) Relative dominance:**

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

The total basal area was calculated from the sum of the total diameter of immersing stems. In trees, poles, and saplings, the basal area was measured at breast height (1.5m) and by using the formula \(\pi r^2\); 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 (\(H\)) was computed using the following formula:

\[
\text{Shannon Wiener Diversity Index (} H \text{)} = -\sum_{i=1}^{n} \left( \frac{n_i}{N} \right) \log_2 \left( \frac{n_i}{N} \right)
\]

Where, \(H\) = 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

| Study Site | Location | Latitude     | Longitude     | Altitude (m above m.s.l.) |
|------------|----------|--------------|---------------|--------------------------|
| S1         | Chandrapuri | 30°25’29.72”N | 79°04’17.68”E | 864                     |
| S2         | Kalimath  | 30°33’43.66”N | 79°05’03.29”E | 1,251                   |
| S3         | Gaundar   | 30°36’09.76”N | 79°10’47.29”E | 1,653                   |
| S4         | Tarsali   | 30°35’07.94”N | 79°01’16.97”E | 1,805                   |
| S5         | Sari      | 30°31’03.75”N | 79°08’06.71”E | 2,015                   |
| S6         | Gaurikund | 30°39’13.42”N | 79°01’26.82”E | 2,156                   |
| S7         | Trijuginarayan | 30°38’25.55”N | 78°58’30.01”E | 2,246                   |
| S8         | Kedarnath | 30°44’07.38”N | 79°04’00.57”E | 3,560                   |
| S9         | Tungnath  | 30°29’17.54”N | 79°12’59.84”E | 3,660                   |

Table 1: Study sites, their location, geographical coordinates, and elevations of the study area.
inventory of plant species, their local names, family, and ethnobotanical uses have been presented in Table 3.

**Study Site S₁**

The study site S₁ 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 S₁ 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 S₁. 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), *Euphorbia chamaesyce* (IVI: 12.127), *Reinwardtia indica* (IVI: 11.902), and *Ganatanthus pumilus* (IVI: 11.798).

**Study Site S₂**

The study site S₂ 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 S₃**

The study site S₃ (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 |
| Narayankot | 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 *Girardinia diversifolia* (IVI: 28.320). The dominant herb species were *Bidens pilosa* (IVI: 14.015), *Agrimonia pilosa* (IVI: 12.262), and *Euphorbia chamaesyce* (IVI: 11.681).

### Study Site S₄

The study site $S₄$ (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), *Rhusodendron arboreum* (IVI: 28.921), and *Neolitsea sericea* (IVI: 19.164). However, the dominant shrub species were *Sarcococca saligna* (IVI: 51.337), *Girardinia 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                          |
|-------|-----------------------------------|------------|-------------|----------------------------------------------|
| 1.    | *Abies spectabilis* (D.Don) Spach | Pinaceae   | Timber, Fuel|
| 2.    | *Aesculus indica* (Wall.ex Camb.) Hook | Sapindaceae | Medicinal, Wild edible, Fuel |
| 3.    | *Alnus nepalensis* D.Don          | Betulaceae  | Timber, Fuel |
| 4.    | *Banania variegata* L.            | Caesalpinaceae | Medicinal, Wild edible, Fuel |
| 5.    | *Betula alnoides* Buch. -Ham.ex D.Don | Betulaceae | Timber, Fuel, Fodder |
| 6.    | *Cedrus deodara* (Roxb.) G.Don    | Pinaceae    | Timber, Fuel |
| 7.    | *Celtis australis* L.             | Cannabaceae | Fodder, Fuel |
| 8.    | *Cinnamomum Spp.* Schaeff.        | Lauraceae   | Fodder, edible, Fuel |
| 9.    | *Cotoneaster affinis* Lindl.      | Rosaceae    | Fuel, Agriculture tool |
| 10.   | *Debregeasia longifolia* (Burm.F.) Wedd. | Urticaceae | Fodder, edible, Fuel |
| 11.   | *Emblica officinalis* Gaertn.     | Euphorbiaceae | Medicinal, edible, Fuel |
| 12.   | *Ficus auriculata* Lour.          | Moraceae    | Fodder, fruit edible |
| 13.   | *Ficus palmata* Forsk.            | Moraceae    | Fodder, fruit edible, medicinal |
| 14.   | *Ficus religiosa* L.              | Moraceae    | Medicinal, Fuel |
| 15.   | *Ficus semicordata* Bunch.-ham.ex J. E.Smith | Moraceae | Medicinal, Wild edible, Fuel |
| 16.   | *Fraxinus americana* L.           | Oleaceae    | Fuel, Timber |
| 17.   | *Grewia optiva* Drummond ex Burtt | Tiliaceae   | Fuel, Fodder |
| 18.   | *Hippophae salicifolia* D.Don     | Elaeagnaceae | Medicinal, Wild edible, Fuel |
| 19.   | *Holmskiodia sanguinea*           | Verbinaceae | Fuel, Fodder |
| 20.   | *Juglans regia* L.                | Juglandaceae | Medicinal, Wild edible, Fish poison, Fuel |
| 21.   | *Lyonia ovalifolia* (Wall.) Prude | Ericaceae   | Fuel, Fish Poison, Medicinal, Fodder |
| 22.   | *Mangifera indica* L.             | Anacardiaceae | Fruit edible, woodwork |
| 23.   | *Morus alba* L.                   | Moraceae    | Fruit edible woodwork, sericulture |
| 24.   | *Myrica esculenta* Buch. -Ham.ex D.Don | Myricaceae | Medicinal, Wild edible, Fish poison, Fuel |
| 25.   | *Neolitsea serobiculata* (Meisn.) Gamble | Lauraceae | Fuel |
| 26.   | *Neolitsea sericea* (Blume) Koidz. | Lauraceae | Fuel |
| 27.   | *Neolitsea Spp.* (Bent. & Hook.F.) Merr. | Lauraceae | Fuel, Timber |
| 28.   | *Phoenix humilis* Royle.          | Areaceae    | Medicinal, Wild edible, Fuel |
| 29.   | *Pinus roxburghii* Sarjent        | Pinaceae    | Wood for construction, resin, medicinal, timber |
| 30.   | *Prunus cerasoides* D.Don         | Rosaceae    | Medicinal, Wild edible, Fuel, Timber |
| 31.   | *Prunus corylifolia* (Wall. ex Royle) | 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* Wallich 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.   | *Symlocos paniculata* (Thunb.) Miq | Lodha      | Symlocaceae   | Fodder, Fuel                            |
| 43.   | *Syzygium cumini* (L.) Skeels     | Jamun      | Myrataceae    | Medicinal, Wild edible, Fuel, Timber    |
| 44.   | *Taxus 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.       | Paman,mairu | Urticaceae   | Fodder, Fuel                            |
| 48.   | *Viburnum mullaha* Buch.-Ham.ex D.Don | Malyo      | Caprifoliaceae | Fodder, Fuel, Medicinal, Wild edible    |
| 49.   | *Zanthoxylum armatum* DC          | Timaru     | Rutaceae      | Fodder, Fuel, Medicinal                  |

**Shrubs**

| S.No. | Name of Species                     | Local Name | Family        | Ethnobotanical Uses                      |
|-------|-----------------------------------|------------|---------------|-----------------------------------------|
| 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.    | *Caesalpinia 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 concinum* DC.          | Sakina     | Fabaceae      | Fodder, Fuel                            |
| 10.   | *Desmodium elegans* DC.           | Chamlai    | Fabaceae, Papilionaceae | Fodder, Fuel               |
| 11.   | *Echinops cornigenus*             | Kandara    | Asteraceae    | Medicinal, Edible                       |
| 12.   | *Elueagnus parvifolia* Wall,ex Royal | Giwain   | Elueagnaceae  | Wild edible, Medicinal, Fuel            |
| 13.   | *Girardinia diversifolia* (Link) Friis | Jhir kandali | Urticaceae | Fodder, Medicinal                       |
| 14.   | *Lantana camara* L.              | Gajar ghass | Verbenaceae  | Fuel, furniture, Medicinal, Weed        |
| 15.   | *Lonicer a 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* Wallich ex G. Don | Burans | 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.   | *Sinarundinaria anceps* (Mittf.) Chao & Ren-voize.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**

| S.No. | Name of Species | Local Name | Family   | Ethnobotanical Uses       |
|-------|----------------|------------|----------|---------------------------|
| 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. |          | Ranunculaceae | 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.   | *Boeninghausenia albiflora* | Upniya ghass | Rutaceae  | Fodder, Medicinal         |
| 30.   | *Bupleurum fruticosum* L. |          | Apiceae  | Fodder                    |
| 31.   | *Carex hirta* L. |          | Cyperaceae | Fodder                    |
| 32.   | *Carex spp.* L. |          | Cyperaceae | Fodder                    |
| 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  | Lichkura   | Amarnathaceae | Fodder, Medicinal         |
| 41.   | *Cymbopogon citratus* (DC.) Stapf    | Lemongrass  | Poaceae      | Fodder, Medicinal         |
| 42.   | *Cynodon dactylon* (L.) Pers.       | Doob       | Poaceae      | Medicinal, Fodder         |
| 43.   | *Cynoglossum zeylanicum* L.         | Ghass      | Cyperaceae, Poaceae | Medicinal |
| 44.   | *Cyperus odoratus* L.               | Poaceae    | Medicinal    |
| 45.   | *Danthonia cachmiriana* L.          | Poaceae    | Fodder       |
| 46.   | *Danthonia spp.* DC.                | Poaceae    | Fodder       |
| 47.   | *Daphne papyracea* Wall.            | Kandara    | Asteraceae   | Fodder                    |
| 48.   | *Digitaria ciliaris* (Retz.) Koeler  | Menaru     | Poaceae      | Fodder                    |
| 49.   | *Dioscorea belophylla* (Prain) Haines Syn. | Tedu    | Dioscoreaceae | Edible, Medicinal         |
| 50.   | *Dioscorea Spp.* L.                 | Farn       | Athyriaceae  | Medicinal                 |
| 51.   | *Diplazium caudatum* (Cav.) Jermy   | Lingra     | Dryopteridaceae, Athyriaceae | Edible, Medicinal |
| 52.   | *Diplazium esculentum* (Retz.) SW.  | Meen       | Araceae      | Medicinal                 |
| 53.   | *Diplazium melanochlamys* (Hook.) T.Moore | Una, fern  | Athyriaceae  | Fodder, Medicinal         |
| 54.   | *Epilobium hirsutum* L.             | Ban pindalu | Araceae     | Medicinal, Edible         |
| 55.   | *Euphorbia spp.* L.                 |            | Euphorbiaceae | Medicinal                 |
| 56.   | *Euphorbia chamaesyce* L.           |            | Zingiberaceae | Fodder, Medicinal         |
| 57.   | *Evolvulus alsinoides* (L.) L.       | Sankpushpi | Convolvulaceae | Medicinal                 |
| 58.   | *Fagopyrum esculentum* (L.) Moench. | Konlya, ougal | Polygonaceae | Fodder, Medicinal, Edible |
| 59.   | *Festuca spp.* L.                   | Grass      | Poaceae      | Fodder                    |
| 60.   | *Fragaria rubicola* L.              |            | Rosaceae     | Medicinal                 |
| 61.   | *Fumaria indica* (haussk.) Pugsl.    | Pit-papra  | Liliaceae    | Medicinal                 |
| 62.   | *Galinsoga parviflora* Cav.         | Khor type  | Poaceae      | Fodder                    |
| 63.   | *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 | Nasselxacter    | Fodder                      |
| 84.   | Lathyrus spp. L. | Kurfaly    | 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.   | Oxera coccinea L. |          | Rubiaceae       | Medicinal                   |
| 89.   | Oxyria digyna (L) Hill |          | Polygonaceae    | Medicinal                   |
| 90.   | Paonia 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 depressa Willd. | Luhurya, symlya  | Plantaginaceae   | Medicinal                   |
| 96.   | Plantago spp. L. |          | Plantaginaceae  | Medicinal                   |
| 97.   | Podophyllum hexandrum Royle | Ban kaki | Podophyllaceae  | Edible, Medicinal, Fodder   |
| 98.   | Polygonatum verticillatum (L.) All. | Malu | Caesalpiniaaceae | Medicinal                   |
| 99.   | Polygonum capitatum (Buch.-Ham. Ex D.Don) | | Remunculaceae    | Medicinal                   |
|      | Polygonum filicaule Wall. ex Meissn | | Polygonaceae     | Medicinal                   |
| 100.  | Polygonum spp. L. |          | Polygonaceae    | Medicinal                   |
| 101.  | Polygonum polystachyum Wall. ex Meissn | | Polygonaceae     | Medicinal                   |
| 102.  | Poteatilla spp. L. |          | Rosaceae        | Medicinal                   |
| 103.  | Potentilla barbata G.WOOD.ex D.Don | | Rosaceae        | Medicinal                   |
| 104.  | Potentilla fulgens L. |          | Rosaceae        | Medicinal                   |
| 105.  | Potentilla fulgens Wall. ex HK.F. | Bajaradanti | Rosaceae        | Medicinal                   |
| 106.  | Potentilla fulgens Wall. ex HK.F. | Bajaradanti | Rosaceae        | Medicinal                   |
| 107.  | Potentilla fulgens Wall. ex HK.F. | Bajaradanti | Rosaceae        | Medicinal                   |
| 108.  | Potentilla fulgens Wall. ex HK.F. | Bajaradanti | Rosaceae        | Medicinal                   |
| 109.  | Potentilla fulgens Wall. ex HK.F. | Bajaradanti | Rosaceae        | Medicinal                   |
| 110.  | Primula spp L. |          | Primulaceae     | Medicinal                   |
| 111.  | Prunella vulgaris L. |          | Lamiaceae       | Medicinal                   |
The study site S5 (2,015 m 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 species | TBA          |
|------|--------------|---------------------------|----------------------------|--------------------------|--------------|
| 1.   | Chandrapuri  | *Grewia optiva*           | *Girardinia diversifolia*  | *Galinsoga parviflora*   | *Banhinia variegata* |
| 2.   | Kalimath     | *Quercus liucotrichophora*| *Solanum viarum*           | *Pilea umbrosa*          | *Quercus leucotrichophora* |
| 3.   | Gaudar       | *Quercus liucotrichophora*| *Sarcococca saligna*       | *Bidens pilosa*          | *Quercus leucotrichophora* |
| 4.   | Tarsali      | *Quercus liucotrichophora*| *Sarcococca saligna*       | *Oplismenus hirtellus*   | *Quercus leucotrichophora* |
| 5.   | Sari         | *Quercus liucotrichophora*| *Girardinia 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* |

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

| Parameters            | Chandrapuri | Kalimath | Gaudar | 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$^3$ha$^{-1}$)              | 21.825     | 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     | 299.977| 299.99    | 300.01        | 299.99    | 300.02   |
| Shannon Index (Tree) ($\bar{H}$) | 3.028      | 3.048    | 2.901  | 3.001   | 2.918 | 2.753     | 2.636         | 1.737     | -        |
| Shannon Index (Shrub) ($\bar{H}$) | 2.788      | 2.696    | 2.629  | 2.492   | 2.594 | 2.404     | 2.047         | 0.192     | -        |
| Shannon Index (Herb) ($\bar{H}$) | 3.613      | 3.787    | 3.531  | 3.305   | 3.156 | 3.367     | 3.317         | 3.712     | 3.115    |

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

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 $S_7$ (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 pilosa* (IVI: 22.48), *Bidens pilosa* (IVI: 14.48), and *Diplazium esculentum* (IVI: 14.27).
Study Site S₈
The study site S₈ (3,568 m 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 roylei (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 S₉
The study site S₉ (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 m²ha⁻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 m²ha⁻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 m²ha⁻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 m²ha⁻¹), possibly due to a higher density of trees (Table 4 and Table 5). In the Gaurikund forest area, the total basal area was higher for Quercus liucotrichophora (4.242 m²ha⁻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 m²ha⁻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 m²ha⁻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 m²ha⁻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 m²ha⁻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 S₁, it was 3.028 for trees, 2.788 for shrubs, and 3.613 for herbs. However, for site S₂, it was found to be 3.048 for trees, 2.696 for shrubs, and 3.787 for herbs. For site S₃, it was 2.901 for trees, 2.629 for shrubs, and 3.531 for herbs. For site S₄, it was 3.001 for trees, 2.492 for shrubs, and 3.305 for herbs. For site S₅, it was 2.918 for trees, 2.594 for shrubs, and 3.1564 for herbs. For site S₆, it was 2.753 for trees, 2.404 for shrubs, and 3.367 for herbs. For site S₇, it was 2.636 for trees, 2.047 for shrubs, and 3.317 for herbs. For site S₈, it was 1.737 for trees, 0.192 for shrubs, and 2.172 for herbs. For site S₉, it was 3.115 for herbs. This pointed out the dominance of herbs and trees at sites S₁, S₂, and S₄, and the dominance of herbs at sites S₅, S₆, S₇, S₈, and S₉. The dominance of both herbs and shrubs is only at site S₆. 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 8.5 no./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 13.5 no./ha, whereas herb density ranged between 0.2 to 22.4 no./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 m², 12.8 shrubs 25 m² and 16.34 herbs m² respectively in Chanderbagni sacred forest of Garhwal Himalaya.

Total basal cover (TBC) for trees showed a range of 9.542 to 0.075 m² 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 m² ha⁻¹ in a forest in Garhwal Himalaya. Vidyasagar et al. (2005) reported the average TBC value of 25.79 m² 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 m² ha⁻¹ in the core and interactive zones of the Haryali 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 m² ha⁻¹ 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 m² ha⁻¹ basal areas of trees in a riverine forest of Katernia ghat Wildlife Sanctuary.

Shannon diversity index (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 (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 (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-
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 m²/ha, Total basal cover (TBC) for trees showed a range of 9.542 to 0.075 m²/ha, and the Shannon diversity index (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.

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