# BIODIVERSITY CONSERVATION AND RURAL LIVELIHOOD IMPROVEMENT PROJECT

## FINAL REPORT

## PLANT COMPONENT

## 2018




THE WORLD BANK

भारतीय वन्यजीव संस्थान
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# EXECUTIVE SUMMARY

The study was conducted from January 2013 - October 2017 between 1000-3900 m in Gori and Dhauli sub-watersheds in Askot landscape in Pithoragarh district of Uttarakhand under Biodiversity Conservation and Rural Livelihood Improvement Project (BCRLIP). A preliminary information was collected regarding vegetation community in the landscape through existing knowledge and reconnaissance surveys. Vegetation plots were laid to study the structure, composition and regeneration pattern in various forest communities in the landscape. Questionnaire survey was conducted in different villages to study the use pattern of various Non-Timber Forest Products and state of traditional knowledge among local communities.

A checklist of 596 species of plants was prepared including some rare and endangered species, of which 132 trees, 121 shrubs, 24 climbers, 36 orchids and 283 herbs were recorded after carrying out a reconnaissance of the landscape. The collected vegetation data was analyzed and 11 forest communities were identified based on TWINSPAN viz, *P. roxburghii, Q. floribunda, Q. leucotrichophora, Q. lanuginosa, A. nepalensis, T. dumosa, Q. semecarpifolia, M. duthiei, A. pindrow, P. wallichiana and B. utilis*. Lopping, weed infestation, forest fire and grazing are some of the threats to the plant biodiversity in the landscape. A Species richness map and disturbance level map was prepared in Arc Gis for the landscape. Based on collected information, a list of nine potential indicator species (*Polygonum, Strobilanthes, Diplazium, Ageratina adenophora, Alnus nepalensis, Quercus leucotrichophora, Quercus lanuginosa, Macaranga pustulata, Rhododendron arboreum* and *Pinus roxburghii)* were prepared. Three plant species (*Ageratina adenophora, Alnus nepalensis,* and *Quercus leucotrichophora*) were selected as indicator species, which will be used for long-term monitoring protocol to detect biodiversity change in the landscape by the local communities.

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# ABBREVIATIONS

BCRLIP- Biodiversity Conservation and Rural Livelihood Improvement Project

CBD- Convention on Biological Diversity

DBH- Diameter at Breast Height

EEA- European Environment Agency

FES- Foundation for Ecological Security

FGC- Focus Group Discussions

GPS- Global Positioning System

KII- Key Informant Interviews

MAP- Medicinal and Aromatic Plant

NBSAP- National Biodiversity Strategy and Action Plan

NRC- National Research Council

NTFP- Non-Timber Forest Product

OCA- Orchid Conservation Areas

OECD- Organisation for Economic Cooperation and Development

RET- Rare Endangered and Threatened

TBA- Total Basal Area

TWINSPAN- Two Way Indicator Species Analysis

USEPA- United States Environmental Protection Agency

VP- Van Panchayat

# CHAPTER 1

# GENERAL INTRODUCTION

## 1.1 Background

The Biodiversity Conservation and Rural Livelihood Improvement Project (BCRLIP) is multi-sectoral and multi-theme project on a landscape level, which makes it unique in many ways. The Project aims at strengthening and mainstreaming biodiversity conservation at the landscape level by improving rural livelihoods, learning and its replication, through participatory approaches. The tasks assigned to it include identifying biodiversity significant areas and the threats to various elements of biodiversity and habitats. The project was initiated in six landscape sites in different bio-geographic zones of the country. The Askot conservation landscape is one such landscape selected for this project.

Askot landscape presents a great diversity of ecosystems because of the great compression of life zones in a small geographical area. To add to the diverse conditions that such a range of altitudes produce is the landscape's special biogeographic location on east-to-west transition of flora of Himalaya, and its proximity to Tibet, that enables it to share characteristic elements and affinities. The landscape is the converging point of the Western Himalaya, the Central (Nepal) Himalaya, and the Trans-Himalaya (Tibetan-Palearctic) transitions. Starting with subtropical Sal, the biome diversity covers temperate and cool-temperate biomes with a rich mix of conifer and Broadleaved forests and moves on through sub-alpine and alpine *Betula* and *Juniper* tree-scrub with extensive alpine grasslands to snow bound peaks with extensive glaciers.

The landscape presents a great diversity of ecosystems because of the great compression of life zones in a small geographical area. It represents over 60% of its native flora as endemic to the Himalaya. To add to the diverse conditions that such a range of altitudes produces is the landscape's special biogeographic location on the east-to-west transition of the flora of Himalaya, and its proximity to Tibet, that enables it to share characteristic elements and affinities. Unique

combinations of these, and other factors such as severity of slope, varying soil depth, and moisture regimes, produce very diverse habitats within a small geographic area, for plant species that have specialized to occupy specific niches. The river valleys in their temperate and sub-tropical course also have distinct bio-climatic variation resulting in a great diversity of arboreal orchids. The inventory of vascular plants lists the presence of over 2359 species, 936 genera, and 199 families. (Compiled list by FES in NBSAP document 2004). Out of 196 threatened species, 16 have already been listed in Red data book of Indian plants and mostly are orchids and herbs.

The landscape is ecologically sensitive due to abrupt altitudinal gradients, glacial and fluvial movements and aspects and slopes create habitats for a variety of life forms of the primary products of this landscape, vegetation stands the first manifestation of life forms. As the landform features change, the vegetation communities also change their pattern. The landscape shows a predominance of typical west Himalayan forest communities (Chir pine and west Himalayan Oaks); it also represents the westernmost limit for the occurrence of East Himalayan communities like *Tsuga* and *Macaranga*. There is a great diversity of forests along an elevational gradient from the valley bottom *Macaranga pustulata* (Ramla) forest followed by Sal (*Shorea robusta*), Broadleaved lauraceous forest and Chir pine (*Pinus roxburghii*). Considering the climax communities, five species of oaks occupy the different habitats at successive altitudes viz., *Quercus glauca* (<1500m, moist slopes); *Q. leucotrichophora* (1100- 2200m; gentle, south facing slopes); *Q. lanuginosa* (1500m – 2000m; on drier slopes); *Q. floribunda* (2200- 33000 m; shady moist slopes), and *Q. semecarpifolia* (2800 – 3500m; Gentle, south–facing slopes often forming timberline). Fir (*Abies pindrow*), Birch (*Betula utilis, Betula alnoides*), Alder (*Alnus nepalensis*), Hemlock (*Tsuga dumosa*), Noble Cypress (*Cupressus torulosa*) and Blue Pine (*Pinus wallichiana*; Rawat *et al.,* 1997) are also found along the gradient.

With an altitudinal increase, a change in the vegetation is clearly visible. Higher up between 1000-3000 m mixed dominant types of *Rhododendron arboreum* (Burans*)*, *Quercus leucotrichopora* (Banj), *Lyonia ovalifolia* (Anyar) and *Myrica esculenta* (Kaphal) are first to appear. In between *Viburnum cotinifolium*, *Symplocos paniculata*, *Neolitsea umbrosa*, *Cornus macrophylla*, etc. are also seen mixed up. *Pinus roxburghii* (Chir) is the first to make appearance among the gymnosperms. These mixed forests are followed by *Quercus floribunda* (Moru), *Q semecarpifolia*

(Kharsu), *Acer* sp. (Khinia). *Prunus puddum* forest with species of *Euonymus*, *Ilex excelsa, Aesculus indica* (Pangar) and *Carpinus viminea.* Some trees, *Cotoneasters* and *Juglans regia* (Akhrot) also make scattered appearance. At certain places pure stands of *Pinus roxburghii*, *Cedrus deodara*, *Taxus wallichiana, Abies pindrow* (Ransula) make a sight to watch. Still higher up is *Betula utilis* (Bhojpatra) that forms the tree limit in this part of Himalaya. Above this altitude shrubby or *herbaceos* plants like species of *Hippophae*, *Juniperus*, *Saussurea*, *Primula*, *Corydalis*, *Pleurospermum*, *Rheum*, *Rhododendron anthopogon*, *Meconopsis aculeata*, etc. make the vegetational cover. (KSLCI, 2010)

**1.2 Ecological studies in Askot**

Dhar et al. (1997) describe some of the biodiversity values in the Askot Wildlife Sanctuary as a base. Rawat (1984) and Samant (1987) worked on floral richness in Alpine region of Pithoragarh District. Dhar *et al.* (1997) worked mainly on composition of forests; Samant *et al.* (1998) worked on diversity of orchids in Gori valley and Adhikari (2009) on coarse woody debris. Uniyal *et al*. (2002) and Bhatt *et al.* (2009) worked on ethnomedicinal plants. Samant et al. (1995) and Jalal (2008) worked on orchids, while Garbyal *et al.* (2005) worked on livelihoods and lifestyle of Askot landscape.

**1.3 Objectives of the study**

The study continued over a period of five years to study Gori and Dhauli valley intensively. The first two years were utilized to study Gori valley from sub tropical to tree line and Dhauli valley over the next two years with the following objectives

1. To study structure and composition of forest communities in the landscape
2. To assess dependence of local communities on NTFPs
3. To understand status of regeneration in dominant tree species
4. To identify potential indicator species
5. To prepare monitoring protocol for the selected indicator species

### 1.4 Study area

Askot landscape lies between the 80° to 81° 5’ E Longitude, and 29° 5’ to 30° N Latitude in Pithoragarh district of Uttarakhand state at the tri-junction of the borders of Nepal, India, and Tibet (China). It encompasses an area of 4463 square kilometers. Area for Askot Wildlife Sanctuary is 600 km² comprising of 289 km² Reserved Forests, 225 km² Civil and Van Panchayats (VP) and 85 km² of Agriculture lands. There is a great altitudinal range from 560 m at Jauljibi to over 7434 m asl at the summit of Nandadevi East (Figure 1). The landscape is physiographically a mix of lower, mid and higher Himalaya, spread from sub-tropical to alpine altitude zones. There are four sub-watersheds in the landscape - Gori, Dhauli, Dharchula, and Kuti. The landscape consists of steep to very steep high mountains and deep narrow valleys. The valleys widen as they approach lower elevations.

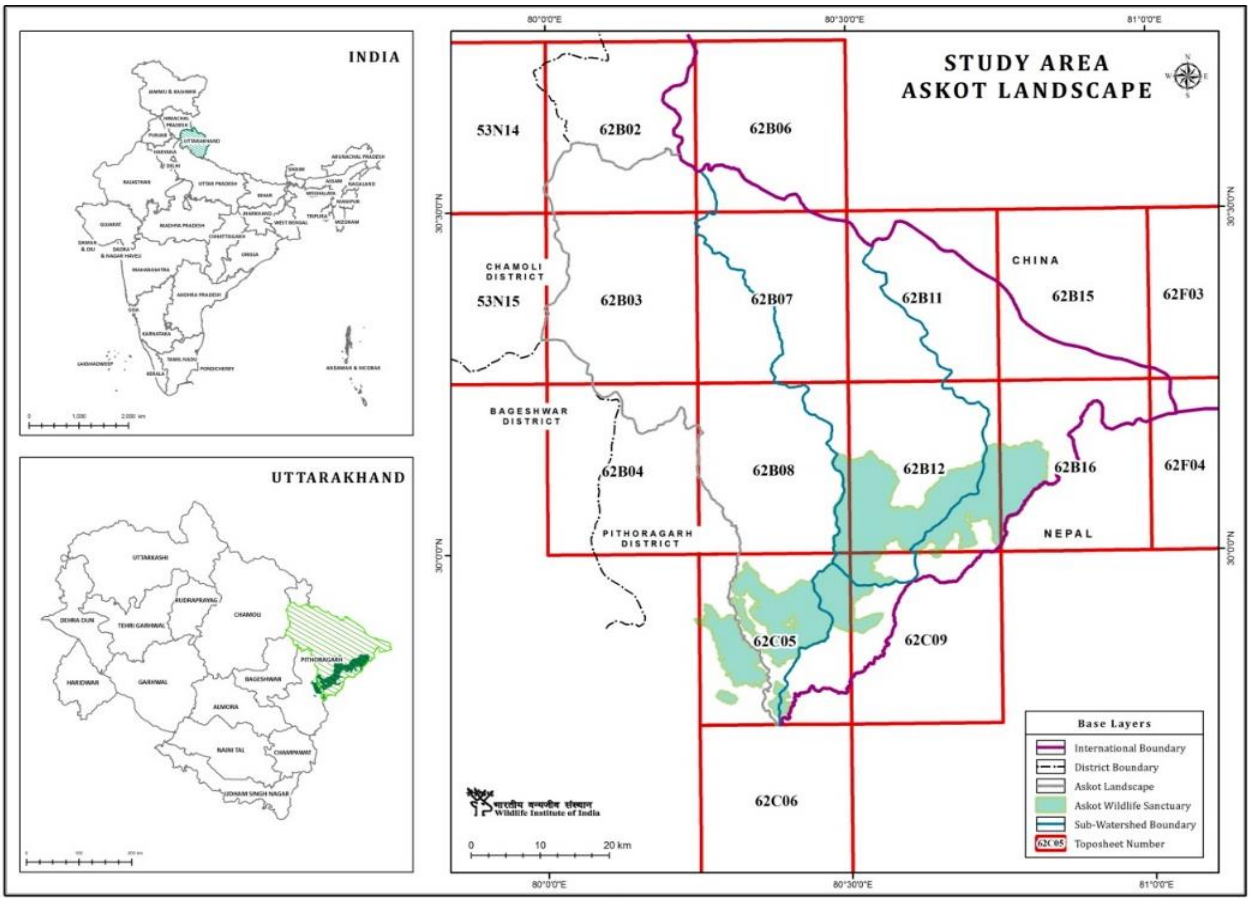


Figure 1. Map of Askot landscape

### 1.4.1 The description of studied sites in Askot Landscape

The two valleys studied for vegetation structure and composition were Gori valley (Baram - Najrikot - Rilkot - Milam) and Dhauli valley (Tijam - Sumdum - Sela - Sipu). Baram is the relatively large flat valley in Gori valley with good orchid population, dominated by warm temperate Chir pine forest in the upper slopes, while the riverside lower valley is dominated by sub-tropical Sal and riverine Macaranga forest. Kanar is rocky, steep slope with extensive agricultural fields along warm temperate mixed forests, mainly dominated by Oak species. Nazrikot occurs in sub alpine climatic zone dominated by *Rhododendron campanulatum*, *Betula utilis* and *Abies pindrow*, while *Danthonia* is the major grass species in the sub alpine region. Rilkot and Milam are temporary settlements of herders during the summer season in the glaciated valley and seasonal cultivation of medicinal plants from such ecologically high sensitive area is detrimental to loss of biodiversity. Sela village is in moderate slope, relatively lower density of human population support warm temperate mixed forests whereas Sipu the last village in Dhauli valley forms sub-alpine forest mainly *Pinus wallichiana, Betula utilis, Abies pindrow* etc. (Figure 2).

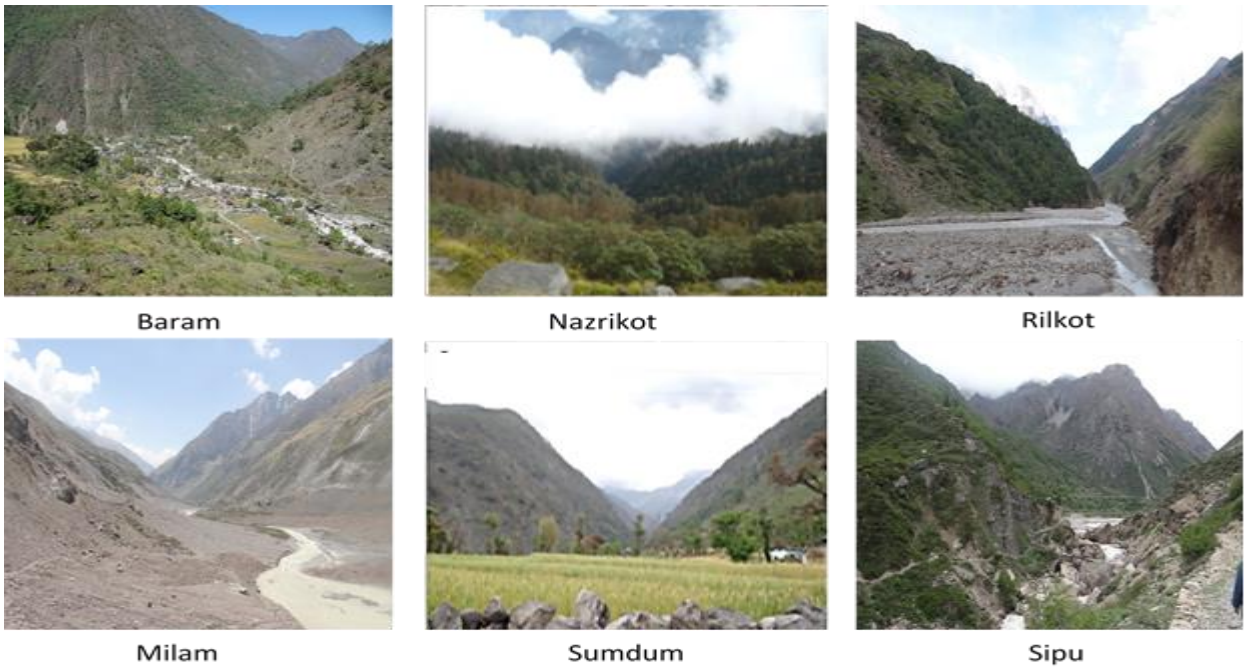


Figure 2. Studied sites in different valleys of Askot landscape

CHAPTER 2

# VEGETATION STRUCTURE AND COMPOSITION

## 2.1 Introduction

It is very crucial to study the structure and composition to understand the landscape vegetation community. The studies on vegetation community, structure and composition reflect the ecosystem properties and ecological conditions of an area, which form the bases for further scientific research and management of an area. The constituent elements of vegetation such as plant species and their assemblages also form the component of the biodiversity of a region that depends on various factors such as elevation, aspect, soil, geology, topography, orography and anthropogenic pressures. This study aims to understand the landscape from the perspective of vegetation that grows over this landscape, which has been designed to create baseline data on vegetation community.

A very few studies have been done on the structure and composition aspect in this landscape. Dhar *et al.* (1997) studied the structural biodiversity of forest vegetation and identified seven forest communities in Askot Sanctuary. Samant *et al.* (1998) studied biodiversity status of protected area. Hussain *et al.* (2008) studied the species composition and community structure in Askot Wildlife Sanctuary. This study creates a baseline information on vegetation aspect for the landscape.

## 2.2 Methodology

To study the structure and composition of various forest communities and their patterns in the landscape the methodology followed was based on initial reconnaissance and existing knowledge of the area, four sites were selected in the two valleys (Gori and Dhauli) of the landscape. In each study site (*ca.* 1 ha), three 10m radius circular plots were laid within each hectare plot for trees using stratified random sampling across different forest community and elevation gradient to

assess vegetation structure and composition. For the study of shrub, climber, sapling, and seedlings of trees circular plot of 5 m radius and for herbs four quadrats (1x1 m) were taken. The smaller plots for shrubs and herbs were laid within the larger (10 m radius) plots using the same center. Quadrats of 1x1m were placed in four directions just outside the circle. Parameters such as GPS location, altitude (m), slope (°), aspect, total number of species, circumference at breast height (dbh at 1.37 m), tree height (m), % canopy cover (tree and shrub), % ground cover (Herb, Grass, Soil,) disturbance (lopping, logging, grazing and fire) and presence of plants with economic importance (MAPs, NTFPs) were recorded for all the trees (Figure 3).

The regeneration pattern was assessed through the plot data following Misra (1968). In each plot, trees with >30 cm dbh (diameter at breast height, i.e., at 1.37 m from the ground) were measured individually for dbh. Each plot was subdivided into 5 m circular plots for examining the saplings (individuals <30 cm dbh) and established seedlings (individuals <3.3 cm and <30 cm in height). Data from all sites were pooled for each forest type. To estimate the population structure of each tree species, the following dbh classes were distinguished: A: seedling, B: sapling, C: 30-60 cm, D: 60-90, E: 90-120, F: 120-150, G: 150-180, H: 180-210, I: 210-240, J: 240-270, K: 270-300 and L: >300 cm. The total number of individuals belonging to each of the mentioned classes was calculated for each species in each forest type. The density of each species in each dbh class was calculated from the number of individuals in that class.

### 2.3 Data Analysis

#### 2.3.1 Structure and composition

The structural aspects of vegetation were quantitatively analysed for density, frequency and total basal area following Curtis and McIntosh (1950), Misra (1968) and Muller- Dombois and Ellenberg (1974), however, Importance Value Index (IVI) was calculated by summing up the relative values of density, frequency and total basal area (Curtis, 1959). Two-way indicator species analysis (TWINSPAN in PC-ORD, version 4.34 software) following Hill (1979) software was done for forest community classification. Plant identification was done by Osmaston (1928) and Polunin and Stainton (1984).

### 2.3.2 Species diversity, richness, and evenness

Species richness is measured as the number of species in a unit area. Species diversity was computed using PAST software for Shannon diversity index, (Magurran, 2004). To assess, how evenly the species are distributed, evenness was calculated in PAST software. The value ranges between zero and one. If the evenness value is higher, the variation in habitats between the species would be less and vice-versa.

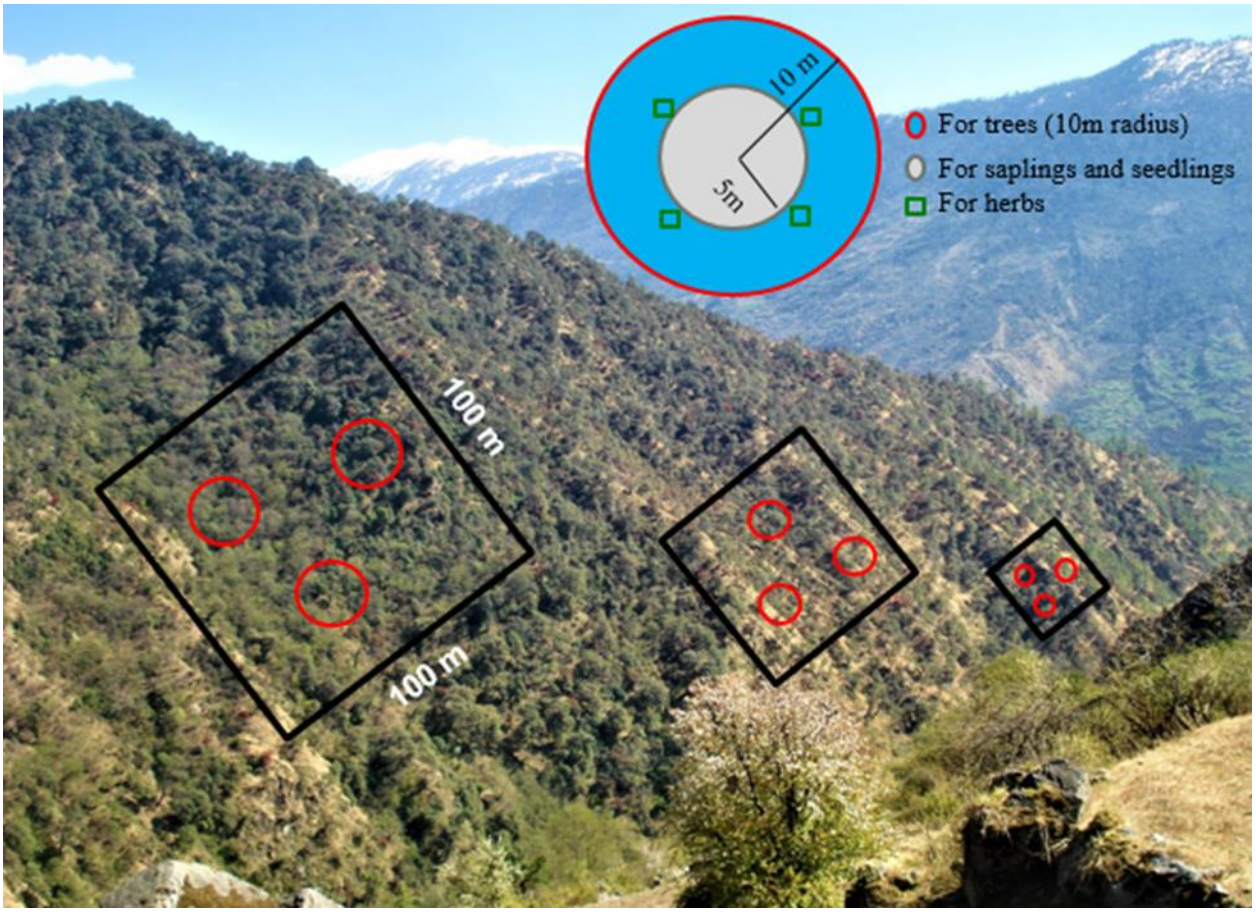


Figure 3. Stratified Random Sampling

## 2.4 Results and Discussion

### 2.4.1 Structure and composition

A total of 116 sites comprising of 348 plots were laid for vegetation sampling in all four pilot sites across the two valleys. The total number of plots in Gori and Dhauli valleys were 165 and 183

respectively from 1000- 3900 m asl. The Plant diversity recorded was 596 species with 117 families and 397 genera. Out of 596, 582 were Angiosperms and 14 were Gymnosperms. Among them, herbs possess the highest growth forms (48%) followed by trees (22%), shrubs (20%), orchids (6%) and climbers (4%, Figure 4). A checklist of 596 plants (excluding unidentified plants) were prepared encountered during the vegetation survey (Annexure I).

The size and number of quadrats needed were determined using the species-area curve (Misra, 1968). The relationship between number of plots and tree species found within studied plots was predicted through Colemon rarefaction curves (Colemon, 1981) using PAST. For adequate number of sampling plots, the species accumulation curve was prepared with diversity index 58 and Chao index 60.3 (Figure 5).

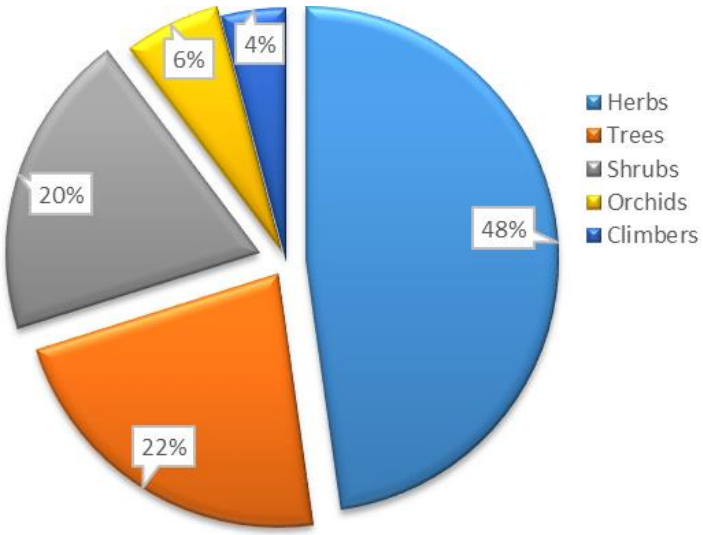


Figure 4. Percentage of habit forms

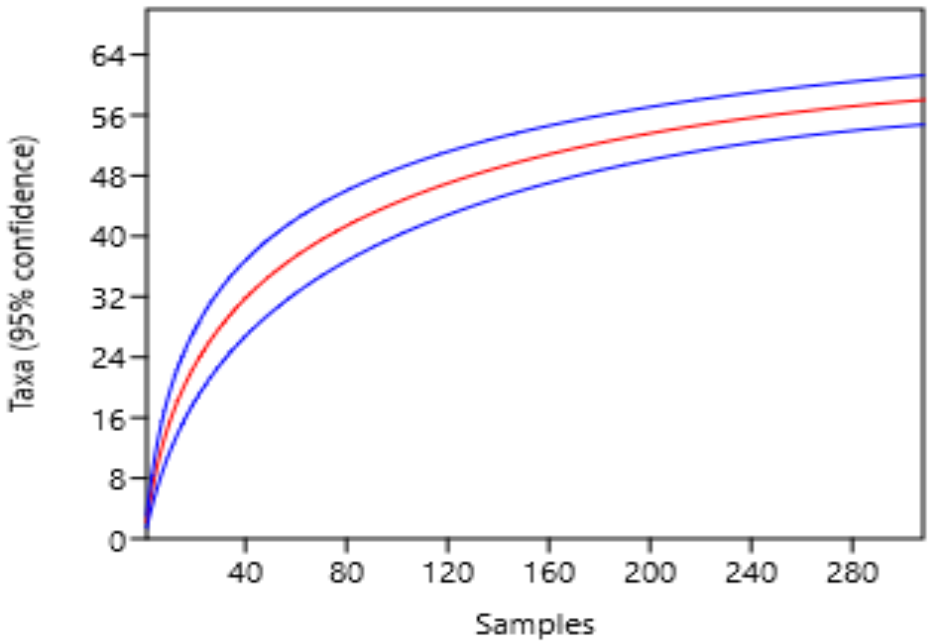


Figure 5. Species accumulation curve

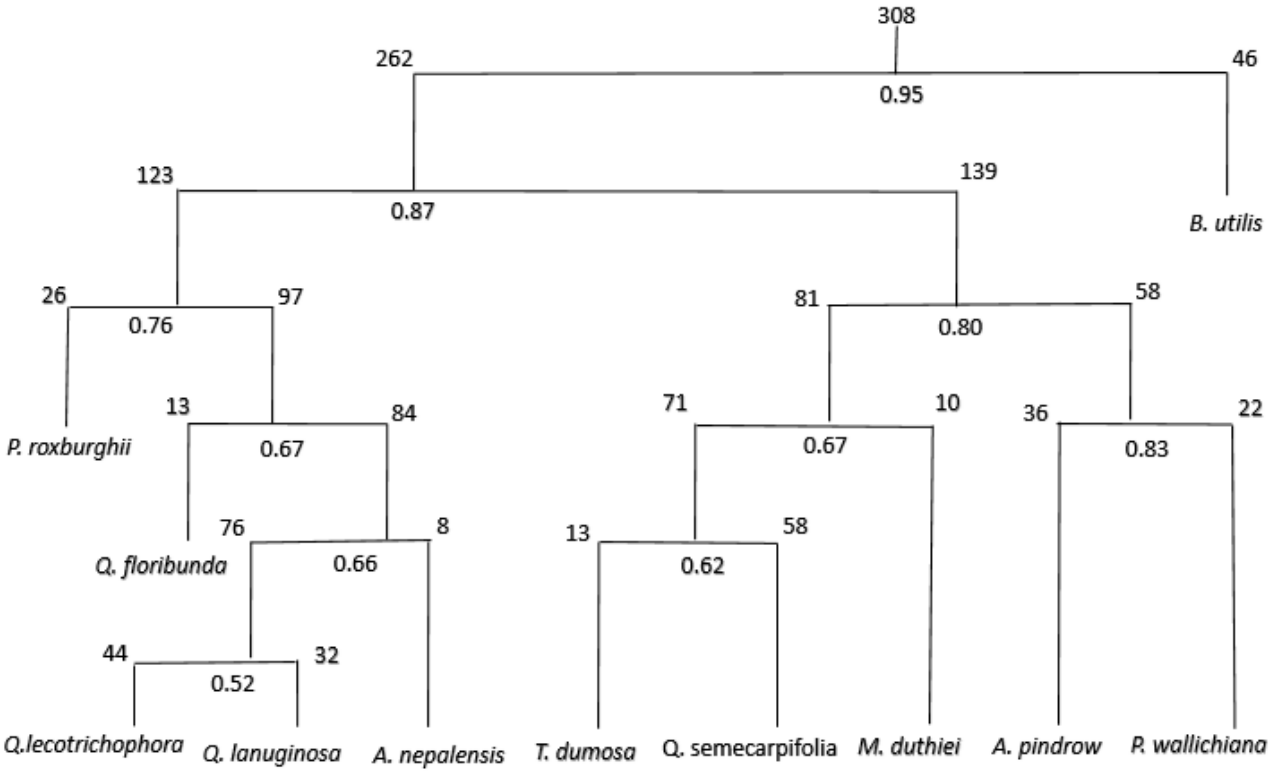


Figure 6. Dendrogram showing tree communities in Askot landscape

Eleven forest communities were identified in the two valleys of the landscape viz. *P. roxburghii* (900-1500 m), *Q. floribunda* (2000-2500 m), *Q. leucotrichophora* (1100-2200 m), *Q. lanuginosa* (1500-2000 m), *A. nepalensis* (600-2000), *T. dumosa* (>2300 m), *Q. semecarpifolia* (2800-3500 m), *M. duthiei* (scattered), *A. pindrow* (>2500 m), *P. wallichiana* (2800-3400) and *B. utilis* (>3000 m). A total of 26 sites were sampled for *P. roxburghii* forest and 22 tree species were recorded. 13 sites for *Q. floribunda* forest with 14 tree species, 44 for *Q. leucotrichophora* with 20 species and 32 for *Q. lanuginosa* with 21 tree species. Similarly, 8 sites were sampled for *A. nepalensis* forest and 4 species were recorded, 13 sites for *T. dumosa* with 9 species, 58 for *Q. semecarpifolia* with 23 species and 10 sites for *M. duthiei* forest with 8 tree species. 36 sites were sampled for *A. pindrow* forest and 8 tree species were recorded, 22 sites for *P. wallichiana* with 4 species and 46 sites for *B. utilis* with only three tree species in the landscape (Figure 6).

Among different forest communities identified in the landscape (Figure 7), Chir pine, Falyant oak, and Rianj oak form the typical forest in Gori valley, whereas Horse chestnut, Hemlock and Blue pine in Dhauli valley. The average tree density was highest for *Alnus nepalensis* (195.06±16.21 trees $ha^{-1}$) ranging between 32 to 350 in Alder forest followed by *Machilus duthiei* (184.71±15.12 trees $ha^{-1}$) ranging between 64 to 414, *Q.leucotichophora* (169.33±5.11 trees $ha^{-1}$) from 32 to 350 and *Pinus wallichiana* (147.65±5.88 trees $ha^{-1}$) from 64 to 255. The average tree density is lowest for *T. dumosa* (100.85±7.18 trees $ha^{-1}$) ranging between 64 to 127. *Q. lanuginosa* forest has the highest total density (1632.61±149.21) with 32 sampled sites followed by *Q.leucotichophora* (1449.69±161.99) with 44 sites whereas it was minimum for B. utilis (302.19±10.34) with 46 sampled sites (Table 1).

The average tree basal area was recorded highest for *Tsuga dumosa* (58.65±11.82 trees $ha^{-1}$) with 13 sampled sites in Hemlock forest followed by *Alnus nepalensis* (32.94±4.13 trees $ha^{-1}$) with 8 sites in Alder forest. TBA *of Q.semecarpifolia* was recorded 24.55±1.84 trees $ha^{-1}$ in 58 sites and basal area for Abies *pindrow* was recorded 21.87±2.71 trees $ha^{-1}$ with 36 sites in Kharsu and Fir forest respectively. The TBA measurements of trees indicates that arboreal species in this part of Askot form an important component of the vegetation.

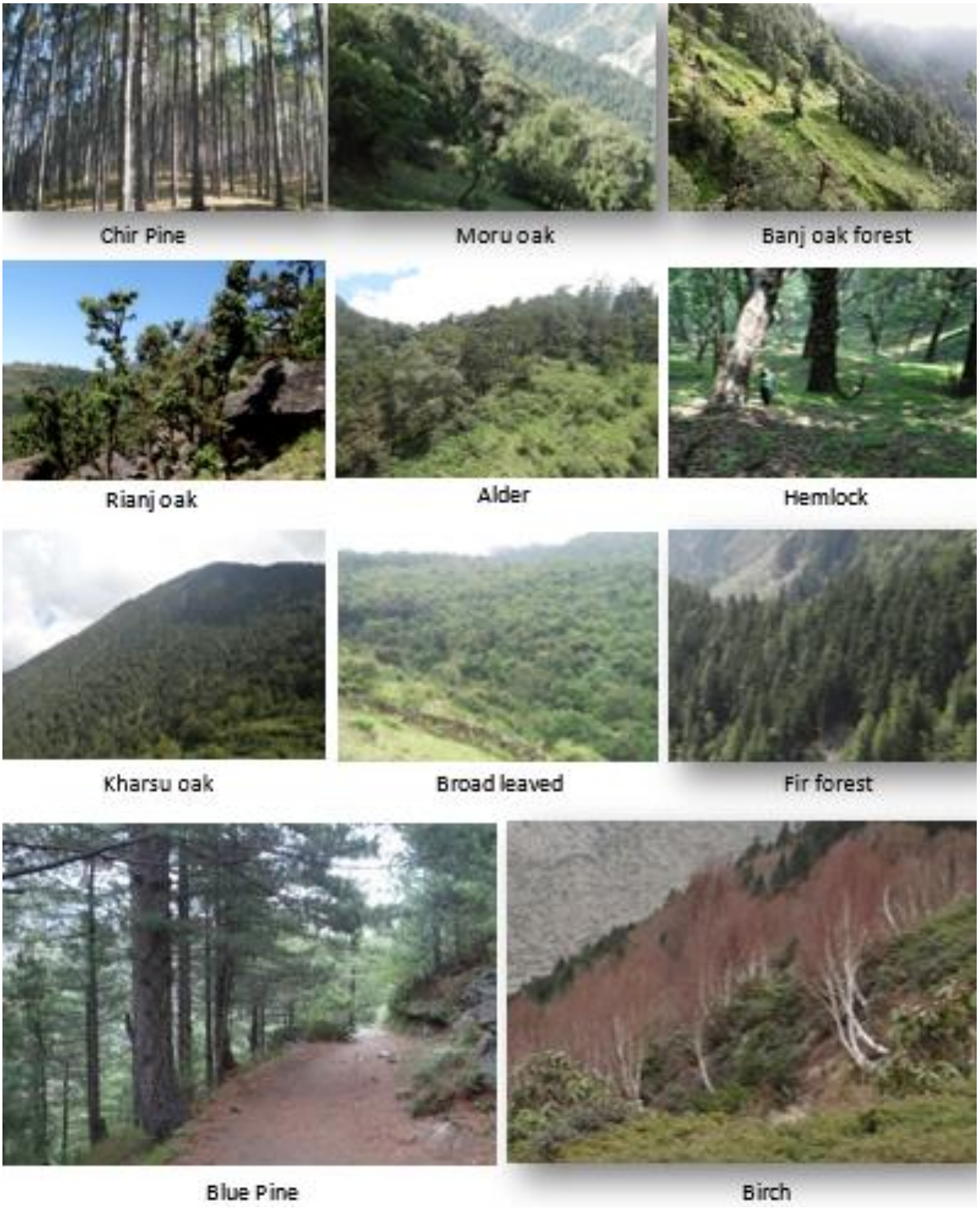


Figure 7. Different Forest communities in Askot landscape

Table 1. Ecological parameters of dominant species in different forest communities (Density (trees $ha^{-1}$), TBA (Total Basal Area, $m^2$ $ha^{-1}$ and IVI, Importance Value Index).

| Forest community | Site | Dominant species | Average | |
|---|---|---|---|---|
| | | | Density | TBA |
| ***Pinus roxburghii*** | 26 | *Pinus roxburghii* | 144.25±9.26 | 18.37±1.04 |
| | | *Q.leucotichophora* | 60.51±7.27 | 6.98±1.31 |
| | | Others (20) | 959.39±63.34 | 54.49±8.65 |
| | | Total | 1164.15±79.87 | 79.85±11.61 |
| ***Q. floribunda*** | 13 | *Q. floribunda* | 147.29±7.37 | 11.35±0.86 |
| | | *Aesculus indica* | 53.08±16.45 | 10.18±2.53 |
| | | Others (12) | 771.91±89.11 | 55.36±5.08 |
| | | Total | 972.29±103.73 | 76.89±7.86 |
| ***Q.leucotichophora*** | 44 | *Q.leucotichophora* | 169.33±5.11 | 10.34±0.81 |
| | | *Q.glauca* | 92.36±10.22 | 7.83±1.29 |
| | | Others (18) | 1188±146.65 | 51.46±13.04 |
| | | Total | 1449.69±161.99 | 69.63±15.13 |
| ***Q.lanuginosa*** | 32 | *Q.lanuginosa* | 108.57±5.86 | 12.23±1.57 |
| | | *R. arboreum* | 115.26±6.68 | 5.70±0.75 |
| | | Others (19) | 1408.78±136.66 | 143.61±13.13 |
| | | Total | 1632.61±149.21 | 161.54±15.45 |
| ***Alnus nepalensis*** | 8 | *Alnus nepalensis* | 195.06±16.21 | 32.94±4.13 |
| | | Others (3) | 127.39 | 13.10 |
| | | Total | 322.45±16.21 | 46.05±4.13 |
| ***Tsuga dumosa*** | 13 | *Tsuga dumosa* | 100.85±7.18 | 58.65±11.82 |
| | | *Taxus wallichiana* | 98.44±5.70 | 32.48±3.60 |
| | | Others (7) | 239.35±29.45 | 60.38±45.03 |
| | | Total | 438.64±42.34 | 151.52±60.46 |
| ***Q.semecarpifolia*** | 58 | *Q.semecarpifolia* | 116.77±3.96 | 24.55±1.84 |
| | | *Taxus wallichiana* | 74.31±27.80 | 17.46±5.07 |
| | | Others (21) | 1034.07±122.24 | 153.07±34.31 |
| | | Total | 1225.15±153.99 | 195.08±41.22 |
| ***Machilus duthiei*** | 10 | *Machilus duthiei* | 184.71±15.12 | 9.12±0.93 |
| | | *Q.semecarpifolia* | 63.69±13.00 | 9.15±1.89 |
| | | Others (6) | 334.39±13 | 77.05±1.38 |
| | | Total | 582.80±41.12 | 95.33±4.19 |
| ***Abies pindrow*** | 36 | *Abies pindrow* | 128.30±3.47 | 21.87±2.71 |
| | | *Betula utilis* | 86.44±9.16 | 3.47±0.30 |
| | | Others (6) | 292.69±15.29 | 23.75±8.85 |
| | | Total | 507.43±27.92 | 49.08±11.86 |

| | | | | |
|---|---|---|---|---|
| ***P.wallichiana*** | 22 | *P.wallichiana* | 147.65±5.88 | 16.82±1.17 |
| | | *Abies pindrow* | 95.54 | 3.33±0.06 |
| | | Others (2) | 159.24 | 13.62 |
| | | Total | 402.43±5.88 | 33.77±1.23 |
| ***Betula utilis*** | 46 | *Betula utilis* | 142.96±3.63 | 5.29±0.25 |
| | | *Abies pindrow* | 95.54±6.71 | 6.24±0.64 |
| | | Others (1) | 63.69 | 5.22 |
| | | Total | 302.19±10.34 | 16.76±0.89 |

**2.4.2 Species diversity, richness, and evenness**

Average diversity is maximum for *Q. lanuginosa* forest (1.199) and it ranged between 0.4 to 1.7 followed by *Pinus roxburghii* (0.815), *Q. leucotrichophora* (0.811) and *Q. semecarpifolia* (0.753) forests whereas it was minimum for *P. wallichiana* (0.141) ranging between 0-0.7 followed by *Betula utilis* (0.090). Evenness was recorded 0.8 for all the layers (tree, shrub, and herb). Evenness was recorded highest for *A. nepalensis* (1.00±0.002) ranging to one and minimum for *Q. leucotrichophora* (0.86±0.01) ranging between 0.6 to 1.

Beta diversity is the change in the species composition along an elevation gradient. The Beta diversity along with the five climatic zones in the two valleys is shown in Figure 8. It was found the maximum in a warm temperate zone for both the valleys as it forms the transition zone between the subtropical and cool temperate zone and indicates that warm temperate zone is more diverse which forms Pine, Banj, Rianj and Broadleaved forests. The Alpine zone had minimum BD as the forests in this zone form the high elevation pure stands like birch and fir forests. It was recorded 14.5 between 300-3600 m elevations for Kumaon (Singh *et al.,* 1991), whereas it is 12.51 between 1000-3900 m for Askot landscape.

The species richness in different forest types ranged between 3-23 for trees. It varies considerably across the great elevation range and number of sampling sites with maximum number of species in *Q. semecarpifolia* (23) followed by *Pinus roxburghii* and *Q. lanuginosa* (22), whereas lowest in *B. utilis* (3), *Alnus nepalensis* (4) and *P. wallichiana* forest (4) in sampled plots as they form the pure stands (Table 2).

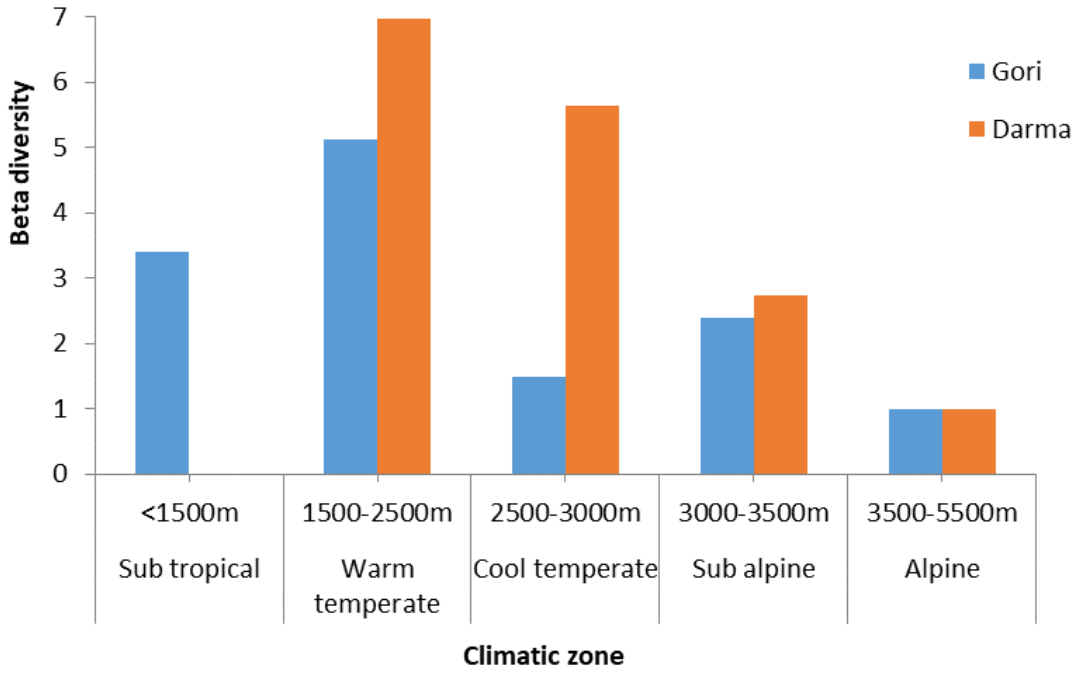


Figure 8. Beta diversity of Gori and Dhauli valley along climatic zone

Table 2. Species diversity, richness and evenness in different forest community. In parentheses the values are in average

| **Forest community** | **Diversity range (average)** | **Species richness** | **Evenness range (average)** |
|---|---|---|---|
| *Pinus roxburghii* | 0- 1.8 (0.815±0.09) | 22 | 0.7- 1 (0.89±0.01) |
| *Q. lanuginosa* | 0.4- 1.7 (1.199±0.05) | 22 | 0.7- 1 (0.87±0.01) |
| *Q. floribunda* | 0- 1.5 (0.696±0.16) | 14 | 0.8- 1 (0.91±0.02) |
| *Q.leucotichophora* | 0- 1.8 (0.811±0.07) | 20 | 0.6- 1 (0.86±0.01) |
| *Alnus nepalensis* | 0- 1.1 (0.222±0.15) | 4 | 1.0- 1 (1.00±0.002) |
| *Tsuga dumosa* | 0- 1.3 (0.699±0.10) | 9 | 0.8- 1 (0.89±0.01) |
| *Q.semecarpifolia* | 0- 1.5 (0.753±0.04) | 23 | 0.7- 1 (0.90±0.01) |
| *Machilus duthiei* | 0- 1.1 (0.571±0.14) | 8 | 0.7- 1 (0.90±0.03) |
| *Abies pindrow* | 0- 1.1 (0.360±0.05) | 8 | 0.8- 1 (0.95±0.01) |
| *P.wallichiana* | 0- 0.7 (0.141±0.05) | 4 | 0.8- 1 (0.98±0.009) |
| *Betula utilis* | 0- 1.0 (0.090±0.03) | 3 | 0.8- 1 (0.99±0.004) |

A species richness map was prepared to show the high conservation zones in the study area (Figure 9). The species richness, which consists of all three layers tree, shrub and herb, were categorized into three high, medium and low level. One point depicts one sampled site out of 116. The red color depicts the high species richness present in lower reaches of Gori valley as the forests were mostly oak dominated. Lower reaches of Gori valley and Dhauli valley forests had medium species richness shown by blue color points. The black color depicts the low species richness present in upper reaches of Gori and Dhauli valley as these forests fall in the sub-alpine climatic zone and forms pure stands.

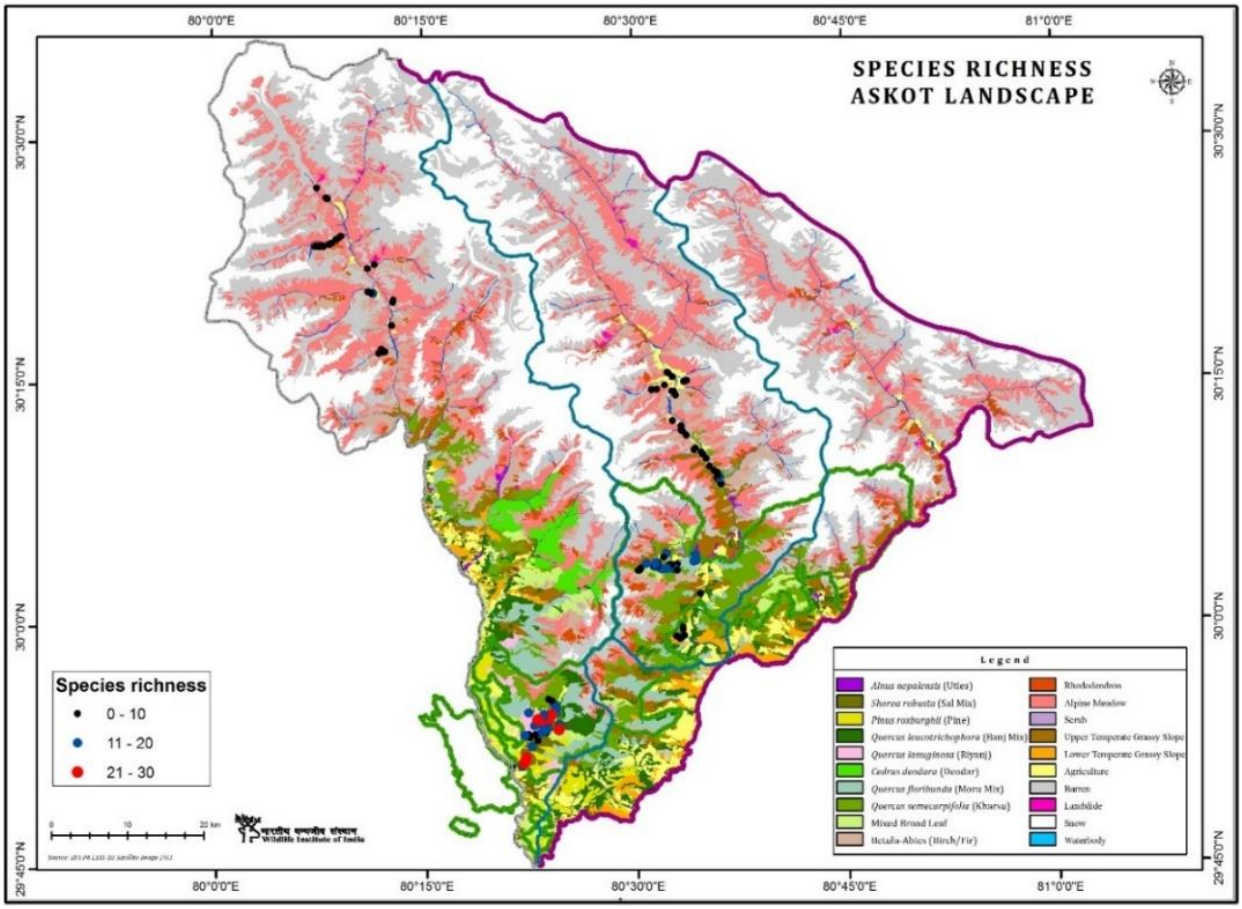


Figure 9. Map showing plant species richness in Askot landscape

### 2.4.2.1 Floristic Diversity

During vegetation explorations, a new orchid *Dendrobium longicornu* was recorded from Gori valley, which is a new record for Uttarakhhand and an addition to Orchid flora of Western Himalaya (Bisht and Adhikari, 2014, Annexure II) that increased the number to 122 orchids in Gori Valley.

## 2.5 Regeneration Pattern

Population (age) structure of a species in a forest can convey its regeneration behaviour. Population structures, characterized by the presence of a sufficient population of seedlings, saplings and young trees, indicate a successful regeneration of forest species. The success or failure of regeneration in the stand depends on abiotic, biotic, and anthropogenic factors. Important abiotic factors that affect forest regeneration are soil, available light, local weather history, climate change etc. whereas biotic factors are native and non-native competing vegetation including invasive species, herbivory, available seed sources, seed production, and seed predation. Species diversity is maintained through regeneration of component species.

To assess the status of regeneration (Population structure) in dominant tree species in a forest community the collected data for circumference was pooled for girth classes arbitrarily following Ralhan *et al*. (1982) and Rikhari *et al*. (1991). Most of the dominant species showed more girth trees with less number and more seedling and saplings (with small girth trees relative to the larger ones) which is usually taken as an indicator of stable and self-regenerating forest and present a low extinction risk (Figure 10).

In this study, population structure of individual species varied across different forest sites. Among oaks, Q. leucotrichophora with seedling (1910.83 indi ha-1) and sapling density (1401.27 indi $ha^{-1}$) indicates that regeneration was not as low as has been previously reported. Moru forest is dominated by *Q. floribunda* with seedling (127.39 indi $ha^{-1}$) and no sapling. Rianj forest is dominated by *Q. lanuginosa* with seedling (4331.21 indi $ha^{-1}$) and sapling density (1910.83 indi $ha^{-1}$). Kharsu forest is dominated by *Q. semecarpifolia* with seedling (636.94 indi $ha^{-1}$) and sapling density (4076.43 indi $ha^{-1}$). Among conifers, Pine forest is dominated by *P. roxburghii* with the greatest seedling (6751.59 indi $ha^{-1}$) and sapling density (891.72 indi $ha^{-1}$). The Blue pine forest is

dominated by *Pinus wallichiana* with 3057.32 indi $ha^{-1}$ seedling and 5477.71indi $ha^{-1}$ sapling density. In Fir forest, the dominant species is *Abies pindrow* with 1910.83 indi $ha^{-1}$ seedling and 5987.26-indi $ha^{-1}$ sapling density. The Hemlock forest is dominated by *Tsuga dumosa* with 636.94 indi $ha^{-1}$ seedling and no sapling.

Among the oaks, *Q. leucotrichophora, Q. lanuginosa* and *Q. semecarpifolia* had good regeneration in the respective forests except *Q. floribunda*. Poor *regeneration of saplings of Q. floribunda* is due to severly-lopped trees, which failed to convert from seedlings to saplings. In conifers, *Pinus roxburghii, Pinus wallichiana* and *Abies pindrow* had good regeneration in the respective forests whereas *Tsuga dumosa* had poor regeneration. The *Tsuga dumosa* and *Betula utilis* supported old mature trees and lack age class diversity in Hemlock forest and Birch forest respectively due to anthropogenic pressure, competition among species, restricted distribution or climatic issues.

In addition to this, oaks have tremendous ability to regenerate through coppicing. *Q. floribunda* is able to regenerate in the moderately disturbed sites when there is no disturbance. *A. nepalensis* is able to regenerate under its own canopy. This species is referred to the first colonizer of the bare site and is able to colonize the landslide sites. A lack of age class diversity in different forest radically alter future forest conditions and management needs.

The issue is important because a lack of tree reproduction threatens the sustainability of forest values. If further disturbance were restricted the oak forest would be revived. Thus, the study indicates that both the level of disturbance and the nature of species strongly affect regeneration. It is also evident that large areas need to be maintained for conservation of the spatio-dynamic nature of the different forest.

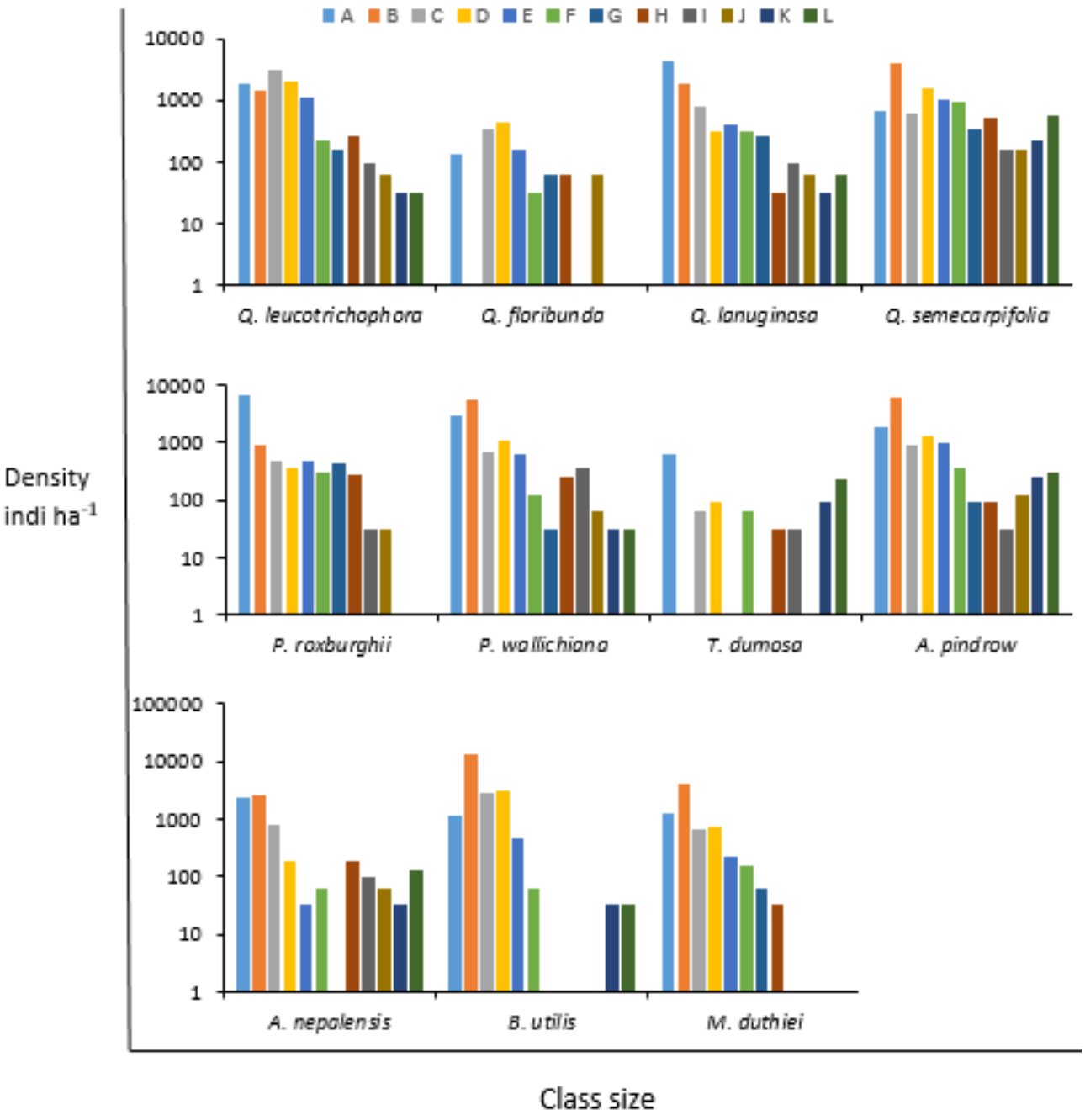


Figure 10. Population structure of dominant tree species in respective forest communitites where A- seedling, B- sapling, C- 30-60 cm, D- 60-90, E- 90-120, F- 120-150, G- 150-180, H- 180-210, I- 210-240, J- 240-270, K- 270-300, L- >300 cm.

CHAPTER 3

# DEPENDENCE OF LOCAL PEOPLE ON NON-TIMBER FOREST PRODUCTS

## 3.1 Introduction

Forests play a central role in economic, cultural and socio-political systems. The entire lives and livelihoods of people revolve around forests. Non-Timber Forest Products (NTFPs) play an important role in supporting rural livelihoods and food security. The present was conducted to explore the spectrum of rural livelihood contributions of NTFPs. People who live in reasonably remote areas traditionally depend on local forest products because they are more easily available and inexpensive. Forest supplies wood, poles, and dwarf bamboo to rural people for the building of houses, construction of plough and handcrafts etc. Various seeds, roots, flowers, fruits, mushrooms, lichens etc. are collected by forest dwellers to supplement their meager food supply. Locals use them because they have less alternative access to food and income. In a landscape like Askot, where a large rural population reliant on forest produce for their sustenance, NTFPs play a major role. At the same time, NTFPs collection should not hamper the environmental objectives such as conservation of forest and biological diversity.

## 3.2 Methodology

To study the use pattern of NTFPs and state of traditional knowledge among local communities the methodology used was based on the questionnaire survey. Initially, a quick reconnaissance survey was conducted that encompassed of short visits to the different areas and villages. Sixty toks of 36 van Panchayats were surveyed from 600 to 3500 m (Figure 11). Twenty-five percent households of each VP were interviewed for use of natural resources viz., fodder, fuelwood, timber and medicinal plants. The quantitative data were collected on NTFPs through focus group discussions (FGD), key informant interviews (KII) and personal field observations. For data analysis, qualitative information observed and collected at the field study sites were used to justify the results.

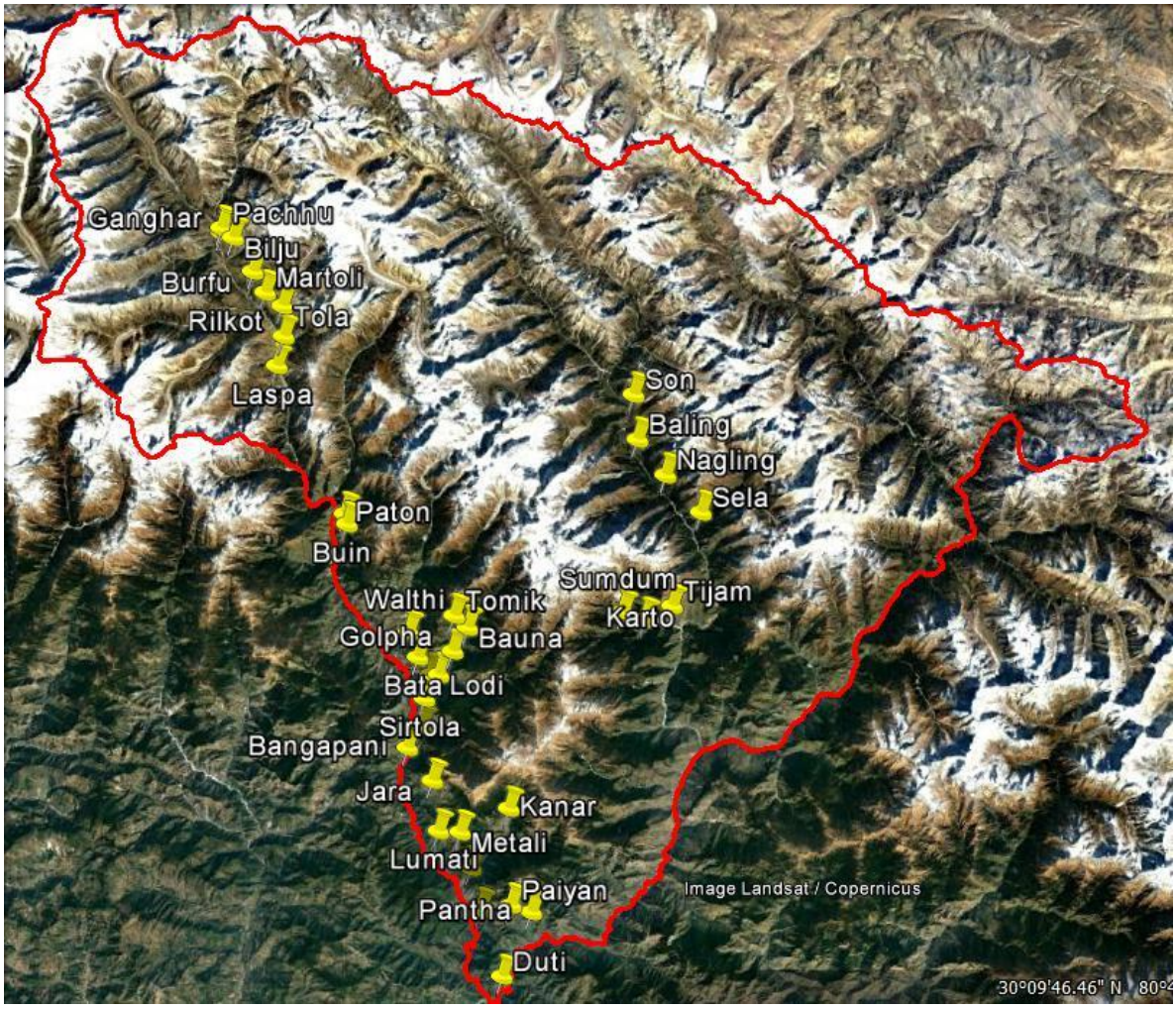


Figure 11. Map showing villages surveyed for NTFPs

### 3.3 Results

The extraction of biomass resources, such as fuelwood, timber, and fodder by rural communities, perhaps once within the carrying capacity of surrounding forests, has crossed this limit in many resource-rich areas. The process of resource extraction has been intensified due to increasing need of human and livestock. Out of 30 species of fodder, the most preferred species is *Quercus lanuginosa* followed by *Litsea monopetala* and *Q. leucotrichophora*. Out of 41 tree species of fuelwood, locals were dependent mainly on *Pinus roxburghii followed by L. umbrosa and Rhododendron arboreum*. Out of 27 species of timber, the locals used *Shorea robusta* followed

by *P. roxburgii* and *Q. glauca* highly. Out of 85 species of medicinal plants, villagers preferred mainly *Ageratina adenophora* (Weed used in skin cut) followed by *Terminalia chebula and Zanthoxylum alatum*. The major species, which were used for fodder, fuelwood, timber and medicinal purposes in the landscape, are shown in Figure 12.

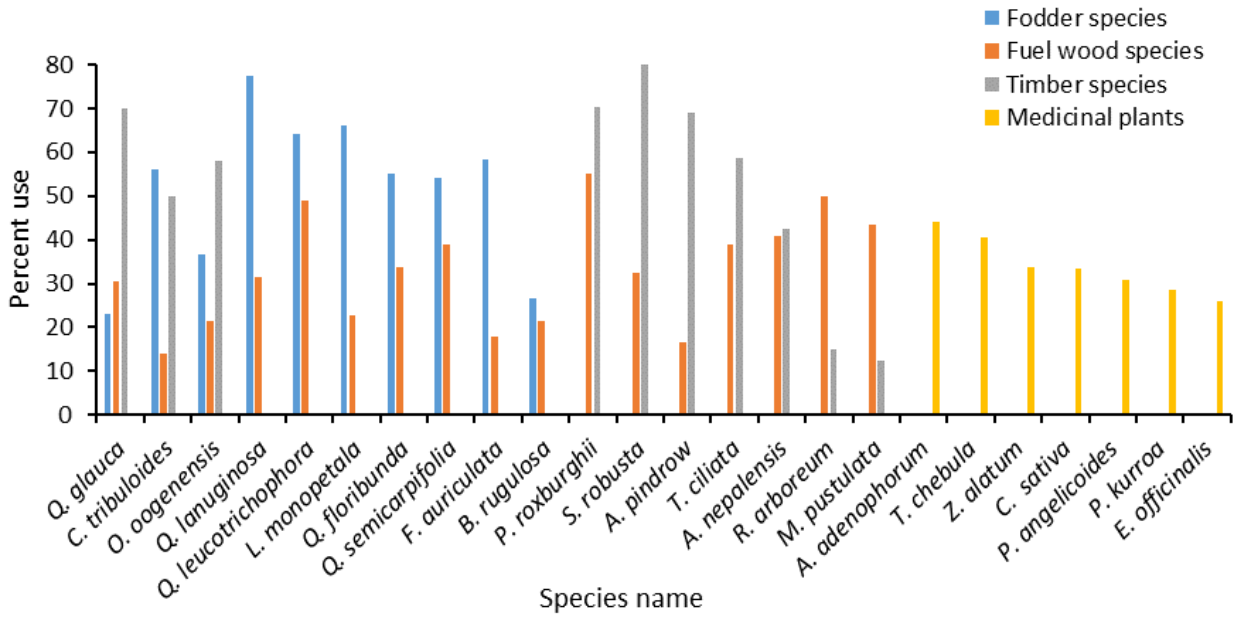


Figure 12. Percent use of major NTFPs in Askot landscape

### 3.3.1 Ethnobotanical use by locals

A total of 85 plants belonging to 49 families and 81 genera were used by local community to treat 26 human and 8 veterinary ailments. Of the total 85 plants, 83 were angiosperm (13 monocots and 70 dicots), 1 gymnosperm and 1 pteridophyte. Among them, herbs possess the highest growth forms (33%) that were used in making traditional preparation, followed by trees (31%) and shrubs (21%). Among plant parts, leaves comprised the major proportion (31%), followed by roots (20 %) and fruits (12%) for the preparation of various medicinal formulations (Figure 13). The chief ailments among the community were stomach problems, boils, cough-cold, fever, headache etc. The maximum species were used for the treatment of stomachache (10) followed by boils (9). cough and cold (8, Figure 14) etc.

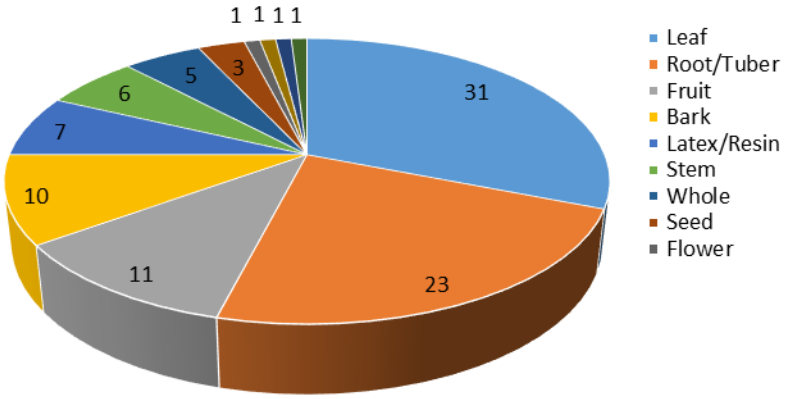


Figure 13. Percentage of habit forms utilized by the local

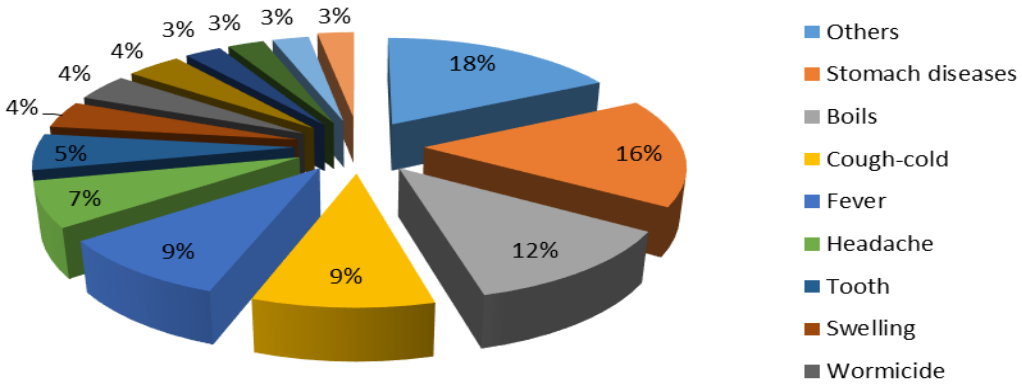


Figure 14. Chief ailments among the local community

Asteraceae (11%), Euphorbiaceae (9%) and Poaceae (5%) were the most dominant plant families. Out of 8 veterinary ailments, the maximum species (5) were used for milk production, 4 species for bone fracture and 3 species for lice. Some of the reported plants were used for other functions such as rituals (11%) and religions, veterinary healthcare (13%) and edible (21%). The use of aerial plant parts (80%) was higher than the underground plant parts. The common medicinal plants with their uses are given in Table 3.

Table 3. Ethnobotanical practices by local communities

| Medicinal plant | Part used | Uses |
|---|---|---|
| *Abrus precatorius* | Seed | Eye problems |
| *Acacia catechu* | Root/Bark | Piles |
| *Aconitum heterophyllum* | Root | Tonic, diarrhea |
| *Adhatoda zeylanica* | Root | Cough, toothache and tuberculosis |
| *Ageratum conyzoides* | Leaf | Skin cuts, blood clotting |
| *Bauhinia variegata* | Fruit | Dysentery |
| *Berginia ciliata* | Root | Stomachache |
| *Bidens pilosa* | Leaf | Wound |
| *Boerhaavia diffusa* | Whole | Stomachache |
| *Casearia graveolens* | Leaf | Heart attack, stone |
| *Celtis australis* | Leaf | Bone problems |
| *Cissampelos pareira* | Leaf | Headache and typhoid |
| *Dactylorrhiza hatagirea* | Tuber | Tonic, kidney complaints |
| *Dioscorea belophylla* | Tuber | Cooked and eaten |
| *Drymaria cordata* | Whole | Burnt |
| *Emblica officinalis* | Seed | Fever |
| *Eupatorium adenophorum* | Leaf | Cut and wound |
| *Ficus auriculata* | Fruit | Dysentery |
| *Ficus clavata* | Leaf | Chicken pox |
| *Fragaria nubicola* | Leaf | Headache and typhoid |
| *Lindenbergia grandiflora* | Root | Cattle disease |
| *Machilus* sp. | Seed | Leprosy |
| *Myrica esculenta* | Bark | Children's fever |
| *Oxalis corniculata* | Leaf | Injury healing, eye problems |
| *Pholidota articulata* | Whole | Bone fractures |
| *Picrorhiza kurrooa* | Stem | Fever, blood purification |
| *Pinus roxburghii* | Resin | External cuts |
| *Pleurospermum angelicoides* | Root | Stomachache |
| *Podophyllum hexandrum* | Fruit | Cough |

| | | |
|---|---|---|
| *Rheum australe* | Root | Internal pain |
| *Sapium insigne* | Latex | Skin wart |
| *Sassuria heteromalla* | Leaf | Toothache and ear problem |
| *Senecio nudicaulis* | Leaf | Toe fungus |
| *Solanum nigrum* | Root | Bodyache and headache |
| *Stellaria media* | Leaf | Headache |
| *Syzygium cumini* | Bark | Burnt area |
| *Terminalia chebula* | Fruit | Stomachache |
| *Zanthoxylum alatum* | Seed | Cough, cold, fever, toothache |

The commonly used medicinal plants to cure diseases by the villagers are *Arnebia benthamii, Pleurospermum angelicoides, Dactylorhiza hatazeria, Aconitum heterophyllum, Rheum australe, Phyllanthus niruri, Oxalis corniculata, Picrorhiza kurrooa, Fragaria nubicola, Emblica officinalis, Ageratina adenophora, Abrus precatorius, Terminalia chebula, Stellaria media, Solanum nigrum, Cissampelos pariera, Berginia ciliata, Bauhinia variegata, Adhatoda zeylanica, Bidens pilosa* (see left to right, Figure 15).

Figure 15. Important medicinal plants used by villagers in Askot landscape

# Chapter 4

# Threats to Plant Biodiversity

## 4.1 Introduction

Increasing human activitie is the root threat to biodiversity leading to its progressive decline. Synthetic disturbance has become a widespread feature in most of the forests. Therefore, understanding the level of anthropogenic pressure and its distribution in these forests is needed to address the site-specific conservation problems and the sustainable use of natural resources of the region. The problems for conservation are reduction in tree forest, weed propagation, fragmentation of forests, habitat degradation, felling of trees by natural calamities (floods, cyclones, landslides, earthquakes etc.), and existing mature Pine trees clear felled and replanted with Broadleaved species. The main problems are habitat degradation due to weed invasion, overgrazing by livestocks, lacking seedlings, forest fire and lopping of trees. In this study, it has been attempted to take a deeper and more nuanced look at the causes of biodiversity decline.

The quality of forests and grasslands in Van Panchayat lands is highly variable. While they appear well maintained in some villages such as Pantha, they are highly degraded in the neighboring Kanar village. VP forests retain the diversity of trees in them even though only a portion of them is directly used for the people. Some villages are keen to protect their VP and are ready to include species of trees that are not directly valuable to them. Biodiversity is best secured whence the livelihoods of dependent local people are made secure. For the present study, cutting and lopping of trees for firewood, timber and fodder, weed infestation, forest fire and overgrazing were considered as criteria for quantification of anthropogenic pressure in the study area.

## 4.2 Anthropogenic activities

**4.2.1 Cutting/Lopping**: Forest resorces are the major source of energy for the villagers. The forest resources in the landscape closely drive the livelihood of the people (Figure 16). Cutting and

lopping of trees is resulting in a huge destruction of host trees of orchids too. Therefore, lopping and cutting of trees becomes one of the major disturbances to the forest.

To quantify the lopping intensity, the proportion of cut/lopped individuals to the total number of individuals were calculated for trees in a 10 m circular plot. The distribution of cut stems had also been observed in six different girth classes to understand if there was any kind of preference by the local people. These girth classes are: (i) <30 cm, (ii) 31–60 cm, (iii) 61–90 cm, (iv)91–120 cm, (v) >121 cm and (vi) very old cuts. The intensity of cut and lopped trees was assessed under different damage categories. The cutting intensity was assessed in terms of percentage damage done to the individual tree by counting the number of cut branches of a tree. It was rated in following three categories (i) 1–25% cut – less damage, (ii) 26–50% cut – medium damage and (iii) >51% cut – high damage. The cut/lopped percent was based on the number of secondary and tertiary branches cut or lopped. In the disturbance map highly lopped regions are shown by big sized red points and the less lopped by small sized red points (Figure 23).

Figure 16. Cutting and Lopping for fodder by the villagers

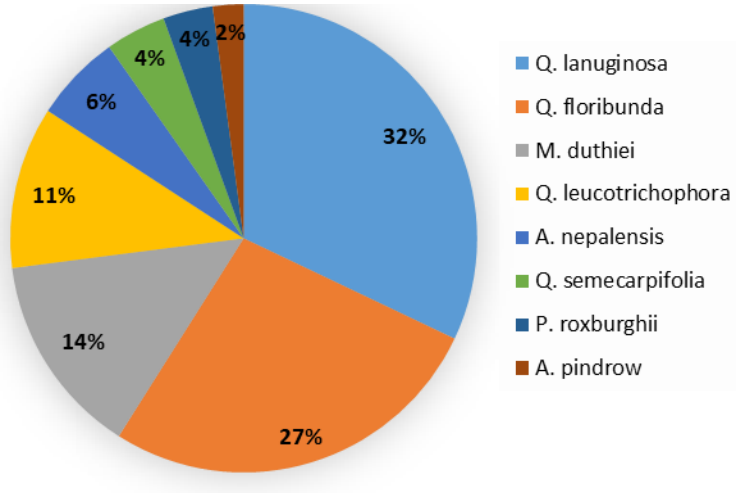


Figure 17. Average disturbance (tree cut/lop) percent in different forest communities

The maximum cutting and lopping was found in Rianj oak forest (32%) and Moru oak forest (27%) due to its high fodder value, moderate in Broadleaved (14%) and Banj oak (11%). In Alder forest (6%) Kharsu oak (4%), Chir pine forest (4%) and Fir forest (2%) disturbance was comparatively low whereas minimal disturbance was found in Hemlock, Birch and Blue pine forest (Figure 17).

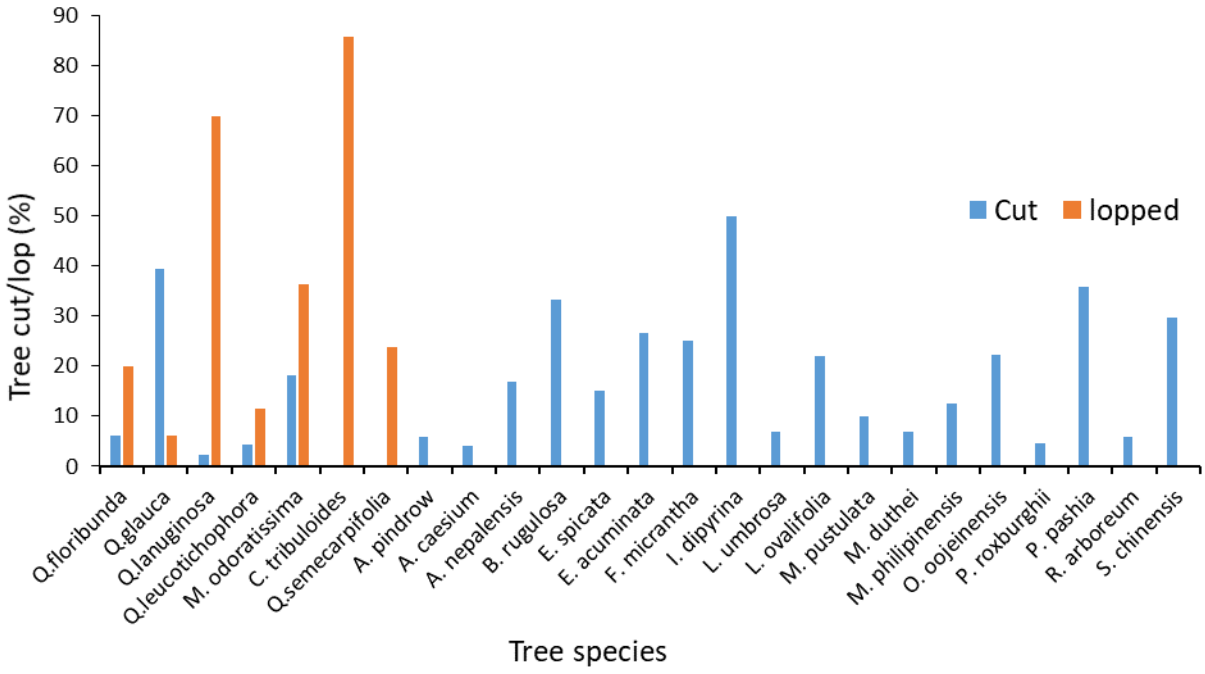


Figure 18. Percent tree species cut/lopped by locals in Askot landscape

The maximum anthropogenic pressure was found in oak species. *Castanopsis tribuloides* (85.7%) and *Quercus lanuginosa* (69.8%) found highly lopped for fodder whereas *I. dipyrina* (50%) and *Q. glauca* (39%) were highly cut for fuelwood (Figure 18). There was no significant correlation found between the distance from village and intensity of lopping.

Oak forests are very important for locals as more than 60% of oak species were used as fodder. The expanding *P. roxburghii* poses a serious threat to native Oak (*Q. leucotricophora* and *Q. floribunda*) in the whole of the Kumaon, as it has been reported earlier also (Singh & Singh 1987). The ecological nature of *P. roxburghii* does not allow other Broadleaved species to replace it, and *P. roxburghii* will continue to hold a site indefinitely once it occupies it. All Oak species are facing severe threats because of the demand for fodder and firewood, which leads to the reduction in seed production. Other valuable tree species such as *A. pindrow* and *P. wallichiana* were felled because of their timber value. *A. pindrow* and *B. utilis* community was mainly represented in Dhauli valley but these forests had a good population size also in Gori valley.

**4.2.2 Weed infestation**: Exotic plant invasions can have substantial impacts on ecosystem structure and on human economic systems. They have altered biodiversity, functioning of natural systems, and aesthetic value of many habitats. Weed reduces land value, and can be difficult and expensive to control. The infestation of weed such as *Ageratina adenophora* (Crofton weed)*, Lantana camara, Parthenium hysterophorus, Ageratum conyzoides* and *Polygonum polystachyum* are some of the weeds spreading in the landscape. Out of them A. adenophora is propagating in a high rate that is degrading the habitats. The Crofton weed locally known as Kala basa or Kala ghas is a very prominent invasive species found mainly in Gori valley (Figure 19).

Figure 19. Proliferation of *A. adenophora* in moist habitat

A forest type wise vegetation sampling was carried out in 5 m circular plots in different forest types across the valleys. It has brought out that *Ageratina* alone has invaded hectares of forestlands in Gori valley. In addition, this exotic weed have also come to occupy most of the roadsides and the wastelands. It was recorded mostly in NW aspect with an average of 33% however; the presence was seen in other five aspects also in the sampled plots (Figure 20). The road length, passing through the sub-tropical or lower temperate zone in the valley being approximately 50 kms with an average of 1 m berm on either side of these roads. It has spread from Dhungatoli to Walthi in the landscape. This is currently confined to high human density areas and around major disturbance regions such as roads, dams, etc. However, many high

altitude regions like Bhanar and Sukhdeo report seeing this shrub due to increasing anthropogenic activities in the region.

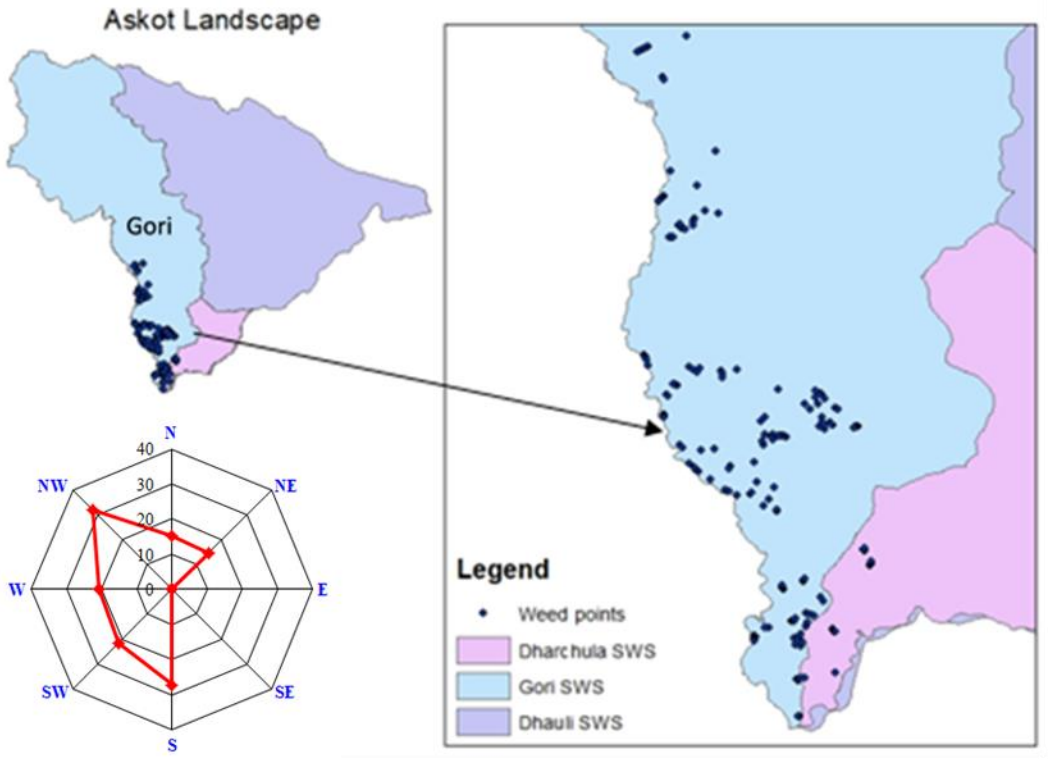


Figure 20. Map showing extent of weed infestation in different aspects in Gori valley

This species is spread all along the roads in the valleys and in much of the sheltered and moist regions with a luxuriant growth. It was recorded in percentage that were laid for vegetation sampling. The high weed regions are shown by big sized green points and the low weed areas are shown by small sized green points in the disturbance map (Figure 23). The lowest altitude villages are completely invaded by these species and according to people of Thulgair, Basantkot, Kanar they are suppressing native vegetation in the undergrowth. Not much attention has been given to this species; though several measures such as the villagers have implemented uprooting, burning, and clearing, the species always came back. Such activities will also facilitate invasion by exotic species that could threaten native flora and fauna. For instance, *Sinarundinaria anceps (Arundinaria jaunsarensis*), which is a native forage for the endangered fauna of the area, could

be lost if this weed invades into the higher reaches. This noxious plant is known to cause acute asthma, diarrhea and even death of livestock.

**4.2.3 Forest fire**: Forest fire destroys biodiversity directly and have more indirect long-term impacts including the encouragement of fire and pioneer species. It causes loss of valuable timber and ill effects on soils, watersheds, water quality and wildlife. Forest fire affects diversity and supports regeneration (Verma *et al.,* 2017). Locals set fire to their fields to get rich grass the next year. Production of biomass briquettes from these pine needles should be promoted, serving as a source of fuel as well as a solution to prevent wildfires. The forest fire was estimated in 10 m circular plots laid in different forests types based on presence-absence data. Chir pine-dominated forests were affected by the past forest fire in the Gori valley with good regeneration (Figure 21). The density of Chir pine seedlings were 6751.59 indi $ha^{-1}$. Forest fire also supports the weed proliferation. Location of forest fire is shown by black solid points in the disturbance map. (Figure 23).

Figure 21. Forest fire in Chir pine forest

**4.2.4 Grazing-** Survival of forests depends on sustainable exploitation and adequate regeneration. Grazing affects the natural regeneration of the forest. Grazing of macro-herbivores has a great effect on forest plant community structure. It was assessed in 5 m circular plots laid

in different forest types of Gori valley based on percentage grazed by the cattles (Figure 22). More than 50% grazing was put in high grazing category shown by big sized pink points whereas less than 50% grazing was put as low grazing and is shown by small sized pink points in the disturbance map (Figure 23).

Figure 22. Cattle grazing on a sapling of *Engelhardtia spicata*

A disturbance level map was prepared to show the high conservation priority areas in the landscape (Figure 23) based on lopping and cutting, weed infestation, forest fire and grazing. Out of the three valleys, Gori valley was found highly disturbed. The various disturbances were categorized into two levels, high and low and shown with big and small size solid points. One point depicts one sampled plot. The red color depicts the cutting and lopping of trees by the villagers of Gori and Dhauli valley whereas green color shows weed invasion in Gori and

Dharchula valley. The pink color depicts grazing in Gori valley and black color depicts forest fire present in Pine forests of lower Gori valley.

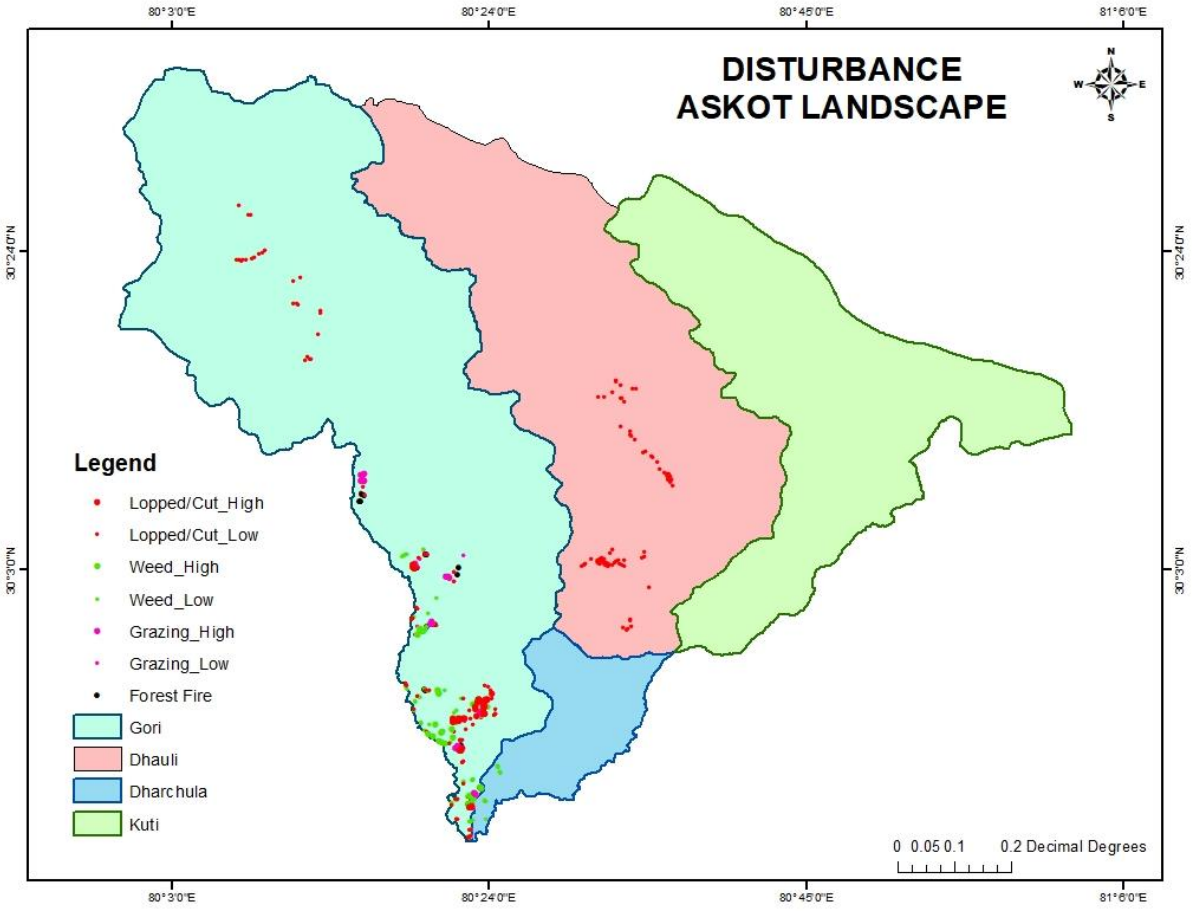


Figure 23. Map showing disturbance level in Askot landscape

### 4.3 Rare Endangered and Threatened (RET) Species

Out of sixteen, fifteen species were encountered in the study area during vegetation sampling which falls under rare, endangered and threatened category (Table 4). Samant *et al.* (1998) reported 23 endemics from AWLS. Out of 16 endemics of Uttarakhand, Anonymous (2002) reported 11 species of endemic angiosperms present in the landscape viz., *B. lambertii* (Berberidaceae), *B. osmastonii (Berberidaceae), Eria occidentalis* (Orchidaceae), *Itea nutans* (Iteaceae), *Gentiana tetrasepala* (Gentianaceae), *Herminium kumaunensis* (Orchidaceae), *Ponerorchis renzii* (Orchidaceae) and *Silene kumaonensis* (Caryophyllaceae). A number of species are rare and threatened in the landscape, owing to habitat degradation and fragmentation

because of various anthropogenic influences such as land development activities, the building of dams, constructions of roads, commercial exploitation of the species, overgrazing and frequent forest fires.

Table 4. RET plant species in Askot landscape (Prakash, 2011, Kala 2007)

| **Botanical name** | **Common name** | **Category** | **Habitat** |
|---|---|---|---|
| *Abrus precatorius* | Ratti | R | Sub-tropical |
| *Aconitum heterophyllum* | Ateesh | CR EN | Alpine |
| *Asparagus adscendens* | Satawar | R | Sub-tropical |
| *Boerhavia diffusa* | Poornnama | R | Sub-tropical |
| *Callicarpa macrophylla* | Daiya | R | Sub-tropical |
| *Cinnamomum tamala* | Tejpat | VU | Sub-tropical |
| *Cypripedium elegans** | Lady slipper orchid | R | Sub-tropical |
| *Dactylorhiza hatagirea* | Salampanja | CR EN | Alpine |
| *Picrorhiza kurrooa* | Kutki | CR EN | Alpine |
| *Pistacia integerrima* | Kakrodi | R | Sub-tropical |
| *Podophyllum hexandrum* | Bankakdi | EN | Alpine |
| *Rheum australe* | Dolu | EN | Sub-alpine |
| *Saussurea obvallata* | Brahmakamal | EN | Alpine |
| *Swertia chirayita* | Chiraita | EN | Sub-alpine |
| *Taxus wallichiana* | Thuner | EN | Warm temperate |
| *Zanthoxylum alatum* | Timur | VU | Warm temperate |

*Not encountered, R: Rare, EN: Endangered, VU: Vulnerable, CR EN: Critically Endangered

# Chapter 5

# INDICATOR SPECIES

## 5.1 Introduction

A biological indicator is any species or group of species whose function, population, or status can reveal the qualitative status of the environment. Indicator species is a useful management tool, and can help us delineate an eco-region; indicate the status of an environmental condition. Thus, a bioindicator is a living organism that gives us an idea of the health of an ecosystem. Indicators tell us something about the environment which is not readily apparent, or which cost prevents us from measuring directly. The primary role of ecological indicators is to measure the response of the ecosystem to anthropogenic disturbances. Biological indicators are primarily used to assess the condition of the environment.

Ecological indicators embody various definitions of ecology, such as the "inter-actions that determine the distribution and abundance of organisms" (Krebs, 1978), or more broadly the "structure and function of nature" (Odum, 1963). Thus, they are often primarily biological and respond to chemical, physical, and other biological (e.g., introduced species) phenomena. The definitions of the US EPA (2002b) and the hierarchy of Noss (1990) were combined, and defined ecological indicators as measurable characteristics of the structure (e.g., genetic, population, habitat, and landscape pattern), composition (e.g., genes, species, populations, communities, and landscape types), or function (e.g., genetic, demographic/life history, ecosystem, and landscape disturbance processes) of ecological systems.

The term indicator species can mean many different things (Spellerberg, 1994), including

(1) A species that indicates particular environmental conditions such as certain soil or rock types (Klinka *et al*., 1989);

(2) A species thought to be sensitive to and therefore to serve as an early warning indicator of environmental changes such as global warming (Parsons, 1991) or modified fire regimes (Wolseley & Aguirre-Hudson, 1991) and

(3) A management indicator species, which is a species that reflects the effects of a disturbance Regime or the efficacy of efforts to mitigate disturbance effects (Milledge *et al*., 1991).

**5.2 Plants as indicator**

Plants cannot select and move their living places as can animals, and thus live their lives responding to their surrounding environment. The occurrence, character and behavior of a plant are thus the indicator of the combined effect of all factors prevailing in a habitat. Since a plant species acts as a measure of environmental conditions, it is referred to as a biological indicator. The knowledge of a relationship between plants and ecological factors can be used as an indicator of the environment. In a plant community, some plants are dominant and found in abundance. These plants are important indicators because they bear full impact on habitat.

Table 5. Criteria, characteristics and indicator of potential indicators

| **Criteria and characteristics** | **Potential indicators** | **Indicator of** |
|---|---|---|
| Disturbance | *Polygonum polystachyum* | Overgrazing |
| | *A. adenophorum* | Anthropogenic activities/disturbance |
| Habitat | *Diplazium esculentum* | open marshy areas/stream banks/canals |
| | *Macaranga pustulata* | River side, regenerates on landslides |
| | *Alnus nepalensis* | colonize rocky sites exposed by landslide |
| | *Pinus roxburghii* | Resistant to fire |
| | *Quercus leucotrichophora* | conservation of soil, water |
| | *Quercus lanuginosa* | rocky and dry sites |
| | *Rhododendron arboreum* | Acidic soil |

### 5.3 Methodology

Initially nine potential plant indicator species viz., *Polygonum polystachyum, Ageratina adenophora, Diplazium esculentum, Macaranga pustulata, Alnus nepalensis, Pinus roxburghii, Quercus leucotrichophora, Quercus lanuginosa* and *Rhododendron arboreum* were identified based on different disturbances and habitats (Table 5). Based on the information collected during the surveys as well as through secondary information these initial potential indicators have been selected considering 7 charecteristics and 20 criterias (Table 6). The indicator species were finally selected based on ranking index which was high for *Ageratina adenophora* (1-20), *Alnus nepalensis* (1-20) and *Quercus leucotrichophora* (1-20). Hence, out of the nine potential indicator species three indicator (*Ageratina adenophora, Alnus nepalensis* and *Quercus leucotrichophora)* species were selected (Table 7), which will be used for long-term monitoring protocol to detect biodiversity change in the landscape by the locals.

Table 6. Criteria and characteristic of Potential plant indicators (Schomaker (1997), OECD (2001), NRC (2000), Riley (2000), Dale and Beyeler (2001), CBD (1999), Pannell and Glenn (2000), Kurtz *et al*. (2001), and EEA (2005 a).

| Characteristic | Criterion |
|---|---|
| Good indicator ability | 1. Provide quantitative or qualitative measurable response (sensitive to the disturbance or stress but do not experience mortality) (Measurability) |
| | 2. Response reflects the whole population/community/ecosystem response |
| | 3. Respond in proportion to the degree of contamination or degradation |
| Abundant and common | 4. Adequate local population density |
| | 5. Common, including distribution within area of question |
| | 6. Relatively stable despite moderate climatic and environmental variability |

| | |
|---|---|
| Well-studied | 7. Ecology and life history well understood |
| | 8. Taxonomically well documented and stable |
| | 9. Easy and cheap to survey |
| Economically/ commercially important | 10. Species already being harvested for other purposes |
| | 11. Public interest in or awareness of the species |
| Systemic dimension | 12. Sensitive to changes in space |
| | 13. High uncertainty about the level of the indicator means we can really gain something from studying it |
| | 14. Sensitive to stresses on the system |
| Financial and practical dimensions | 15. Simple to measure, manage and analyze |
| | 16. Achievable (in terms of the available resources and time) |
| | 17. Not require excessive data collection skills |
| Policy and management dimensions | 18. Simply and easily understood by target audience |
| | 19. Well established links with specific management practice or interventions |
| | 20. Thresholds that can be used to determine when to take action |

Table 7. Criteria and Ranking for selection of potential indicators

| S. No. | Potential indicators | Criterion | Rank |
|---|---|---|---|
| **1.** | *P. polystachyum* | 1, 2, 3, 4, 5, 6, 7, 8, 9, 15, 16, 17, 18, 19, 20 | 9 |
| **2.** | *A. adenophorum* | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14. 15, 16, 17, 18, 19, 20 | 1 |
| **3.** | *D. esculentum* | 1, 2, 3, 4, 5, 7, 8, 9, 10, 15, 16, 17, 18, 19, 20 | 8 |
| **4.** | *M. pustulata* | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 15, 16, 17, 18, 19, 20 | 4 |

| | | | |
|---|---|---|---|
| **5.** | *A. nepalensis* | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20 | 2 |
| **6.** | *P. roxburghii* | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 15, 16, 17, 18, 19, 20 | 5 |
| **7.** | *Q. leucotrichophora* | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20 | 3 |
| **8.** | *Q. lanuginosa* | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 15, 16, 17, 18, 19, 20 | 6 |
| **9.** | *R. arboreum* | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 15, 16, 17, 18, 19, 20 | 7 |

### 5.4 Description, Distribution and Ecology of Indicator species

#### A) *Ageratina adenophora*

*Ageratina adenophora* is a species of flowering plant in the daisy family Asteraceae, known by many common names, including eupatory, sticky snakeroot, crofton weed, and Mexican devil. Locally it is known as “Kala basa” (Figure 24). *Eupatorium adenophorum* is a synonym.

Figure 24. Different parts of *Ageratina adenophora* plant

It is a perennial herbaceous shrub that may grow to 1 or 2 metres (3.3 or 6.6 ft) high. It has opposite trowel-shaped serrated leaves that are 6–10 cm (2.4–3.9 in) long by 3–6 cm (1.2–2.4 in) in width. The small compound flowers occur in late spring and summer, and are found in clusters at the end of branches. Each flower head is up to 0.5 cm in the diameter and creamy white. A small brown seed follows them with a white feathery 'parachute'.

It is native to Mexico, southern America, and introduced to China in the 40's of 20$^{th}$ century. Currently this weed has distributed and seriously infested in many areas of China. The Crofton weed is an alien species with strong invasibility. It has caused great economic loss in agriculture and proved threatening to native biodiversity in other places. This noxious weed has spread along the Gori valley from 600 to 2200 m asl and its rapid spread is due in part to its allelopathic competition with other plant species. It is forming dense colonies, preventing the seedlings of native species from establishing in a wide range of habitats. It is also invading shaded areas, forest edges, shrublands, streamsides and open forest replacing vulnerable species. It shows a clear preference for moister locales. It invades the places where rainfall is more than 70 mm, less tree cover and high steepness. The successful invasion of this weed might be due to its strong ability of adaptation and competitive power. Flowering stage of growth is most toxic to cattles, who causes death after eating it. It is rated a Class 4 Noxious Weed under the NSW Noxious Weeds Act of 1993.

The plant can spread vegetatively, that is the stems can sprout roots and grow upon contact with ground. The seed is also carried by the wind or water and colonises disturbed areas, such as fields and areas near human habitation, readily. Seed may also be transported on animals and in soil. The plant causes allergic reactions and is a potential health hazard however it is used as an herbal medicine for treating skin cuts by the locals.

**B) *Alnus nepalensis***

*Alnus nepalensis* is a tree belonging to family Betulaceae. It is a large deciduous alder tree found in the subtropical zone of the landscape. The tree is called Utis in Hindi and Alder in English (Figure 25).

It is used in land reclamation and as firewood. It has silver-gray bark that reaches up to 30 m in height. The leaves are alternate, simple, shallowly toothed, with prominent veins parallel to each other, 7–16 cm long and 5–10 cm broad. The flowers are catkins, with the male and female flowers separate but produced on the same tree. The male flowers are 10 to 25 cm (4 to 10 in) long and pendulous, while the female flowers are erect, 1 to 2 cm (0.4 to 0.8 in), with up to eight together in axillary racemes. Unusually for an alder, they are produced in the autumn, with the seeds maturing the following year.

Figure 25. Images of *Alnus nepalensis*

It occurs at 600–3000 m of elevation in the landscape. It grows best on deep volcanic loamy soils, but also grows on clay, sand and gravel. It tolerates a wide variety of soil types and grows well in very wet areas. It needs plenty of moisture in the soil and prefers streamside locations, but also grows on slopes.

The tree grows quickly and is planted as erosion control on hillsides and for land recovery in shifting cultivation. It has nodules on the roots that fix nitrogen. The wood is moderately soft, used for making boxes and in light construction. As this species is an important source of fuel wood and it burns rapidly, it may be threatened by over-collection by locals. However as it is a pioneer species, human disturbances may be beneficial to this species. Alnus nepalensis is fast growing. It is considered a 'habitat pioneer' species, as it can occupy the newly formed habitats and is first colonizer of the landslide sites. It is able to regenerate under its own canopy.

**C) *Q. leucotrichophora***

*Quercus leucotrichophora* is a tree belonging to family Fagaceae, commonly known as Banj oak, Himalayan oak, blackjack oak, white oak. Some authors named it as *Quercus incana* Roxburgh (Figure 26).

The banj oak grows to a height of 15-25 m. Banj oak has a full, rounded canopy. The bark is a smooth tan-brown at first, becoming lightly furrowed and corky with age. The leaves are alternate, elongated ovals with jagged teeth. Young leaves are pink purple in colour and the upper surface turns deep green as it matures, while the lower side is silvery grey due to the presence of white hairs (hence the name *leucotrichophora*, meaning "which has white hairs"). The male inflorescences (catkins) are borne on the tips of the branches, while the tiny round female flowers are borne at the base of the leaves. The fruits are orange-tan, marble-sized acorns. It flowers in April to May and fruits in August to October. Naturally, it regenerates via seeds

Figure 26. Different parts of *Quercus leucotrichophora* tree

In the landscape, the banj oak is found at altitudes between 1500 and 2400 m above sea level in association with *Rhododendron arboreum* and *Lyonia ovalifolia*. Banj oak is the most common Broadleaved tree in the mid-elevations. *Quercus leucotrichophora* is best adapted to regions with a mild and moist climate. It thrives on loamy and clayey soils and does better on soils with a pH ranging from neutral to basic (alkaline soils). The banj oak tree does better on moist soils. It is an indicator of soil and water conservation. It is a multipurpose tree. Its foliage is a major source of fodder and the trees are lopped from December to June. Its wood is used in building purposes. It is a good fuel and is used for making agricultural implements. The acorns are edible.

# CHAPTER 6

# MONITORING PROTOCOL

## 6.1 Introduction

The need for monitoring protocol was identified as a top research priority. This protocol will detect change over time and across the landscape. Repeated surveys will be required to determine changes in the status of abiotic resources, species, habitats, or ecological communities in regular intervals of time and will be helpful in identifying threats to high-value ecological sites or resources. Protocols will be adaptable to local communities needs, yet flexible for different situations. Our research findings document the critical need and strong support for a standard monitoring protocol. Monitoring designed and executed effectively is a powerful tool for better management of resources.

## 6.2 *Ageratina adenophora*

A large-scale invasion of the landscape by alien plant species over the past 20 odd years has become a cause of serious concern from the ecological, biodiversity, socio-economic and health point of view. The fast 'Speed of Spread' of this weed shows the increasing human disturbance in the landscape. This invasive alien plant species, with major incidence in the subtropical and lower temperate areas in the region, have come to affect the quality of forests and the agriculture lands. Their incidence seems to be increasing every year at a high rate.This protocol can play an essential role in managing invasive plants and providing nonbiased information to make well-informed management decisions.

### 6.2.1 Methodology for monitoring

A Grid cell method is used to measure the status and extent of spread of *A. adenophora* in forest and roadside land. Different sites will be selected based on elevation, community composition

and topography, which are already infested by this weed. The density of *A. adenophora* will vary based on the topography and other factors. In each permanently marked site of 1 hectare square plot, number of individuals of *A. adenophora* will be counted in each infested grid before and after physical uprooting (Figure 27). This will tell the growth rate of weed over a period. Number of tree seedlings, tree species regeneration and RET species will also be recorded in the permanent plots for every six months to determine any change in population abundance. This method is only applicable to weed monitoring situations. This monitoring will determine effects of invasive plant species on biota and processes of the ecosystem.

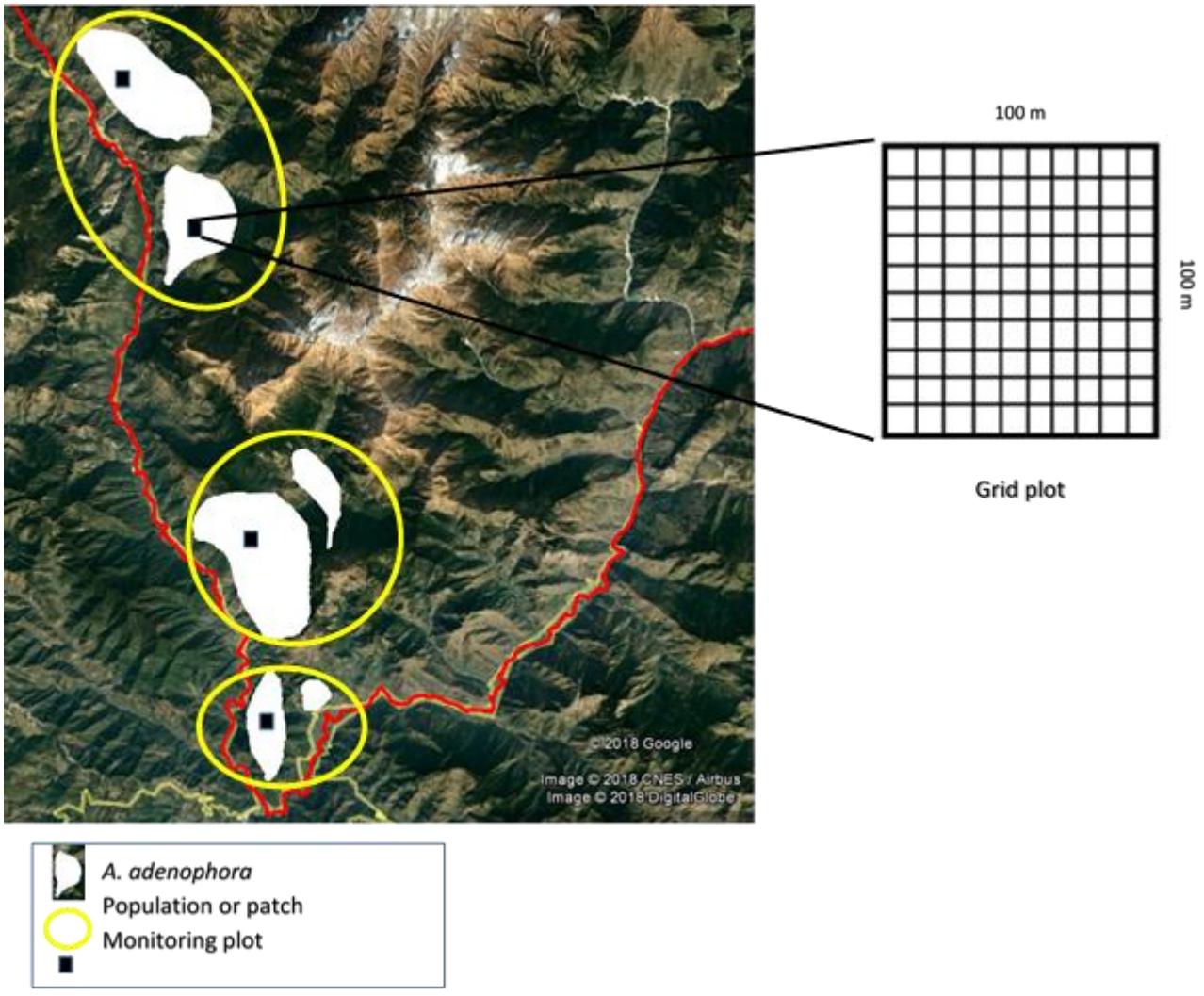


Figure 27. Monitoring of *A. adenophora* under 1 hectare grid plot

### 6.3 *Alnus nepalensis* and *Q. leucotrichophora*

These two indicator tree species can be monitored by documenting the growth, mortality and regeneration rates and types of changes that occur in response to natural processes such as succession and disturbance.

#### 6.3.1 Methodology for monitoring

The method for tree monitoring will be based on stratified random sampling. Monitoring sites will be selected based on elevation gradient and forest community. If the target population is small, but has irregular boundaries, then regular-shaped 1 hactare square/rectangle plot, over the bulk of the population can be taken (Figure 28 A). If the target population covers a very large geographic area, small 1 hactare area can be defined to sample randomly (Figure 28 B). In each site of 1 ha permanent plot total number of tree, sapling (individuals <30 cm dbh) and seedling (individuals <3.3 cm in height and <30 cm in dbh) will be recorded every year.

Parameters such as GPS location, altitude (m), diameter at breast height (dbh at 1.37 m), tree height (m), % canopy cover (tree), disturbance (lopping, logging, grazing, fire and dead tree) and date will be recorded . Accuracy level of GPS coordinates, units, and coordinate system should be noted down. Dbh will be measured with d-tape (Figure 29, 30). Tree height will be estimated on visual observation. Canopy cover is the vegetation covering the ground surface above the ground surface. It can be visualized by considering a bird's-eye view of the vegetation.

To estimate the population structure of each tree species, the following dbh classes will be considered- A: seedling, B: sapling, C: 30-60 cm, D: 60-90, E: 90-120, F: 120-150, G: 150-180, H: 180-210, I: 210-240, J: 240-270, K: 270-300 and L: >300 cm. The total number of individuals belonging to each of the mentioned classes will be calculated for each species. The density of each species in each dbh class will be calculated from the number of individuals in that class for polulation size/age. This will determine growth rate, regeneration pattern and mortality rate over time.

The number of individuals cut and distribution of cut stems will also be recorded in six different girth classes. These girth classes are: (i) <30 cm, (ii) 31–60 cm, (iii) 61–90 cm, (iv) 91–120 cm, (v) >121 cm and (vi) very old cuts. The intensity of cut and lopped trees will be assessed under

different damage categories. It will be rated in following three categories (i) 1–25% cut – less damage, (ii) 26–50% cut – medium damage and (iii) >51% cut – high damage. The cut/lopped percent will be based on the number of secondary and tertiary branches damaged estimated by ocular observation.

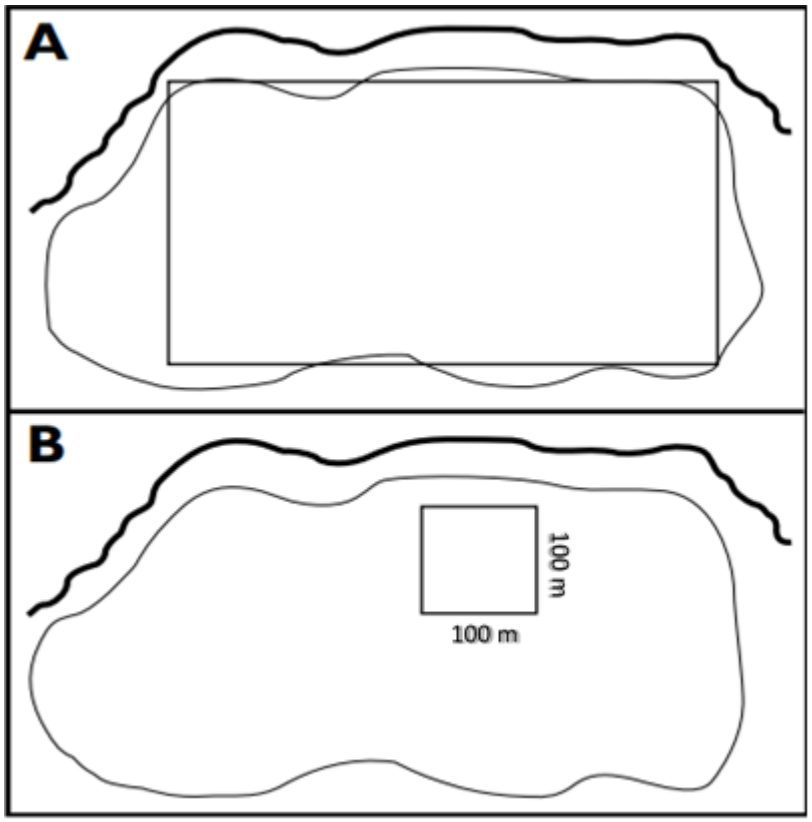


Figure 28. Positioning of plots within irregularly shaped target populations. A. A single plot is placed over the bulk of the target population. B. Three plots are randomly placed


Tree with ID tag in permanent plot


Documenting tree record


Reccord the d-tape reading where the 0 mark overlaps (reading is 4.3)

Figure 29. Data to record during fieldwork

| | |
|---|---|
| **Tree on Slope** | Measure diameter at 4.5 ft (1.37 m) from the ground along the trunk on the uphill side of the tree. If the tree is leaning on the slope, measure diameter as noted under "Leaning Tree". |
| **Live Windthrown Tree** | Measure from the top of the root collar along the length to 4.5 ft (1.37 m). |
| **Root Sprouts** | Root sprouts are handled the same as forked trees, with the exception that stump sprouts are not required to be 1/3 the diameter of the dead trunk. See pages 44-46. |
| **Tree in Raised Planter** | Height to DBH point is taken from the soil line, and DBH may need to be measured at 1-2 ft from soil for practical access. |

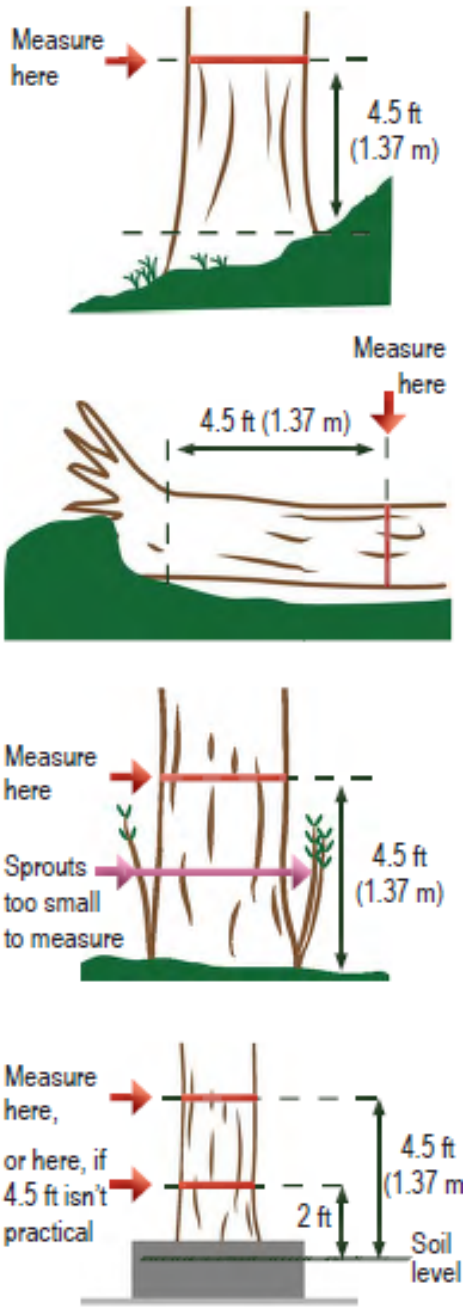


Figure 30. Special consideration for dbh of a tree

### 6.4 Field equipment checklist

The following is a list of equipment that should be taken into the field

- Field Guide
- Species ID resources
- Clipboard
- Pen
- Data collection sheets
- GPS
- DBH tape (with 1/10th inch increments)
- Caliper tool (for small trees under 3 inches diameter)
- Densiometer to measure canopy cover
- Camera
- Contractor grade measuring tape
- Hard Hat
- Safety Vest

## CONCLUSION

The Askot landscape is a vital ecological entity harboring a range of biological diversity, providing ecological services and supporting livelihoods of a large population of mountain people. People for their sustenance have used the trees, shrubs, and herbs of various kinds since millionaire. Increasing demands for better livelihoods, however, is gradually increasing pressure on highly vulnerable natural vegetation patches. The study thus far has tried to document the vegetation characteristic of the landscape represented by the selected sites in the two valleys, in identification and description of various vegetation community. Being a mountainous country, the hills and valleys along altitudinal gradient create multiple vegetation community were from the local communities have been extracting resources from their own sustenance. Through aspect, the study of human impacts slopes has been identified which are under greater pressure and conditional vegetation on those areas. Three indicator species have been identified which will be used to monitor by the locals to detect any biodiversity change in the landscape. Biologically significant areas have been well researched with good baseline data. Now effective monitoring of biodiversity indicators is required to initiate. All these outputs may lead to better development of management plan of the Askot landscape.

It will enable forest department to rationalize management on a larger canvass to secure biodiversity and ensure sustainable availability of bio-resources to the subsistence dependent. This would afford options for provisioning livelihoods that if dependent on forests is sustainable, as well as others capable of reducing unsustainable dependence.

The conservation of biological diversity has become one of the important goals of managing forests in an ecologically sustainable way. Ecologists and forest resource managers need measures to judge the success or failure of management regimes designed to sustain biological diversity. Carefully designed studies are required to test relationships between the presence and abundance of indicator species and other taxa and the maintenance of critical ecosystem processes in forests.

## RECOMMENDATIONS

1. Regeneration pattern is poor in *Q. floribunda* and, is highly lopped thus, recommended for plantation and regulation

2. Alternate species for highly lopped *Q. floribunda* and *Q. lanuginosa* could be fast growing fodder species *Litsea monopetala* and *Ficus* species respectively, recommended by local people (Questionnaire survey)

3. Practices that increase the rate of regeneration and establishment of young forests can help in increasing landscape-scale structural diversity

4. Plantation of fast growing native grasses (dwarf bamboo) and multipurpose tree species

5. Creating awareness about coppice technique among villagers for sustainable use

6. Construction of nurseries and poly houses for high value medicinal plants

7. Establishment of Orchid Conservation Areas (OCAs), Relocation and rehabilitation of orchid species in them.

8. Plantation of the most important host species for orchids viz. *Toona ciliata, Engelhadrtia spicata* and *Quercus leucotrichophora* in the OCAs

9. Construction of orchid trails in Gori valley and propagation of fast growing orchids can be used as livelihood improvement

10. To stop propagation of *Ageratina adenophora* weed, anthropogenic activities should be minimized along with its physical eradication and control programs

11. The eradication efforts need to be integrated with rehabilitation of treated areas and should be of long-term duration for effective results

12. Awareness and training to villagers and school children about flora and fauna through power point presentations, workshops and camps

13. Dissemination of dried fruit seeds while travelling to different places

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## ANNEXURE I: CHECKLIST OF PLANTS OBSERVED DURING THE SURVEY IN ASKOT LANDSCAPE

| Species | Family |
|---|---|
| **Trees** | |
| *Acer oblongum* | Aceraceae |
| *Acer acuminata* | Aceraceae |
| *Acer caesium* | Aceraceae |
| *Pistacia integerrima* | Anacardiaceae |
| *Rhus punjabensis* | Anacardiaceae |
| *Rhus semialata* | Anacardiaceae |
| *Lannea grandis* | Anacardiaceae |
| *Plumeria rubra* | Apocynaceae |
| *Holarhena antidysenterica* | Apocynaceae |
| *Schefflera arboricola* | Araliaceae |
| *Leucomeris spectabilis* | Asteraceae |
| *Alnus nepalensis* | Betulaceae |
| *Betula alnoides* | Betulaceae |
| *Betula utilis* | Betulaceae |
| *Carpinus viminea* | Betulaceae |
| *Jacaranda ovalifolia* | Bignoniaceae |
| *Oroxylum indicum* | Bignoniaceae |
| *Bombax ceiba* | Bombacaceae |
| *Boswellia serrata* | Burceraceae |
| *Bauhinia variegata* | Caesalpiniaceae |
| *Delonix regia* | Caesalpiniaceae |
| *Trema orientalis* | Cannabaceae |
| *Terminalia bellirica* | Combretaceae |
| *Terminalia chebula* | Combretaceae |
| *Terminalia tomentosa* | Combretaceae |
| *Alangium alpinum* | Cornaceae |
| *Cornus oblonga* | Cornaceae |
| *Cornus macrophylla* | Cornaceae |
| *Thuja orientalis* | Cupressaceae |
| *Shorea robusta* | Dipterocarpaceae |
| *Rhododendron arboreum* | Ericaceae |
| *Lyonia ovalifolia* | Ericaceae |
| *Bischofia javanica* | Euphorbiaceae |
| *Daphnephyllum himalayense* | Euphorbiaceae |
| *Emblica officinalis* | Euphorbiaceae |
| *Glochidion velutinum* | Euphorbiaceae |
| *Macaranga pustulata* | Euphorbiaceae |
| *Mallotus philippensis* | Euphorbiaceae |
| *Sapium insigne* | Euphorbiaceae |
| *Acacia catechu* | Fabaceae |
| *Acacia mearnsii* | Fabaceae |
| *Albizia julibrissin* | Fabaceae |
| *Albizia lebbek* | Fabaceae |
| *Butea monosperma* | Fabaceae |
| *Dalbergia sissoo* | Fabaceae |
| *Ougeinia oojeinensis* | Fabaceae |
| *Quercus floribunda* | Fagaceae |
| *Quercus glauca* | Fagaceae |
| *Quercus lanuginosa* | Fagaceae |
| *Quercus leucotrichophora* | Fagaceae |
| *Quercus semecarpifolia* | Fagaceae |
| *Ilex dipyrena* | Ilicaceae |

| | |
|---|---|
| *Engelhardtia spicata* | Juglandaceae |
| *Juglans regia* | Juglandaceae |
| *Gmelina arborea* | Lamiaceae |
| *Cinnamomum tamala* | Lauraceae |
| *Litsea monopetala* | Lauraceae |
| *Litsea umbrosa* | Lauraceae |
| *Machilus duthiei* | Lauraceae |
| *Machilus odoratissima* | Lauraceae |
| *Phoebe lanceolata* | Lauraceae |
| *Duabanga grandiflora* | Lythraceae |
| *Melia azedarach* | Meliaceae |
| *Toona ciliata* | Meliaceae |
| *Toona serrata* | Meliaceae |
| *Cocculus laurifolius* | Menispermaceae |
| *Ficus auriculata* | Moraceae |
| *Ficus benghalensis* | Moraceae |
| *Ficus hispida* | Moraceae |
| *Ficus palmata* | Moraceae |
| *Ficus religiosa* | Moraceae |
| *Ficus rumphii* | Moraceae |
| *Ficus semicordata* | Moraceae |
| *Ficus virens* | Moraceae |
| *Morus alba* | Moraceae |
| *Moringa oleifera* | Moringaceae |
| *Myrica esculenta* | Myricaceae |
| *Psydium guajava* | Myrtaceae |
| *Eucalyptus obliqua* | Myrtaceae |
| *Syzygium cumini* | Myrtaceae |
| *Fraxinus micrantha* | Oleaceae |
| *Osmanthus fragrans* | Oleaceae |
| *Phoenix sylvestris* | Palmaceae |

| | |
|---|---|
| *Bridelia ferruginea* | Phyllanthacae |
| *Abies spectabilis* | Pinaceae |
| *Abies densa* | Pinaceae |
| *Cedrus deodara* | Pinaceae |
| *Cupressus torulosa* | Pinaceae |
| *Pinus roxburghii* | Pinaceae |
| *Pinus wallichiana* | Pinaceae |
| *Tsuga dumosa* | Pinaceae |
| *Grevillea robusta* | Proteaceae |
| *Cyclostemon assamicus* | Putranjivaceae |
| *Rhamnus* sp. | Rhamnaceae |
| *Prunus cerassoides* | Rosaceae |
| *Prunus communis* | Rosaceae |
| *Prunus cornuta* | Rosaceae |
| *Prunus nepalensis* | Rosaceae |
| *Prunus persica* | Rosaceae |
| *Pyrus lanata* | Rosaceae |
| *Pyrus pashia* | Rosaceae |
| *Sorbus foliolosa* | Rosaceae |
| *Mitragyna parvifolia* | Rubiaceae |
| *Wendlandia exserta* | Rubiaceae |
| *Aegle marmelos* | Rutaceae |
| *Populus trimula* | Salicaceae |
| *Salix disperma* | Salicaceae |
| *Flacourtia cataphracta* | Salicaceae |
| *Casearia graveolens* | Samydaceae |
| *Aesculus indica* | Sapindaceae |
| *Sapindus mukorossi* | Sapindaceae |
| *Diploknema butyracea* | Sapotaceae |
| *Saurauia nepaulensis* | Saurauiaceae |
| *Symplocos chinensis* | Styraceae |

| | |
|---|---|
| *Symplocos* sp. | Styraceae |
| *Taxus wallichiana* | Taxaceae |
| *Grewia oppositifolia* | Tiliaceae |
| *Grewia optiva* | Tiliaceae |
| *Celtis australis* | Ulmaceae |
| *Boehmeria rugulosa* | Urticaceae |
| *Callicarpa arborea* | Verbenaceae |
| *Premna latifolia* | Verbenaceae |
| *Tectona grandis* | Verbenaceae |
| *Vitex nigundo* | Verbenaceae |
| **Shrubs** | |
| *Adhatoda zeylanica* | Acanthaceae |
| *Aechmanthera gossypina* | Acanthaceae |
| *Barleria cristata* | Acanthaceae |
| *Dicliptera bupleuroides* | Acanthaceae |
| *Eranthemum pulchellum* | Acanthaceae |
| *Lepidagathis* sp. | Acanthaceae |
| *Rungia pectinata* | Acanthaceae |
| *Strobilanthes atropurpureus* | Acanthaceae |
| *Agave americana* | Agavaceae |
| *Rhus wallichii* | Anacardiaceae |
| *Heptapleurum venulosum* | Araliaceae |
| *Hoya lanceolata* | Asclepiadaceae |
| *Bidens pilosa* | Asteraceae |
| *Xanthium indicum* | Asteraceae |
| *Berberis asiatica* | Berberidaceae |
| *Berberis chhitria* | Berberidaceae |
| *Berberis Jaeschkeana* | Berberidaceae |
| *Berberis kumonensis* | Berberidaceae |
| *Berberris erythroclada* | Berberidaceae |
| *Xylosma longifolium* | Bixaceae |

| | |
|---|---|
| *Opuntia* sp. | Cactaceae |
| *Lonicera metalis* | Caprifoliaceae |
| *Viburnum coriaceum* | Caprifoliaceae |
| *Viburnum grandiflorum* | Caprifoliaceae |
| *Viburnum mullaha* | Caprifoliaceae |
| *Viburnum nervosum* | Caprifoliaceae |
| *Lonicera spinosa* | Caprifoliaceea |
| *Eunymous pendulus* | Celastraceae |
| *Coriaria nepalensis* | Coriariaceae |
| *Juniperus communis* | Cupressaceae |
| *Juniperus indica* | Cupressaceae |
| *Juniperus recurva* | Cupressaceae |
| *Juniperus squamata* | Cupressaceae |
| *Dillenia sp.* | Dilleniaceae |
| *Hippophae tibetana* | Elaeagnaceae |
| *Ephedra gerardiana* | Ephedraceae |
| *Gaultheria nummularioides* | Ericaceae |
| *Gaultheria trichophylla* | Ericaceae |
| *Rhododendron anthopogon* | Ericaceae |
| *Rhododendron barbatum* | Ericaceae |
| *Rhododendron campanulatum* | Ericaceae |
| *Rhododendron lepidotum* | Ericaceae |
| *Cassiope fastigiata* | Ericaceae |
| *Excoecaria acerifolia* | Euphorbiaceae |
| *Euphorbia royleana* | Euphorbiaceea |
| *Jatropha curcas* | Euphorbiaceea |
| *Ricinus communis* | Euphorbiaceea |
| *Sarcococca saligna* | Euphorbiaceea |
| *Astragalus candolleanus* | Fabaceae |
| *Astragalus grahamianus* | Fabaceae |

| | |
|---|---|
| *Butea minor* | Fabaceae |
| *Flemingia macrophylla* | Fabaceae |
| *Indigofera heterantha* | Fabaceae |
| *Crotalaria* sp. | Fabaceae |
| *Desmodium heterocarpon* | Fabaceae |
| *Lespedeza* sp. | Fabaceae |
| *Piptanthus nepalensis* | Fabaceae |
| *Ribes alpestre* | Grossulariaceae |
| *Hypericum oblongifolium* | Hypericaceae |
| *Colebrookia oppositifolia* | Labiateae |
| *Pogostemon benghalensis* | Labiateae |
| *Lygodium japonicum* | Ligodiaceae |
| *Reinwardtia indica* | Linaceae |
| *Dendropthoe falcata* | Loranthaceae |
| *Scurulla elata* | Loranthaceae |
| *Viscum album* | Loranthaceae |
| *Woodfordia fruticosa* | Lythraceae |
| *Abutilon indicum* | Malvaceae |
| *Urena lobata* | Malvaceae |
| *Osbeckia stellata* | Melastomataceae |
| *Ficus clavata* | Moraceae |
| *Ardisia solanacea* | Myrsinaceae |
| *Maesa indica* | Myrsinaceae |
| *Callistemon citrinus* | Myrtaceae |
| *Boerhavia diffusa* | Nyctaginaceae |
| *Syringa emodi* | Oleaceae |
| *Plumbago zeylanica* | Plumbaginaceae |
| *Rumex hastatus* | Polygonaceae |
| *Rumex nepalensis* | Polygonaceae |
| *Zizyphus mauritiana* | Rhamnaceae |

| | |
|---|---|
| *Rosa webbiana* | Rosaceae |
| *Rubus ellipticus* | Rosaceae |
| *Rubus foliolosus* | Rosaceae |
| *Rubus nepalensis* | Rosaceae |
| *Rubus niveus* | Rosaceae |
| *Cotoneaster acuminatus* | Rosaceae |
| *Cotoneaster affinis* | Rosaceae |
| *Cotoneaster integrifolius* | Rosaceae |
| *Cotoneaster microphyllus* | Rosaceae |
| *Prinsepia utilis* | Rosaceae |
| *Pyracantha crenulata* | Rosaceae |
| *Sorbus lanata* | Rosaceae |
| *Viburnum cotinifolium* | Rosaceae |
| *Randia dumetorum* | Rubiaceae |
| *Randia tetraspermum* | Rubiaceae |
| *Leptodermis kumaonensis* | Rubiaceae |
| *Leptodermis lanceolata* | Rubiaceae |
| *Pavetta indica* | Rubiaceae |
| *Murraya koenigii* | Rutaceae |
| *Murraya paniculata* | Rutaceae |
| *Meliosma pungens* | Sabiaceae |
| *Buddleja paniculata* | Scrophulariaceae |
| *Datura stramonium* | Solanaceae |
| *Datura suaveolens* | Solanaceae |
| *Stachyurus salicifolia* | Stachyuraceae |
| *Hypericum japonicum* | Tamaricaceae |
| *Myricaria rosea* | Tamaricaceae |
| *Myricaria squamosa* | Tamaricaceae |
| *Eurya acuminata* | Theaceae |
| *Daphne papyracea* | Thymelaeaceae |
| *Boehmeria macrophylla* | Urticaceae |

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|---|---|
| *Debregeasia hypoleuca* | Urticaceae |
| *Callicarpa macrophylla* | Verbenaceae |
| *Lantana camara* | Verbenaceae |
| *Caryopteris odorata* | Verbenaceae |
| *Clerodendron benghalensis* | Verbenaceae |
| **Climbers** | |
| *Raphidophora decursiva* | Araceae |
| *Hedera helix* | Araliaceae |
| *Hedera nepalensis* | Araliaceae |
| *Ceropegia longifolia* | Asclepiadaceae |
| *Bauhinia vahlii* | Caesalpiniaceae |
| *Caesalpinia decapetala* | Caesalpiniaceae |
| *Ipomea purpurea* | Convolvulaceae |
| *Cuscuta reflexa* | Cuscutaceae |
| *Dioscorea belophylla* | Dioscoreaceae |
| *Dioscorea bulbifera* | Dioscoreaceae |
| *Abrus precatorius* | Fabaceae |
| *Millettia auriculata* | Fabaceae |
| *Mucuna pruriens* | Fabaceae |
| *Hydrangia anomala* | Hydrangeaceae |
| *Smilax elegans* | Liliaceae |
| *Cissampelos pareira* | Menispermaceae |
| *Tinospora cordifolia* | Menispermaceae |
| *Ficus hederacea* | Moraceae |
| *Jasminum multiflorum* | Oleaceae |
| *Clematis gauriana* | Ranunculaceae |
| *Helinus lanceolatus* | Rhamnaceae |
| *Rosa macrophylla* | Rosaceae |
| *Rubus paniculatus* | Rosaceae |
| *Neohymenopogon parasiticus* | Rubiaceae |
| *Zanthoxylum alatum* | Rutaceae |

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|---|---|
| *Leea indica* | Vitaceae |
| *Vitis* sp. | Vitaceae |
| **Herbs** | |
| *Allium humile* | Alliaceae |
| *Allium* sp. | Alliaceae |
| *Allium wallichii* | Alliaceae |
| *Achyranthes aspera* | Amaranthaceae |
| *Aerva scandens* | Amaranthaceae |
| *Cyathula capitata* | Amaranthaceae |
| *Cyathula tomentosa* | Amaranthaceae |
| *Crinum amoenum* | Amaryllidaceae |
| *Zephyranthes carinata* | Amaryllidaceae |
| *Angelica archangelica* | Apiaceae |
| *Centella asiatica* | Apiaceae |
| *Pleurospermum angelicoides* | Apiaceae |
| *Pleurospermum benthamii* | Apiaceae |
| *Pleurospermum candolei* | Apiaceae |
| *Prangos pabularia* | Apiaceae |
| *Salinum tenufolium* | Apiaceae |
| *Arisaema griffithii* | Araceae |
| *Arisaema intermedium* | Araceae |
| *Arisaema jacquemontii* | Araceae |
| *Arisaema propinquum* | Araceae |
| *Remusatia hookeriana* | Araceae |
| *Thomsonia nepalensis* | Araceae |
| *Asclepias curassavica* | Asclepiadaceae |
| *Polygonatum verticillatum* | Asparagaceae |
| *Smilacina purpurea* | Asparagaceae |
| *Eremurus himalaicus* | Asphodelaceae |
| *Ageratum conyzoides* | Asteraceae |
| *Anaphalis cinnamomea* | Asteraceae |

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|---|---|
| *Anaphalis contorta* | Asteraceae |
| *Anaphalis royleana* | Asteraceae |
| *Anaphalis triplinervis* | Asteraceae |
| *Artemisia nilagirica* | Asteraceae |
| *Aster fulconerii* | Asteraceae |
| *Cicerbita micrantha* | Asteraceae |
| *Cichorium intybus* | Asteraceae |
| *Circium berutum* | Asteraceae |
| *Cirsium arvense* | Asteraceae |
| *Crassocephalum crepidioides* | Asteraceae |
| *Cremanthodium arnicoides* | Asteraceae |
| *Encilia latifolia* | Asteraceae |
| *Erigeron andryaloides* | Asteraceae |
| *Eupatorium adenophorum* | Asteraceae |
| *Galinsoga parviflora* | Asteraceae |
| *Gerbera gossypiana* | Asteraceae |
| *Gnaphalium affine* | Asteraceae |
| *Inula cappa* | Asteraceae |
| *Lactuca dolichophylla* | Asteraceae |
| *Laggera crispata* | Asteraceae |
| *Leontopodium monocephalum* | Asteraceae |
| *Ligularia amplexicaulis* | Asteraceae |
| *Myriactis nepalensis* | Asteraceae |
| *Myriactis wallichi* | Asteraceae |
| *Parthenium hysterophorus* | Asteraceae |
| *Prenanthes brunoniana* | Asteraceae |
| *Sassuria hypoleuca* | Asteraceae |
| *Sassuria obvallata* | Asteraceae |
| *Saussuria heteromalla* | Asteraceae |
| *Senecio chrysanthemoides* | Asteraceae |

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|---|---|
| *Senecio ellatus* | Asteraceae |
| *Senecio kunthianus* | Asteraceae |
| *Senecio nudicaulis* | Asteraceae |
| *Siegesbeckia* sp. | Asteraceae |
| *Sonchus arvense* | Asteraceae |
| *Synotis alatus* | Asteraceae |
| *Tanacetum gracile* | Asteraceae |
| *Tanacetum longifolium* | Asteraceae |
| *Taraxacum officinale* | Asteraceae |
| *Tridax procumbens* | Asteraceae |
| *Vernonia* sp. | Asteraceae |
| *Youngia japonica* | Asteraceae |
| *Youngia* sp. | Asteraceae |
| *Leontopodium stracheyi* | Asteraceae |
| *Impatiens cristata* | Balsaminaceae |
| *Impatiens edgeotheri* | Balsaminaceae |
| *Impatiens racemosa* | Balsaminaceae |
| *Impatiens scabida* | Balsaminaceae |
| *Impatiens sulcata* | Balsaminaceae |
| *Arnebia euchroma* | Boraginaceae |
| *Cynoglossum zeylanicum* | Boraginaceae |
| *Eritrichium canum* | Boraginaceae |
| *Hackelia uncinata* | Boraginaceae |
| *Lindelofia anchusoides* | Boraginaceae |
| *Lindelofia longiflora* | Boraginaceae |
| *Arabidopsis himalaica* | Brassicaceae |
| *Barbarea vulgaris* | Brassicaceae |
| *Megacarpaea polyandra* | Brassicaceae |
| *Thlaspi arvense* | Brassicaceae |
| *Campanula latifolia* | Campanulaceae |
| *Campanula pallida* | Campanulaceae |

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|---|---|
| *Cyananthus lobatus* | Campanulaceae |
| *Lobelia pyramidalis* | Campanulaceae |
| *Morina longifolia* | Caprifoliaceae |
| *Nardostachys grandiflora* | Caprifoliaceae |
| *Nardostachys jatamasi* | Caprifoliaceae |
| *Valeriana hardwichi* | Caprifoliaceae |
| *Arenaria festucoides* | Caryophyllaceae |
| *Arenaria globiflora* | Caryophyllaceae |
| *Arenaria polytrichoides* | Caryophyllaceae |
| *Drymaria cordata* | Caryophyllaceae |
| *Silene setisperma* | Caryophyllaceae |
| *Stellaria media* | Caryophyllaceae |
| *Chenopodium ambrosoides* | Chenopodiaceae |
| *Commelina benghalensis* | Commelinaceae |
| *Murdannia hookerii* | Commelinaceae |
| *Swertia ciliata* | Convulvulaceae |
| *Rhodiola wallichiana* | Crassulaceae |
| *Sedum filipes* | Crassulaceae |
| *Sedum trifidum* | Crassulaceae |
| *Dipsacus mitis* | Dipsacaceae |
| *Equisetum arvense* | Equisetaceae |
| *Euphorbia hirta* | Euphorbiaceae |
| *Euphorbia pilosa* | Euphorbiaceae |
| *Euphorbia sp.* | Euphorbiaceae |
| *Phyllanthus urinaria* | Euphorbiaceae |
| *Astragalus rhizanthus* | Fabaceae |
| *Cassia occidantalis* | Fabaceae |
| *Cassia tora* | Fabaceae |
| *Desmodium microphyllum* | Fabaceae |
| *Flemingia fruticulosa* | Fabaceae |
| *Hedysarum cachemirianum* | Fabaceae |

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|---|---|
| *Oxytropis cachemiriana* | Fabaceae |
| *Oxytropis lapponica* | Fabaceae |
| *Oxytropis mollis* | Fabaceae |
| *Parochetus communis* | Fabaceae |
| *Thermopsis barbata* | Fabaceae |
| *Trigonella emodi* | Fabaceae |
| *Corydalis cashmeriana* | Fumariaceae |
| *Corydalis govaniana* | Fumariaceae |
| *Corydalis juncea* | Fumariaceae |
| *Corydalis racemosa* | Fumariaceae |
| *Gentiana capitata* | Gensianaceae |
| *Circa chirata* | Gentianaceae |
| *Gentiana moorcroftiana* | Gentianaceae |
| *Gentiana ornata* | Gentianaceae |
| *Gentiana tubifora* | Gentianaceae |
| *Gentiana urnula* | Gentianaceae |
| *Halenia elliptica* | Gentianaceae |
| *Lomatogonium carinthiacum* | Gentianaceae |
| *Swertia petiolata* | Gentianaceae |
| *Geranium pratense* | Geraniaceae |
| *Geranium procurrens* | Geraniaceae |
| *Geranium wallichianum* | Geraniaceae |
| *Arundinaria falcata* | Gramineae |
| *Bambusa arundinarea* | Gramineae |
| *Chrysopogon gryllus* | Gramineae |
| *Cynodon dactylon* | Gramineae |
| *Dendrocalamus strictus* | Gramineae |
| *Pennisetum purpureum* | Gramineae |
| *Saccharum spontaneum* | Gramineae |
| *Thamnocalamus falconeri* | Gramineae |
| *Thysanolaena maxima* | Gramineae |

| | |
|---|---|
| *Hypoxis aurea* | Hypoxidaceae |
| *Iris clarkei* | Iridaceae |
| *Iris hookerana* | Iridaceae |
| *Iris kemaonensis* | Iridaceae |
| *Iris milesii* | Iridaceae |
| *Iris potaninii* | Iridaceae |
| *Leucas lanata* | Labiateae |
| *Ajuga bracteosa* | Lamiaceae |
| *Anisomeles indica* | Lamiaceae |
| *Clinopodium umbrosa* | Lamiaceae |
| *Micromeria biflora* | Lamiaceae |
| *Phlomis bracteota* | Lamiaceae |
| *Plectranthus rugosus* | Lamiaceae |
| *Prunella vulgaris* | Lamiaceae |
| *Scutellaria prostrata* | Lamiaceae |
| *Scutellaria scandens* | Lamiaceae |
| *Stachys crisis* | Lamiaceae |
| *Thymus* sp. | Lamiaceae |
| *Utricularia striatula* | Lentibulariaceae |
| *Asparagus racemosus* | Liliaceae |
| *Fritillaria roylei* | Liliaceae |
| *Lilium nanum* | Liliaceae |
| *Lilium oxypetalum* | Liliaceae |
| *Theropogon pallidus* | Liliaceae |
| *Linum usitatissimum* | Linaceae |
| *Loranthus* sp. | Loranthaceae |
| *Malva rotundifolia* | Malvaceae |
| *Sida cordata* | Malvaceae |
| *Anagallis arvensis* | Myrsinaceae |
| *Circaea alpina* | Onagraceae |
| *Circea ciliata* | Onagraceae |

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|---|---|
| *Epilobium royleanum* | Onagraceae |
| *Aeginetia indica* | Orobanchaceae |
| *Lathraea squamaria* | Orobanchaceae |
| *Oxalis corniculata* | Oxalidaceae |
| *Eschscholzia caespitosa* | Papaveraceae |
| *Meconopsis aculeata* | Papaveraceae |
| *Picrorhiza kurrooa* | Plantaginaceae |
| *Veronica cana* | Plantaginaceae |
| *Veronica persica* | Plantaginaceae |
| *Bistorta affinis* | Polygonaceae |
| *Bistorta emodi* | Polygonaceae |
| *Bistorta vaccinifolia* | Polygonaceae |
| *Bistorta vivipara* | Polygonaceae |
| *Persicaria perfoliata* | Polygonaceae |
| *Polygonum barbatum* | Polygonaceae |
| *Polygonum capitatum* | Polygonaceae |
| *Polygonum hydropiper* | Polygonaceae |
| *Polygonum koeningia* | Polygonaceae |
| *Polygonum polystachyum* | Polygonaceae |
| *Polygonum scandens* | Polygonaceae |
| *Rheum acuminatum* | Polygonaceae |
| *Rheum australe* | Polygonaceae |
| *Androsace delavayi* | Primulaceae |
| *Androsace muscoidea* | Primulaceae |
| *Androsace primuloides* | Primulaceae |
| *Primula calderana* | Primulaceae |
| *Primula denticulata* | Primulaceae |
| *Primula drummondiana* | Primulaceae |
| *Primula glomerata* | Primulaceae |
| *Primula involucrata* | Primulaceae |
| *Primula minutissima* | Primulaceae |

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|---|---|
| *Primula redii* | Primulaceae |
| *Primula* sp. | Primulaceae |
| *Primula sturtii* | Primulaceae |
| *Aconitum heterophyllum* | Ranunculaceae |
| *Anemone rivularis* | Ranunculaceae |
| *Anemone tetrasepla* | Ranunculaceae |
| *Anemone vitifolia* | Ranunculaceae |
| *Aquilegia* sp. | Ranunculaceae |
| *Caltha palustris* | Ranunculaceae |
| *Delphinium brunonianum* | Ranunculaceae |
| *Oxygraphis polypetala* | Ranunculaceae |
| *Paraquilegia microphylla* | Ranunculaceae |
| *Ranunculus diffuses* | Ranunculaceae |
| *Thalictrum foliolosum* | Ranunculaceae |
| *Agremonia pilosa* | Rosaceae |
| *Campanula argyrophylla* | Rosaceae |
| *Duchesnea indica* | Rosaceae |
| *Fragaria nubicola* | Rosaceae |
| *Geum elatum* | Rosaceae |
| *Potentilla argillophylla* | Rosaceae |
| *Potentilla atrosanguinea* | Rosaceae |
| *Potentilla cuneata* | Rosaceae |
| *Potentilla eriocarpa* | Rosaceae |
| *Potentilla fructicosa* | Rosaceae |
| *Potentilla fulgens* | Rosaceae |
| *Potentilla peduncularis* | Rosaceae |
| *Potentilla plurijuga* | Rosaceae |
| *Potentilla sundaica* | Rosaceae |
| *Sibbaldia cuneata* | Rosaceae |
| *Sibbaldia purpurea* | Rosaceae |
| *Galium aparina* | Rubiaceae |

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|---|---|
| *Rubia cordifolia* | Rubiaceae |
| *Boenninghausenia albiflora* | Rutaceae |
| *Bergenia ciliata* | Saxifragaceae |
| *Chrysosplenium forrestii* | Saxifragaceae |
| *Parnassia nubicola* | Saxifragaceae |
| *Saxifraga personifolia* | Saxifragaceae |
| *Euphrasia himalica* | Scrophulariaceae |
| *Hemiphragma heterophyllum* | Scrophulariaceae |
| *Lindenbergia grandiflora* | Scrophulariaceae |
| *Mazus pumilus* | Scrophulariaceae |
| *Pedicularis hoffmeisteri* | Scrophulariaceae |
| *Peducularis sp.* | Scrophulariaceae |
| *Peducularis pectinata* | Scrophulariaceae |
| *Scrophularia decomposita* | Scrophulariaceae |
| *Scrophularia* sp. | Scrophulariaceae |
| *Scrophularia himalaica* | Scrophulariaceae |
| *Verbascum thapsus* | Scrophulariaceae |
| *Nicandra physalodes* | Solanaceae |
| *Solanum nigrum* | Solanaceae |
| *Solanum verbascifolium* | Solanaceae |
| *Solanum xanthocarpum* | Solanaceae |
| *Withania coagulans* | Solanaceae |
| *Stellera chamaejasme* | Thymelaeaceae |
| *Elatostema sessile* | Urticaceae |
| *Gerardinia diversifolia* | Urticaceae |
| *Pouzolzia* sp. | Urticaceae |
| *Urtica dioica* | Urticaceae |
| *Valeriana hardwichi* | Valerianaceae |
| *Viola biflora* | Violaceae |
| *Viola canescens* | Violaceae |
| *Cautleya gracilis* | Zingiberaceae |

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|---|---|
| *Costus barbatus* | Zingiberaceae |
| *Curcuma angustifolia* | Zingiberaceae |
| *Curcuma aromatica* | Zingiberaceae |
| *Hedychium spicatum* | Zingiberaceae |
| *Globba andersonii* | Zingiberaceae |
| *Roscoea alpina* | Zingiberaceae |
| *Roscoea purpurea* | Zingiberaceae |
| *Zingiber chrysanthum* | Zingiberaceae |
| **Orchids** | |
| *Acampe rigida* | Orchidaceae |
| *Aerides odorata* | Orchidaceae |
| *Bulbophyllum affine* | Orchidaceae |
| *Bulbophyllum reptans* | Orchidaceae |
| *Calanthe tricarinata* | Orchidaceae |
| *Cephlanthera longifolia* | Orchidaceae |
| *Coelogyne corymbosa* | Orchidaceae |
| *Coelogyne cristata* | Orchidaceae |
| *Coelogyne ovalis* | Orchidaceae |
| *Dactylorrhiza hatagiera* | Orchidaceae |
| *Dendrobium amoenum* | Orchidaceae |
| *Dendrobium chrysanthodium* | Orchidaceae |
| *Dendrobium denudans* | Orchidaceae |
| *Dendrobium fimbriata* | Orchidaceae |

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|---|---|
| *Dendrobium heterocarpum* | Orchidaceae |
| *Epipactis helleborine* | Orchidaceae |
| *Eria lasiopetala* | Orchidaceae |
| *Eria spicata* | Orchidaceae |
| *Vanda cristata* | Orchidaceae |
| *Zeuxine flava* | Orchidaceae |
| *Gastrochilus calceolaris* | Orchidaceae |
| *Guderia fushia* | Orchidaceae |
| *Liparis viridiflora* | Orchidaceae |
| *Malaxis mucifera* | Orchidaceae |
| *Nervilia mackinnonii* | Orchidaceae |
| *Oberonia pachyrachis* | Orchidaceae |
| *Oberonia prainiana* | Orchidaceae |
| *Oberonia pyrulifera* | Orchidaceae |
| *Otochilus lancilabius* | Orchidaceae |
| *Phalaenopsis taenalis* | Orchidaceae |
| *Rhynchostylis retusa* | Orchidaceae |
| *Satyrium nepalense* | Orchidaceae |
| *Smitinandia micrantha* | Orchidaceae |
| *Spiranthes sinensis* | Orchidaceae |
| *Spiranthes spiralis* | Orchidaceae |
| *Thunia alba* | Orchidaceae |

# ANNEXURE II: A NEW ADDITION TO THE ORCHID FLORA OF WESTERN HIMALAYA: PUBLISHED PAPE

## *Dendrobium longicornu*: an addition to the orchid flora of Western Himalaya[a]

Soni Bisht[1] & Bhupendra S. Adhikari[1]*

**Keywords/Mots-clés** : Askot WS, Long-horned dendrobium, Nigro-hirsute dendrobium, Uttarakhand.

**Abstract**

*Dendrobium* is one of the largest genera of the Orchidaceae. Hitherto, 116 species of the genus have been reported from India, of which 17 (including 2 doubtful taxa) have been recorded from Western Himalaya and 7 from the Askot Wildlife Sanctuary (AWS). By this publication, we add *Dendrobium longicornu* to the flora of Western Himalaya.

**Résumé**

***Dendrobium longicornu* : une espèce supplémentaire pour la flore de l'Himalaya occidental** – Le genre *Dendrobium* est l'un des genres les plus vastes parmi les Orchidaceae. Jusqu'ici 116 espèces ont été enregistrées pour l'Inde, dont 17 (en comptant deux taxons douteux) pour l'Himalaya occidental et 7 pour le sanctuaire AWS (Askot Wildlife Sanctuary). Le présent article ajoute une espèce, *Dendrobium longicornu*, à la flore de l'Himalaya occidental.

### Introduction

Orchidaceae is one of the largest families of flowering plants with an estimate of 24,500 species worldwide (73% epiphytic: Dressler, 2005). Most of the species has been listed under appendix II of CITES, due to their mycorrhizal associations (Gill, 1989; Taylor & Bruns ,1997; McCormick *et al.*, 2004; Otero & Flanagan, 2006; Shefferson *et al.*, 2007), habitat specificity

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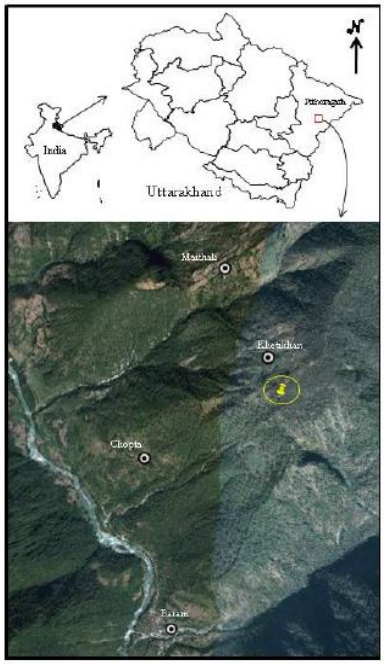


**Fig. 1: Location of *Dendrobium longicornu* in Askot Wildlife Sanctuary**
in the state of Uttarakhand, India (yellow circle)



2-4 cm, sheaths tubular, funnel shaped, black-hairy, 2.5-4 cm long. Leaves 6-10, distichous, lamina ovate-elliptic to oblong-lanceolate, base a tubular clasping sheath, apex acuminate, emarginate, puberulose, leathery, both surfaces with blackish brown rigid hairs including leaf sheaths, sessile, 2.5-8 × 1-2.2 cm. Inflorescence 5-7.5 mm, terminal or axillary racemes on leafless stem with 1-3 pedicellate flowers; peduncle attenuate *ca.* 5 mm, terete, smooth, enveloped by 2-4, 0.4-1.5 cm long, ovate to lanceolate, acute, imbricate scarious sheaths, with black hairs; rachis 0-2 mm, slightly terete, smooth. Pedicel and ovary nearly cylindric, 2.5-3.5 cm, obscurely ribbed, smooth, slender; floral bracts ovate-lanceolate, 0.5-1.7 cm, subacute to acuminate, coarsely black-hairy, 8 × 3 mm. Flowers white with a lip with yellow or red-orange lamellae, fragrant, 3.0-4.5 cm across, pendulous, pointing downward, cylindric, often not opening fully, nodding, sepals carinate, mentum straight or hooked, 1.5-2 cm long, forming a spur (Fig. 2). Flowering takes place during rainy season (August-September) and flowers are long lasting (up to December).

**Fig. 2: *Dendrobium longicornu***
front (right) and side (left) view of flower

Sepals sub-similar, ovate-lanceolate, acuminate, keeled; dorsal sepal ovate, 1.5-2.0 × ca. 0.5-0.7 cm, 7-veined, mid-vein slightly keeled abaxially, apex acute; lateral sepals obliquely ovate-triangular; petals oblong or lanceolate, 15-20 × 4-7 mm, 5-veined, margin irregularly denticulate, apex acute; lip 3-lobed, broadly triangular when spread, 2.2-3.0 × 2.4-2.9 cm; lateral lobes rounded, margins entire to weakly undulate, 2.2-2.5 × 1.0-1.1 cm; mid-lobe small, suborbicular, fimbriate-lacerate, 6-9 mm wide; disc with a broad

### Results

#### Ecology

Habitat: *Dendrobium longicornu* (Long-horned *Dendrobium*) is found in conifer-broadleaved mixed forest, coniferous forest or oak forest on the stem and branches of the trees between 1200 and 3000 m elevation. The species was encountered in few quadrats laid for vegetation assessment in oak-conifer forest (*Quercus lanuginosa, Q. leucotrichophora* and *Pinus roxburghii*) by the first author.

Host plants: The host species were *Quercus leucotrichophora, Q. lanuginosa* with an association of other tree species (*Lyonia ovalifolia, Myrica esculenta, Pinus roxburghii, Pyrus pashia*) and *Rhododendron arboreum*. The plants were growing on the branches of oak species (80-85%) and stems of *Lyonia* (15-20%) in exposed sites (moderate canopy cover and windy) on a south facing gentle slope (< 25°) in Askot WS (Fig. 1). The populations comprised 300 to 350 individuals.

#### Systematic treatment

*Dendrobium longicornu* Lindley
*Genera and Species of Orchidaceous Plants*: 80 (1830).
Homotypic Synonym: *Callista longicornis* (Lindley) Kuntze, *Revisio Generum Plantarum* 2: 655 (1891)
Heterotypic Synonyms:
*Froscula hispida* Rafinesque, *Flora Telluriana* 4: 44 (1838)
*Dendrobium flexuosum* W.Griffith, *Notulae ad Plantas Asiaticas* 3: 317 (1851)
*Dendrobium hirsutum* W.Griffith, *Notulae ad Plantas Asiaticas* 3: 318 (1851)
*Dendrobium bulleyi* Rolfe, *Notes from the Royal Botanic Garden, Edinburgh* 8:20 (1913)
*Dendrobium fredianum* hort.

#### Description

The plant, commonly described as a nigro-hirsute dendrobium which refers to the fine black hairs that cover the pseudobulbs, is a 10-40 cm tall epiphyte. The plant is tufted, minutely sulcate, somewhat fractiflex, several noded. Its roots are fasciculate. The plant carries 5-11 obliquely pointed linear lanceolate deciduous leaves. It blooms on very short, axillary racemes that arise from the top of leafed canes with 1-3, fragrant, waxy, long-lasting flowers. Stems clustered, pendulous, cylindric, 7-35 cm, 2-4 mm thick, slightly rigid, erect, wavy, unbranched, with many nodes, internodes