A STUDY ON THE STRUCTURE AND COMPOSITION OF FORESTS ALONG AN ALTITUDINAL GRADIENT IN UPPER BHAGIRATHI CATCHMENT, GARHWAL HIMALAYA

Thesis Submitted
to the
FRI, Deemed University
for the award of degree of
Doctor of Philosophy
In
Botany

By
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March 2001

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CERTIFICATE

This is to certify that the thesis entitled "**A study on the structure and composition of forests along an altitudinal gradient in upper Bhagirathi catchment, Garhwal Himalaya**" submitted for the award of degree of **Doctor of Philosophy** in Botany to Forest Research Institute (Deemed University), Dehra Dun (Uttaranchal), is a record of bonafide research work carried out by Shri Sanjay Kumar Uniyal under my guidance and supervision. No part of this thesis has been submitted for any other degree and it fulfils all the requirements laid down in the ordinance of FRI (Deemed University) for this purpose.

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Dated: 23rd March 2001

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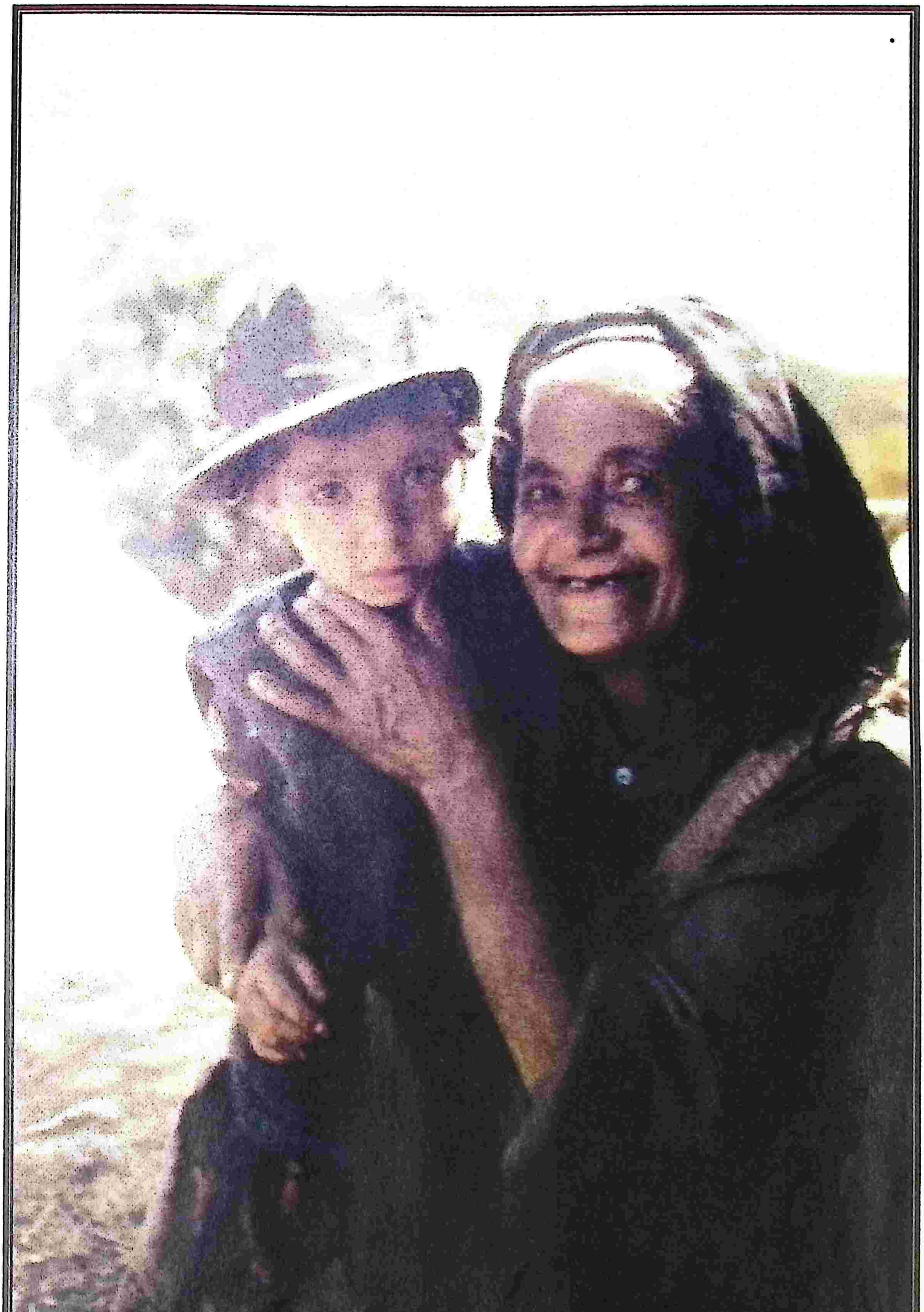

Dedicated to the hill people

Acknowledgements

During the course of this study several people had helped me in various ways; some morally, some physically and some mentally. Regarding the large number of people who had helped me I am sure to miss some. With due apologies to such people I acknowledge their help.

I express my thanks to Shri S.K. Mukherjee, Director Wildlife Institute of India, for providing me all the necessary facilities at the Institute for successful completion of this work.

I express my deep sense of gratitude to my supervisor Dr. G.S. Rawat (WII) for his invaluable supervision and guidance from the inception of this work to its present form. I am highly indebted to Dr. Sas Biswas (FRI) my co-supervisor for his valuable suggestions and fruitful discussions during the entire study.

Upendra Singh, Brijmohan Panwar, Chatur Singh, Gabbar Singh and Virendra Singh not only provided assistance in data collection but were also a good company in the field. Villagers of the Bhagirathi valley are thanked for their full cooperation and hospitality. Mr. S.R. Reddy, DLM and Mr. Tewari, DFO Uttarkashi provided all the necessary help. Ms. C.P. Aitwal, Ms. Suman and Mr. Karan were uncomplaining hosts during my Uttarkashi visits.

All the faculty members and researchers in the institute, are acknowledged for their help in various ways. My sincere thanks are due to Dr. A. Rajvanshi for critically going through the draft and rendering her valuable advice. Dr. B.S. Adhikari helped in the initial phases of the study and in site selection. Dr. Jagdish was very co-operative and helped in the analyses of remote sensing data. Several researchers especially Shomita, Prachi, Nima, Dr. Silori, Dr. Kala, Christy and many others also helped in the initial phase of the study. My colleagues Manisha, Pradeep, Aprajita, Jayanti, Reena, Anil, Ronald, Ramesh, Sanjay singh, Badrish, Rashid, Neel, Joy Das, Anjana, Ashish, Harish, Areendran, Karthik, Bivash, Archana, Suneet, Jatinder, Amrendra and all others whose names are not mentioned here helped me in different ways.

The staff of WII library especially Mr. M.S Rana, Mr. Vermajee, Mr. Madan Uniyal, Ms. Shashi, Mr. Mahesh, and Ms. Padma were all very helpful. I am very thankful to all of them. Mr. Saklani and Mr. Babu of Herbarium section were very helpful in plant identification. All the necessary help in data analyses and report writing was provided by the computer staff Shri Sukumar,Mr. Narendra Bist, Mr. Leknath, Late Mr. Shanmugum, Mr. Dinesh Pundir, Mr. Mukesh, Mr. Veerappan and Mr. Rajeev Thapa were all very co-operative. Mr. Virendra of DTP centre is especially thanked for his invaluable help in taking out the final printouts. I am grateful to all the GIS and Database cell staff Dr. Manoj, Mr. Pannalal, Mr. Rajesh Thapa, Dr. Navneet Gupta and Mr. Kathyet were also very cooperative. I acknowledge the help rendered by them. Without the help of Pannalaljee, analyses in GIS would have been very difficult. He took extra pains so that the work could be completed in time. I am especially thankful to him.

I am also thankful to people in the Accounts Section for the prompt clearance of my bills and helping me in maintaining my accounts. I would also like to thank people in the Audio Visual unit and Dispatch section. People in the lab also provided the needed help. Mr. Virender and Mr. Vijay helped in photocopying and binding of the thesis.

Staff and faculty members of FRI, BSI, ZSI and IIRS are also thanked for their cooperation and guidance. Dr. D.K. Singh and Dr. J.R. Sharma of BSI and Dr. Sarnam Singh of IIRS read the drafts and gave useful suggestions.

It was the blessings of my elders and parents, which helped me in overcoming every hurdle. Most of my evenings were spent with Anjali's family who were a constant source of inspiration. Both of my sisters were always behind me to help me. Last but not least, the help by my colleague Anjali was instrumental. She was always present in all the ups and downs no words can justify her help.

Sanjay Kumar Uniyal

Executive Summary

1. The structure and composition of the vegetation reflect the properties and processes of terrestrial ecosystem. Information on these parameters at spatio-temporal scale helps in conservation planning and restoration of degraded ecosystems. Ever increasing anthropogenic pressures on the Himalaya forests have greatly modified the vegetation converting the forests into secondary scrub or monoculture. The stability of the Himalayan slopes, the livelihood of the villagers and the native fauna depend on the health and productivity of these forests. Despite several ecological studies on the structure and composition in other parts of the Himalaya, information on these parameters along the gradients of altitude and human use has not been adequately documented. Bhagirathi valley is one such area where historical as well as recent developmental activities have influenced the status of forests yet ecological information on their current status is still lacking. Therefore the present study was initiated in a part of Bhagirathi catchment to assess the status of forests along an altitudinal and human use gradient.

2. The study area lies between 78^0 18' to 78^0 57' E long and 30^0 30' to 31^0 08' N lat. It covers an area of *ca* 2050 sq.km. and has an altitudinal gradient of 279 to 6600 m. For the intensive work two representative watersheds viz., north facing Duggada watershed (DWS) and south facing Bhatwari watershed (BWS) were selected. Objectives of the study include: preparation of baseline vegetation maps of the area, assessment of forest structure and composition, quantification of available woody biomass, documentation of ethnobotanical knowledge of local people and assessing the conservation status of rare plants in the area.

3. Data were collected from primary and secondary sources. Field work (primary source) was carried out during July 1996 to July 1999. Stratified random sampling was done for quantification of various vegetation and site parameters. The above ground tree biomass was calculated using regression equations whereas for shrubs harvest method was followed. Ethnobotanical surveys were conducted to document the information on plants used by villagers. Secondary information was gathered from published and unpublished reports, forest department records and district gazetteer. Besides, Survey of India toposheets and satellite data were also used for vegetation mapping and classification. IRS-1C LISS-III data for November 1998 were acquired from National Remote Sensing Agency (NRSA). Analyses were carried out at the Wildlife Institute of India. Different plant communities were segregated using software package TWINSPAN and compared in terms of various phytosociological parameters. Regression equations were developed to quantify the biomass of important shrub species. Above ground woody biomass was also compared amongst different communities and watersheds. Plants of ethnobotanical importance were segregated on the basis of their uses by locals. Satellite data were processed using digital image processing

techniques (for vegetation classification) with the help of computer software ERDAS IMAGINE. The maps were refined using GIS software ARC/INFO. The classified map was correlated with abiotic variables such as altitude, aspect and slope in ARC/VIEW. Statistical tests such as t-Test, Correlation Coefficient and Regressions were applied wherever necessary.

4. The vegetation maps serve as valuable tools in natural resource management and conservation planning. Most of the present study area being extremely rugged and inaccessible, remotely sensed data were used for classifying different vegetation types. Of the total 205065.66 ha area, maximum (24%) was covered by broadleaf-conifer mixed forest followed by broadleaf and scrub vegetation. Non-forest category (comprising habitation/agriculture, rocks/boulders, snow and river/waterbody) accounted for *ca* 27% of the area. Although maximum geographical area (38%) was under south facing slopes, maximum forest cover (26.58%) was found on the north facing slopes.

5. In mountainous terrain abiotic features such as altitude and aspect play a very important role in distribution of vegetation communities and plant species. In the present study ten plant communities in DWS and four in BWS were identified. These communities followed gradients of altitude and anthropogenic pressures. Phytosociological analyses of these communities revealed that density, IVI, regeneration and diversity were influenced equally by the anthropogenic factors. It was found that species preferred by local people had poor regeneration in the forests close to habitation. On the other hand, mid-elevation forests, which were away from the habitations, had relatively good status in terms of regeneration and diversity.

6. Availability of standing biomass and productivity defines the sustainability of a forest ecosystem. In the Himalayan region where life of villagers is dependent on surrounding forests, the available biomass also defines the sustainability of the agro-ecosystem. The availability of biomass is in turn influenced by the patterns of resource extraction by the local people. In the present study, availability of above ground tree biomass was higher in north facing slopes (DWS) while that of shrub was higher in south facing slopes (BWS). The biomass of common species preferred by locals was also higher in DWS when compared to BWS indicating good status of forests in the north facing slopes.

7. Information on plants used by local people not only provides an insight into the relationship of man with plants but also gives a clue for lesser known sources of medicine, food, fibre and others. Local people used 211 species for various purposes. The maximum number of plant species were used for medicinal purposes followed by fuel and fodder. Data analyses revealed that bamboos were the most preferred species for various purposes while oaks were the most preferred fuelwood and

fodder species. Availability of bamboo was more in DWS compared to BWS. A rapid survey of rare and threatened species in the study area revealed that 67 species fall under various threat categories and are under legal conservation. Of these 67species, six plant species, which occurred in the sampling plots, were quantitatively analyzed.

8. The present study highlighted the role of anthropogenic factors in distribution of plant communities in addition to altitude, aspect and slope. Market oriented economy has influenced the ethnobotanical knowledge of the local people. Though human-induced pressures are increasing in the area, still the status of forests in Bhagirathi valley is satisfactory compared to neighbouring areas. Hence, proper conservation and scientific management of such rich and diverse forest in small watersheds should be taken up on a priority basis.

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List of Abbreviation/ Local Names

A/F = Abundance to Frequency

AOI = Area of Interest

AP= Aerial Photograph

BIL = Band Interleaved by Lines

Br-con Mixed = Broadleaf Conifer mixed

BSI = Botanical Survey of India

BWS= Bhatwari Watershed

CBH = Circumference at breast height

CCA = Canonical Correspondence Analysis

Cd = Concentration of Dominance

CGL = Circumference at ground level

Chhans = Temporary Huts

CITES= Convention on International Trade on Endangered Species of Fauna and Flora

DEM = Digital elevation model

DIP = Digital Image Processing

DWS = Duggada Watershed

EH = Eastern Himalaya

ERTS= Earth Resource Technology Satellite

FD = Forest department

FRI = Forest Research Institute

FSI= Forest Survey of India

GCP = Ground control Points

GH= Garhwal Himalaya

Ghasnis = Grasslands closed for rainy season

GHNP = Great himalayn national Park

GIS = Geographical information system

GPS = Global positioning system

H.P= Himachal Pradesh

H' = Diversity

IR = Infra red

IRS = Indian Remote Sensing Satellite

ISS = Intensive study sites

IUCN= International Union for Conservation of Nature and Natural Resources

IVI = Importance Value Index

JFM = Joint Forest management

Katil = Shifting Cultivation

Kharaks = Seasonal Camping Sites

L.V. Scrub = Low valley scrub

LISS = Linear Imaging Self Scanner

Nayabad = Cultivation amidst forest

NBDR = Nanda devi Biosphere reserve

NGO = Non Governmental Organisations

NRSA = National Remote Sensing Agency

P.N= Public Notice

Pula = Gathering of livestock in forest

Rakeeta = Opening up of grasslands after rainy season

RD = Relative density

RDB= Red Data Book

RDo = Relative dominance

RF = Relative frequency

RMS = Root Mean Square Error

RS = Remote Sensing

SOI = Survey of India

STATECOL = Statistical ecology

TM= Thematic Mapper

TWINSPAN = Two way indicator species analysis

U.P.= Uttar Pradesh

UV= Use Value

VOF = Valley of Flowers

VP = Van Panchyats

WH = Western Himalaya

WII = Wildlife Institute of India

CHAPTER-1

Introduction

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Introduction

1.1 Background

The Himalayan mountains, one of the most remarkable physical feature in world, represent structurally complex, tectonically active, biologically diverse, ecological fragile and young ecoregion. These features of Himalaya have aroused great deal of curiosity world over and man has been exploring and exploiting its resources since time immemorial. Among its major resources are the forests, which have experienced a great deal of changes due to natural as well as anthropogenic factors. The commercial exploitation of the Himalayan forests, as in other parts of India, .began during colonial period. The Western Himalaya (WH), on account of its congenial climate, proximity to the industrial and business centres, and rich forests were first targeted by the timber industries during British period (Nanda 1990). The forests of Garhwal Himalaya in the erstwhile Tehri Garhwal were leased to Mr. Wilson in 1840 who exploited the forest produce such as musk, feathers and meat of monal, hides of wild animals besides fuel and timber. Valuable Deodar (*Cedrus deodara*) trees were felled for timber but later he used them for railway sleepers (Johri and Prasad 1985, Rawat 1985) thus depleting the wealth of forests. Not only the Britishers but also the local contractors added to the reduction of forest cover in the region. Besides timber many of the naturally occurring medicinal plants such as *Aconitum heterophyllum*, *Picrorhiza kurrooa*, *Nardostachys jatamansi, Selinum elatum*, *Gentiana kurrooa*, *Dactylorhiza hatagirea*, *Angelica glauca*, *Swertia chirayita*, and *Podophyllum hexandrum* were also collected in large scale for commercial purposes during pre as well as post colonial period (Shah 1983, Gaur and Semwal 1983, Goel and Bhattacharya 1983, Jain and Sastry 1980, Jain and Rao 1983).

Increasing population of human and livestock has had a noticeable effect on the high altitude forests of WH (Kumar 1983, Singh and Singh 1987). Climax oak species, which are heavily lopped for fuelwood, fodder and timber, have degraded in many areas (Pandey and Singh 1984), which has led to drying up of natural springs and consequent scarcity of water. The incidences of overgrazing are 2.5 to 4.5 times higher than the carrying capacity of these forests (Valdiya 1985) resulting in failure of regeneration, erosion and growth of weedy species. The invasion by weeds such as *Lantana camara, Parthenium hysterophorus, Xanthium strumarium and Eupatorium adenophorum* has resulted in the modification of forest structure and composition (Paliwal 1984). Besides, a large number of developmental projects and mass tourism have also played a major role in the degradation of forests, and decline of a large number of floral and faunal species.

The upper catchments of river Bhagirathi in Garhwal Himalaya support a reasonably good cover (*ca* 40%) of forest vegetation rich in native flora and fauna. Increasing human population, extension of agriculture on steeper slopes, mass tourism at higher areas and developmental activities in the lower valleys have adversely affected the ecology of these forests. Degradation of climax forests and decline in the health of agroecosystems in the region is one of the major conservation concerns among the environmentalists in the country.

1.2 Evolution of Himalayan forests

The collision of northward moving Indian subcontinent with rest of the Asian plate resulted in the rise of Himalaya about 40 million years before the present (Wadia 1975). Some of the special features of Himalaya, which make it ecologically interesting, are its location in the middle of a vast continental mass, the tertiary orogeny, the Pleistocene glaciations and continued post Pleistocene uplift (Valdiya 1999).

> "There grows the tree where rolled the deep. Oh earth, what changes has thou seen, There where the snow cap rises has been the stillness of the sea" (Anon. cited from Janki Ammal 1960).

The upliftment of Himalaya and subsequent orogeny not only resulted in the formation of land and river systems but also in the evolution and migration of species (Table-1.1). During the lower Miocene, tropical forests covered the southern slopes of Himalaya. However, due to lack of identification, the species that formed the forests, are not known at present. During mid-

Table-1.1: Chronology of the evolution of Himalayan forests with the upliftment of Himalaya

Million Years (B.P)	Epoch	Key Features of Himalayan forests
-	Recent	• Local extinction of several taxa • Deforestation for commercial purposes
1.5	Pleistocene	• Formation of alpine and subalpine zones • Immigration of alpine flora • Radiation and diversification of conifers at higher altitudes • Broadleaf forest dominated by oaks
5	Pliocene	• Immigration of conifers (such as *Cedrus deodara*) at higher altitudes • Disappearance of *Dipterocarpus* and *Anisopetra* forest
10	Upper and Mid Miocene	• Altitudinal distribution of forests • Lower slopes- wet tropical forests (dominant genera *Gluta, Bursera, Dipterocarpus* and *Anisoptera*) • Higher slopes-wet temperate forests (dominant genera *Pinus, Picea* and *Abies*)
24	Miocene	• Tropical forests • Lack of identification

Miocene the forests of Himalaya showed an altitudinal distribution, lower slopes were occupied by wet tropical forests and the higher slopes by wet temperate forests. The genera dominant in the lower slope were *Gluta, Bursera, Anisoptera* and *Dipterocarpus* while the higher slopes were occupied by genera such as *Pinus, Abies, Picea* and *Betula*. The most drastic changes in the floristics of Himalaya seem to have taken place during the Pliocene, when the forests of *Dipterocarpus* and *Anisoptera* totally disappeared from the Western Himalaya and the wet forests were transformed into moist or dry forests types. It was during this time *Cedrus deodara* immigrated into the Himalaya. The upliftment of Himalaya during Pleistocene led to the formation of alpine and sub-alpine regions. Almost all the Dipterocarps excluding *Shorea robusta* disappeared from the Western Himalaya during this time (Vishnu-Mittre 1984, Lakhanpal 1991 and Sharma 2000). According to palaeoclimatologists, the alpine vegetation of the Himalaya evolved only after its final upliftment (Vishnu-mittre 1965). Collisions of continents along with climatic changes during Pleistocene controlled the migration of flora and fauna (Mani 1978), which not only influenced the forest types, but also the genetics of some plants. The polyploidy in Asian Magnolias (*M. campbelli, M. mollicomata*) is found only in the deciduous species, which have migrated into India along the Himalaya. All the evergreen species of Magnolia and related genera *Michelia*, *Talauma* remained diploid. Similarly increase in polyploidy amongst Rhododendrons with increase in altitude is believed to be one of the reasons how they combat the effect of altitude (Janki Ammal 1960). All these processes were natural. However, at present the overexploitation of climax oak species has led to their replacement by chirpine in some parts of Western Himalaya (Singh *et al.*1984).

1.3 Review of Literature

The forests of Garhwal Himalaya have been explored and studied in terms of floristics, ecology, ethnobotany and more recently, mapped using Remote Sensing (RS) data by several authors. A brief review of published literature on the above aspects, especially from the Bhagirathi valley of GH and adjoining areas is given below.

1.3.1 Phytogeography and floristics: Himalayan mountains have been divided into different phytogeographical zones by various authors. Earlier workers (e.g., Hooker 1906) recognized two phytogeographic divisions of Himalaya viz., the western and the eastern Himalaya. Later workers (Chatterjee1939, Razi 1955) identified four regions. The third region common to these later classifications was Central Himalaya. The fourth region was Assam in Chatterjee's (1939) and North-eastern India in Razi's (1955) classification. Rau (1974) divided Himalayan ranges with wide variation between tropical foothills and highest limits of alpine vegetation into the Northwest Himalaya including Kashmir and Himachal Pradesh, the Western Himalaya (WH) which lies between the valleys of rivers Sutlej and Kali bordering Nepal, the Central or Nepal Himalaya and the Eastern Himalaya. Recently Rodgers & Panwar (1988) have divided Himalaya into six provinces viz., Ladakh mountains, Tibetan plateau, North-West Himalaya, Western Himalaya, Central Himalaya and the Eastern Himalaya. The WH comprises part of Himachal Pradesh (H.P) and Garhwal and Kumaun areas of Uttaranchal. The WH has more of European elements in its flora whereas the eastern Himalaya has Malayan, Burmese and Chinese elements. The WH has a wide representation of conifers while the EH harbours a vast diversity of Rhododendron and Orchids. Furthermore, the treeline in WH is comparatively lower (3500±200m) than that in the EH (4000±200m) (Meusel 1971, Rau 1974). About 44.3% of the total geographical area of WH is covered with forests (FSI 1997). One or the other species of oak dominate these forests and forms the climax vegetation in Garhwal while the conifers are regarded as seral communities. The distribution of various species of oaks depends on altitudinal gradients but for conifers it has little effect and soil plays a major role (Puri 1960). The undercanopy of these forests is mainly formed by species of *Cotoneaster, Berberis, Spirea, Sarcococca* and *Daphne* alongwith with ferns and orchids. Presence of under canopy dwarf bamboos *Sinarundinaria falcata* and *Thamnocalamus spathiflorus* highlights the ecological richness of these broad-leaved forests. Alpine habitat (alpine scrub and pastures) usually starts at timberline (ca 3500 asl) and is characterized by complete absence of trees and lianas. The floral diversity of this zone is well represented by genera such as *Polygonum, Saxifraga, Astragalus, Primula, Gentiana, Carex, Potentilla,* *Impatiens*, *Corydalis*, and *Saussurea* all with more than 20 species each (Rau 1975).

Thomas Hardwick was perhaps the first botanist to collect the plants in the Himalaya from Alaknanda valley in 1796 (Burkill 1965). Hooker's "Flora of British India" (1872-1897) included most of the plants known from the area. Gupta (1956, 1957, 1962) undertook botanical explorations in the Bhilangana valley and descried the flora of different forest types starting from subtropical forests to alpine meadows while Dey *et al.* (1969) surveyed the medicinal plant diversity in Bhagirathi valley. Biswas (1985, 1988, 1994) worked on the floristics of erstwhile Tehri and later Tehri Garhwal and highlighted the importance of the area by reporting seven new taxa from the region. Goel and Bhattacharayya (1981) made fern collections from the Tehri area and based on their collection proposed declaration of this area as a fern sanctuary. Uniyal *et al.* (1995) prepared a checklist of plants occurring in the Tehri dam submersible area. Naithani (1984-85) dealt with plants in Chamoli and was second only after Duthie to explore Jadhganga valley in Uttarkashi (1995). Negi *et al.* (1985) prepared a checklist of 275 plants occurring around the Dodital in Uttarkashi while Lal *et al.* (1997) described the aquatic vegetation of Uttarkashi. Rau (1963) described the plants from Jumnotri valley. Naithani and Tiwari (1982, 1983) described plant species in and around the vicinity of Pauri Garhwal while Gaur (1999) has published the results of survey carried in district Garhwal along with the uses of different plant species. Other workers include Hajra (1983) and Hajra and Balodi (1995) who have worked on the floristics of Nanda Devi Biosphere Reserve while Mani (1978), Gaur and Semwal (1983), Aswal (1994) have mainly discussed the high altitude plants of Garhwal Himalaya.

Goel and Bhattacharya (1983), Rawat (1994), Shah (1983), Aswal and Goel (1985). Uniyal and Malhotra (1984) have highlighted the economic and rare plants of Garhwal Himalaya. Malhotra *et al.* (1988) Dangwal *et al.* (1993, 1994, 1995, 1996, 1997), Gaur *et al.* (1993,1994), have discussed the rare and little known plants of Fabaceae from Garhwal Himalaya. Joshi *et al.* (1993) have prepared an inventory of disappearing angiosperms of Kumaun and Garhwal while Gaur and Rajwani (1995) have published a preliminary report on the threatened arborescent plants of Garhwal Himalaya. Most of these authors have opined that overexploitation and habitat degradation are the main threats to these taxa.

1.3.2 Ecological Studies: Osmaston (1922) was perhaps the first person to emphasize the need for detailed ecological study in Garhwal. Subsequently Dudgeon and Kenoyer (1925) described broad vegetation types from erstwhile Tehri Garhwal viz., Monsoon forest, Broad-leaved Sclerophyll forest and Alpine forests, which were further divided into various categories. Anthropogenic activities in forms of cultivation on steeper slope, commercial harvesting of *Cedrus deodara* and *Pinus longifolia* and uncontrolled grazing were cited as the most important reasons for forest degradation. Later Gupta and Singh (1962) worked on forest communities and successions in Tons valley where he opined that the Chirpine forest in the valley was bioedaphic climax and under favourable conditions it progresses towards climax oak forests. Similar trends were observed by Saxena and Srivastava (1973) during their analysis of forest communities around Mussoorie. Kumar *et al.* (1997) studied the forests of Malari valley and found that excessive removal of *Taxus baccata* by "*Tolchhas*" (nomadic tribe) for fuelwood has affected their regeneration. Bhandari *et al.* (1997) studied the forest vegetation on hill slope viz., upper, middle and lower in Tehri and found that the diversity was highest in upper slopes and also that the treeline was higher on southern slopes. Pangtey *et al.* (1987) focussed on the importance of mixed coniferous forest for sustaining the watershed in Pauri while Joshi (1984) studied the riverine vegetation of Koh and highlighted the failure of regeneration of dominant species as threat to these watersheds. Joshi and Tiwari (1990) quantified the forest structure in Alaknanda catchment and observed that the maximum shrub diversity was in disturbed forests due to the coming up of weedy and thorny species. Similar results were obtained by Rawat *et al.* (1999) for the forests surrounding Kedarnath Musk Deer Sanctuary where the old growth forests had low shrub diversity when compared to disturbed forests. Mehta *et al.* (1997) studied the effects of fire on the forests of Garhwal. The fire results in the opening up of oak canopy and in turn helps in their replacement by *Pinus roxburghii*. Bhandari *et al.* (2000) have also pointed towards the replacement of oak by Chirpine in Chamoli as a result of anthropogenic factors. Baduni and Sharma (1996) studied the effect of aspect on *Quercus semecarpifolia* and recommend its plantation on the north east and south east aspects for sustainable development. Joshi and Srivastava (1991), Tiwari and Gupta (1984), Kala (1998) have discussed the status of grazing lands in Garhwal. Rajwar (1987, 1988, 1989), Rajwar & Dobhal 1991, Nayak *et al.* (1991) have worked on various vegetational and ecological aspects and contributed a lot towards the studies in Garhwal.

1.3.3 Ethnobotanical surveys: The ethnobotanical studies have received due importance only in the last few decades and organized studies on this subject are very recent. Uniyal (1968) described 61 locally used medicinal plant species from the Bhagirathi valley. Chauhan and Bhattacharyya (1992) listed important plant species used by locals in Chamoli and have highlighted that large scale deforestation due to industralization and road construction has adversely affected the population of these species. Gaur and Bhatt (1994) described the uses of pteridophytes such as *Ampelopteris prolifera, Diplazium esculentum, Drynaria quercifolia Woodwardia unigemmata* and many more by the locals in Garhwal while Upreti and Negi (1996) has documented the uses of *Thamnolia vermicularis* (Lichen) by Lata villagers of Nanda Devi Biosphere Reserve (NDBR). Samant *et al.* (1996) have described the resource use by the locals of NDBR and have advocated the cultivation of these plants to reduce pressure on wild resources. Negi *et al.* (1999) dealt with food and medicinal plants of Har-Ki-Doon and have documented the uses of 72 different plant species used by the locals while Awasthi *et al.* (1999) has described the ethnobotanical uses of plant species found in the Tehri Dam Submersible area, majority of which were used for medicinal purposes. Singh *et al.* (1990) have described the uses of Gymnosperms by the locals in Garhwal. Rana *et al.* (1996) and Jain & Saklani (1991) have worked on the ethnobotany of tribals in Tons region while Pangtey *et al.* (1989) have studied the ethnobotany of Bhotia tribes. Negi *et al.* (1985), Negi and Gupta (1987) and Biswas (1994) have recorded the forest resources and their use in Garhwal. Gaur and Semwal (1983), Shah (1975), Kumar and Rohagti (1996) and Badoni (1987) are other major workers who have worked on the ethnobotany of Garhwal region.

1.3.4 Resource inventory and mapping based on Remote sensing: The Remote Sensing (RS) programme in India was initiated in 1970 when aerial surveys were conducted to produce Infra Red (IR) imageries for studying the coconut wilt disease in Kerala (Kasturirangan *et al.* 1992). The passive microwave radiometers launched by India in 1979 and 1981 using Soviet rockets generated imageries, which were utilised to study changes in pattern of snow cover in Himalayas (Chandrasekhar *et al.* 1992). Recently Saraf *et al.* (1995) have also presented their results on the extent of snow and snow depth in the Himalayan region and found that bands 4, 5 and 7 of Landsat were suitable not only for snow cover mapping but also for delineating different glacial landforms. Philip and Ravindran (1998) have mapped features of the Gangotri glacier. Kawosa (1988) has done extensive inventory of the Himalayan resources using Landsat imageries. Van Es (1972, 1974) worked on the forest vegetation of the Doon valley using Aerial Photographs (AP) and ERTS-1 (Earth resources technology satellites, renamed as Landsat) imageries and distinguished 11 different vegetation classes while Tiwari (1978) presented landuse and forest type classification of Tehri Garhwal using AP and highlighted the use of AP for preparing ground stock maps. Negi (1980) pointed towards the chances of misclassification between terraced cultivation and barren land while analysing the Landsat data for Alaknanda catchment. Tiwari *et al.* (1985) prepared an inventory of forest biomass for the Central Himalaya and later Tiwari *et al.* (1992) also classified the vegetation in Western Himalaya using IRS LISS-II data. The effect of landslide in Central Himalya has also been done by Tiwari *et al.* (1986) while Kimothi and Jadhav (1998) have studied the effect of forest fires in Garhwal Himalaya, their study indicated that the rate of spread of fire in chirpine forests is higher compared to oak forests. Jain *et al.* (1996) and Pant *et al.* (1996) have also studied the effect of fire on vegetation using RS. Porwal and Pant (1989) prepared forest cover and landuse maps of Chakrata using Landsat TM. They found that while oak forests and deodar/mixed conifer forest could be easily differentiated. Sub-tropical chirpine forest and northern tropical miscellaneous forests could only be distinguished after using geographical data. Later Pant and Roy (1990, 1994) analysed the forest cover and landuse dynamics in Tehri Garhwal. Rathore *et al.* (1997) studied the changes in forest cover in central Himalya and observed 3-5% reduction in the area under forest, similar results were obtained by Pant and Kharkwal (1995) for Jaunpur block in Tehri where there was conversion of close forest to open and open forest to scrub. A reverse trend was obtained by Sahai and Kimothi (1994-95) while studying the vegetation and landuse in the NDBR where 12 sq. km of area of open forest in core zone and 2 sq. km of area in buffer zone has been converted into close forest after its declaration as a protected area. The status of other protected areas have been evaluated by Tiwari *et al.* (1992) who studied the wildlife habitat and forest cover in the Rajaji National Park and Das *et al.* (1996) who studied the forest cover in Dhaulkhand range of Rajaji National Park using RS and GIS.

The perusal of above literature clearly indicates that floristic studies have been given more importance in Garhwal Himalaya. Vegetation studies particularly the structure and composition of forests are meagre and negligible work has been done in this field in the Bhagirathi catchment of Garhwal Himalaya. Studies on the structure and composition of forests are essential for the proper conservation and management of these forests, which not only sustain the major drainage systems of India but also form an important resource base for the local people. The sustainability of these watersheds, livelihood of the villagers and the status of native flora and fauna depends on the structure, composition and productivity of these forests. Hence, the present study was undertaken to analyze the structure and composition of these highly fragile and ecologically diverse forests, which have faced several phases of exploitation since the past few decades.

1.4 Objectives

The main objectives of the present study were:

- to prepare a baseline vegetation map of the area for future comparisons
- to study the structure and composition of forest along the gradients of altitude,
- to quantify the above ground woody biomass of these forests and
- to document the traditional knowledge of locals on the uses of plant species.

CHAPTER-2

Study Area

CHAPTER-2

Study Area

2.1 Western Himalaya

2.1.1 Physical and biogeographic zones: The sector of the Himalaya lying between river Sharda in the eastern Kumaun and the river Sutlej in Himachal Pradesh is generally referred to as the Western Himalaya (WH). It extends approximately from 76^0 36' to 81^0 E long. and 28^0 to 32^0 N lat . The defile of the river Sutlej forms an important landmark. To the east of it, the Himalaya forms a distinct biogeographic unit where more of Indo-Chinese and Malayan elements are found whereas to the west of this river more Ethiopian and Mediterranean elements are concentrated (Mani 1974). To the west of this defile there is an abrupt fall in the mean elevation of all ranges while in the other part the high peaks rise to mean elevations of 6500m. Nanda Devi (7822m), Swargarohini (6562m), Satopanth (7075m), Gangotri group of peaks (6613m), Bhagirathi group of peaks (6607m), Bandarpunch (6720m) and Kamet (7758m) are some of the better known peaks of WH. The mountain ranges in the east of the defile are aligned mostly on east-westerly direction whereas in the other part there is a southeast-northwest trend. The cold arid areas of Indo-Tibet border in west Himalaya fall in the Trans Himalayan zone whereas high zones extending up to 6000m with perpetual snow cover fall in the Greater Himalayan range. Mountain ranges with an average altitude of 3600-4600m come under Lesser Himalaya and the *Tarai* and *Bhabhar* areas of Kumaon and *Duns* of Garhwal lie in the outer Himalaya. Geologically, the Tibetan zone is composed of sediments of all ages from Cambrian to the late tertiary whereas the Central Himalayan zone of the snow covered peaks is composed of some sedimentary and metamorphic rocks of Pre-Cambrian and Palaeozoic. The Sub-Himalayan (Lesser Himalaya) is formed of sediments ranging from Pre-Cambrian upward to the Mesozoic and are mostly unfossiliferous and the Siwalik hills are composed of Tertiary sandstones and shales (Wadia 1975). According to biogeographic classification of Rodgers and Panwar (1988), WH has been placed in 2B biotic province. It has an area of 72000 sq. km. (covering 17.04% of the total Himalayan region) of which about 74% is under Uttaranchal (Garhwal- Kumaun) and rest under eastern Himachal Pradesh. Presently *ca.* 20% area (existing and proposed) of the WH including biologically rich areas of Nanda Devi, Valley of Flowers, Kedarnath, Har-ki-Dun and Askot has been brought under protected area network. Still a large portion of forests in WH remains unprotected and need immediate conservation measures.

2.1.2 Eco-climatic zones: Western Himalaya experiences lower monsoonal rainfall compared to the Eastern Himalaya (EH) but receives higher snowfall during winters. Local variations in the climate due to topography and relief features are common. Within the altitudinal range of 800-1200m the climate is warm subtropical, in 1200-2400m belt the climate is cool temperate while in 2400-3600m elevational range climate becomes alpine and above 3600m climate is more or less arctic type (Mani 1974).

2.1.3 Flora and Distribution of Vegetation*:* Climate plays a major role in the distribution of flora and fauna. There occurs a noticeable difference between the WH and EH. The EH is more humid than the WH. The precipitation is also much higher in the EH compared to WH. The timberline in WH (3500±200 m) is comparatively lower than in the EH (4000±200 m). The WH has wide representation of conifers while the EH has a greater diversity of rhododendrons and orchids (Rao 1994). Though EH is more rich in endemic species but restricted distribution of species such as *Microschoenus duthiei, Aphyllorchis gollanii, Balanophora involucrata* (a saprophyte) and *Cypripedium cordigerum* represent endemic taxa in WH. Also, WH is one of the eight centers of diversity in India (Arora & Nayar 1984). The WH has contributed species of the genera of *Pyrus, Prunus, Sorbus, Rubus, Ribes, Hordeum, Elymus, Eremopyrum, Cicer* and *Cucumis*. Besides climate, variation in altitude, aspect and soil also define the distribution of vegetation types. Broadly, Tropical Moist Deciduous (below 1300 m), Subtropical Pine (800-1800m), Himalayan Moist Temperate (1800-3300 m), Himalayan Dry Temperate (2000-2500m), Sub-alpine forests (2500-3500 m) and Alpine pastures and scrub (above 3500m) types of vegetation are found here (Champion & Seth 1968, Kawosa 1988, Puri *et al.* 1989).

Tropical Deciduous Forest (<1300m): These forests are found all along the foothills of the WH. *Shorea robusta* (Sal) is the dominant species. The main associates of Sal in these forests are *Anogeissus latifolia, Terminalia alata* and *Bauhinia retusa.* Species such as *Acacia catechu* and *Dalbergia sissoo* are observed along the riverbanks on sandy alluvium. In humid places *Syzygium cuminii* and *Toona ciliata* are found. *Cinnamomum tamala, Ougeinia oojeinensis,* are common in gorges whereas climbers such as *Bauhinia vahlii* are common in the lower altitudes. The dominant shrubs of the zone include *Clerodendron viscosum, Woodfordia fruticosa, Indigofera pulchella, Helicteres isora, Murraya koenigii,* and *Carissa spinarum. Berberis* spp. and *Ziziphus* spp are the other important shrubs. These forests have been referred to as subtropical moist winter deciduous forests by Puri *et al.* (1989), northern tropical dry deciduous forests by Champion & Seth (1968) and tropical deciduous forest by Schweinfurth (1957).

Subtropical Pine Forest (800-1800m): Chir pine (*Pinus roxburghii*) is widely distributed in the outer ranges of WH. Pure formations of Chir can be seen on the quartzite and lime-stone belts. At lower altitudes it is mixed with species such as *Shorea robusta, Anogeissus latifolia, Dalbergia sissoo, Mallotus philippinensis* and *Terminalia* spp. whereas on its upper limits it is associated with *Quercus leucotrichophora, Rhododendron arboreum* and *Lyonia ovalifolia. Rhus parviflora, Rubus ellipticus, Colebrookea oppositifolia, Glochiodon velutinum, Carissa opaca* and *Berberis* spp. are the common shrubs. The common grasses of the forest are *Heterepogon contortus, Arundinella intricata* and *Themeda anathera.* The hot dry slopes are covered by *Euphorbia royleana* and under biotic pressure they may extend and become denser and purer owing to the elimination of less resistant species. These are often referred to as *subtropical Euphorbia scrub* (Champion and Seth, 1968).

Himalayan Moist Temperate Forests (1800-3300m): Associations of evergreen oaks and conifers cover the temperate zone. In these forests the dominant species are *Quercus leucotrichophora, Quercus floribunda* and *Quercus semecarpifolia.* Associated conifers are *Cedrus deodara, Picea* *smithiana* and *Abies pindrow.* Other tree species include *Lyonia ovalifolia, Rhododendron arboreum, Litsea umbrosa, Betula alnoides, Carpinus viminea, Acer caesium, Fraxinus micrantha, Acer pictum, Pyrus lanata* and *Prunus cornuta.* The common shrubs found are *Berberis lycium, Desmodium tiliaefolium, Cotoneaster bacillaris, Rhamnus purpurea, Rosa macrophylla, Viburnum cotinifolium, Rubus niveus, Sarcococca saligna and Daphne papyracea.* The ground is covered with *Thalictrum foliolosum, Galium aparine, Fragaria nubicola, Viola canescens, Senecio nudicaulis, Valeriana wallichii* and *Podophyllum hexandrum.* Some of common climbers include *Clematis montana* and *Vitis himalayana.* Various workers have named these forests differently e.g., Oak and Low level silver fir forest (Osmaston 1927), Broad leaved sclerophyllous forest (Dudgeon and Kenoyer 1925), and Temperate mixed oak and conifer forest (Schweinforth 1957).

Himalayan Dry Temperate Forests (2000-2500m): The forests are predominantly dominated by conifers (Champion and Seth 1968). The principal component of this zone is *Cedrus deodara,* which occupies belt ranging from 2000-2500m where it occurs in pure formations. However in the lower altitudes and warmer localities it may either be replaced or mixed with *Pinus wallichiana.* Towards the higher altitudes and mesic sites, it is mixed with or replaced by *Abies pindrow* and *Picea smithiana.* In this zone broad-leaved species are *Q. floribunda, Ulmus wallichiana, Corylus colurna, Acer caesium* and *Populus ciliata.* Important shrubs of this forest type are *Berberis lycium, Indigofera, Gerardinia, Desmodium tiliaefolium, Rhus punjabensis, Artemisia* spp and *Astragalus* spp. The ground cover is composed of *Plectranthus rugosus, Salvia glutinosa* and *Fragaria vesca.* These forests have been referred to as *Cedrus-Pinus* formations by Osmaston (1927).

Subalpine Forests (2500-3500m): These are located above temperate forests and extend upto tree line. *Betula utilis* is one of the important components of these forests. Other associated species are *Sorbus foliolosa, Rhododendron campanulatum.* Evergreen *Quercus semecarpifolia* also extend upto the timberline zone in many parts of Himalaya and may be associated with *A.pindrow. P. wallichiana* (blue pine) may also form treeline community in some parts. Other genera widely represented are *Salix, Lonicera, Ribes, Viburnum* and *Polygonum* (Champion and Seth 1968).

Alpine Forests (> 3500m): The vegetation above treeline (3500±200 m) in WH is characterized by scattered scrubs, herbaceous meadows, sedge-grass formations and sparse xerophytic communities. The area remains under snow for at least six months. These forests are divisible into three sub-types *viz.*, alpine meadows, moist alpine scrub and dry alpine scrub (Puri *et al.* 1989) . The alpine meadows are found on smooth and stable slopes and chiefly comprise of plant species such as *Potentilla, Geranium, Ranunculus, Carex* and *Kobresia*. The moist alpine scrubs extend immediately above the tree line at 3600m. Species of *Rhododendron* and *Betula* dominate these forests. The herbaceous elements are represented by species of genera such as *Primula, Iris, Gentiana, Saxifraga, Anemone, Corydalis, Rumex, Cardamine, Thymus, Aster, Viola, Fritillaria*, and *Epilobium*. The common grasses are *Agropyron* spp., *Bromus asper* and *Poa annua*. The dry alpine scrub is mostly composed of xerophytic plants. This zone is characterized by *Juniperus squamata* and *Juniperus macropoda.* Other common scrub species found are *Hippophae rhamnoides, Elaeagnus umbellata, Oxyria digyna* and *Atriplex hortensis* whereas the important herbaceous vegetation is composed of species of genera such as *Festuca, Stipa, Bromus and Carex*. Schweinfurth (1957) describes this vegetation type as Alpine steppe.

2.1.4 Fauna: WH, owing to a great deal of variation in altitude, latitude and habitats, supports a diverse fauna. According to Mani (1974) fauna of WH has strong affinities with Oriental, Mediterranean and Ethiopian regions. In the tropical deciduous forests typical mammals found are the Asian elephant (*Elephas maximus*), tiger (*Panthera tigris*), rhesus macaque (*Macaca mullata*), common langur (*Presbytes entellus*), Sambar (*Cervus unicolor*) Chital (*Axis axis*), Jackal (*Canis aureus*) and many others. Important birds of the area include Indian pea fowl (*Pavo cristatus*) and red jungle fowl (*Gallus gallus*). Important animals of the Temperate zone include common leopard (*Panthera pardus*), Asiatic black bear (*Selenarctos thibetanus*), sambar (*Cervus unicolor*), barking deer (*Muntiacus muntjac*), serow (*Capricornis *sumatraensis*), goral (*Nemorhaedus goral*) and wild boar (*Sus scrofa*). Cheer pheasant (*Catreus wallichii*), Khaleej pheasant (*Lophura leucomelana*) and patridges such as chukar (*Alectoris chukar*) and black partridge (*Francolinus francolinus*) are the important birds of this zone. In the sub-alpine zone the Himalayan tahr (*Hemitragus jemlahicus*), brown bear (*Ursos arctos*), Himalayan musk deer (*Moschus chrysogaster*) are some of the important faunal species. Monal (*Lophorus impejanus*), Western Tragopan (*Tragopan melanocephalus*) and Koklas (*Pucrasisa macrolopha*) are the prominent pheasants of the area. Alpine zone is inhabited by animal species such as blue sheep (*Pseudois nayaur*), red fox (*Vulpes vulpes*) and snow leopard (*Panthera uncia*) whereas important avi-fauna include snow-cock (*Tetraogallus tibetanus*), yellow and red billed Himalayan chough (*Pyrrhocorax* spp) and snow partridge (*Lerwa lerwa*).

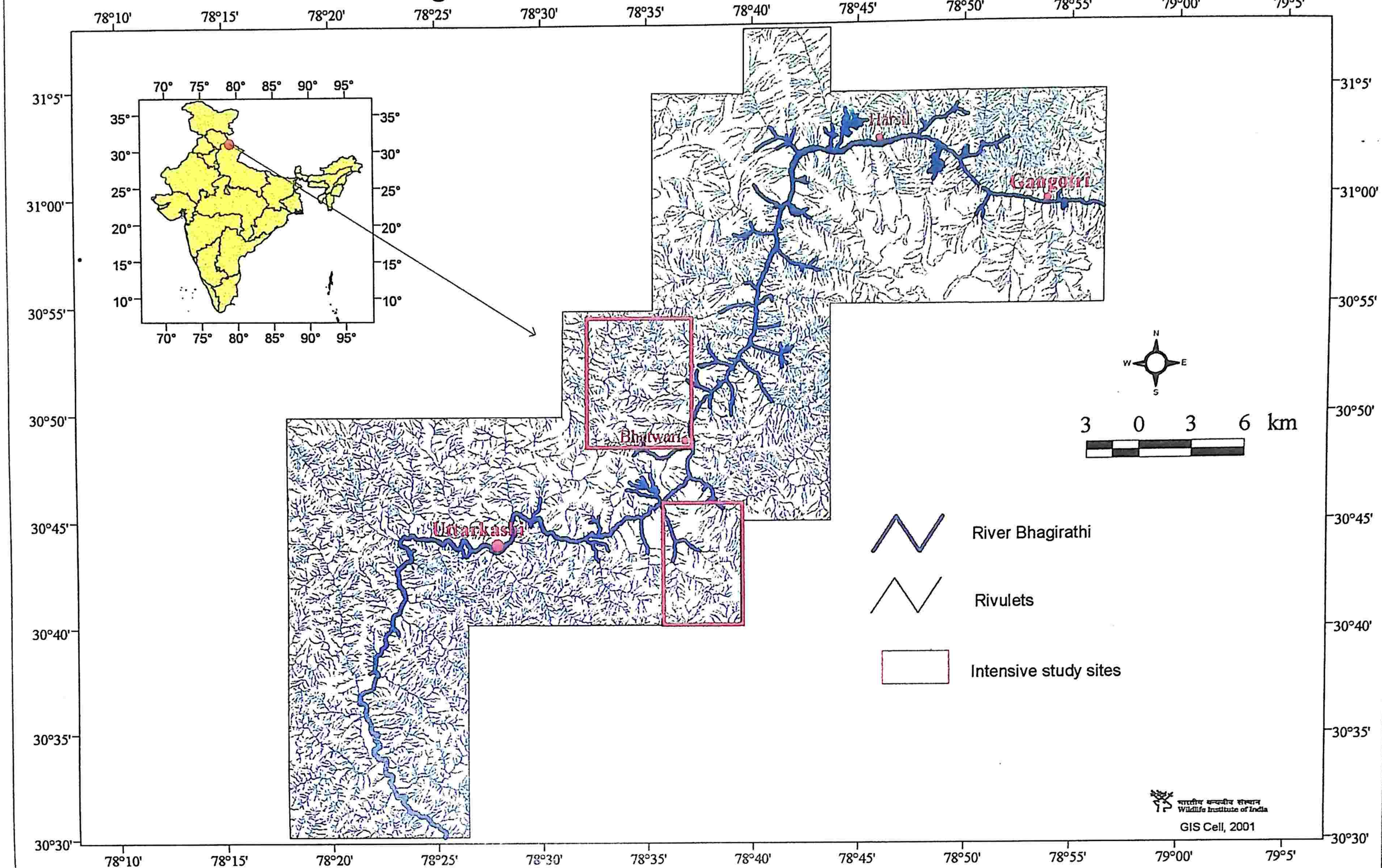
Recently concerns have been raised to preserve the fast depleting wildlife of the WH on a priority basis (Anonymous 1992).

2.2 The Intensive study area

The intensive study area lies in the upper catchment of river Bhagirathi in district Uttarkashi. The district comprises 4 tehsils and 6 community development blocks. It has 3 towns and 686 villages, which are distributed under different blocks *viz.*, Mori, Purola, Naugaon, Dunda, Chinyalisaur and Bhatwari. The study area is located between 30^0 30' to 31^0 08' N lat and 78^0 18' to 78^0 57' E long. It covers an area of *Ca* 2050 sq. km. Kinnaur district of Himachal Pradesh and territory of Tibet (China) form its northern boundaries, the eastern boundary is formed by a part of Tibet and district Chamoli, while the districts of Tehri and Dehradun form the southern and Western boundaries respectively (Figure-2.1). The terrain is mountainous consisting of high hill ridges, plateaus and narrow valleys.

2.2.1 Drainage*:* The whole district is well drained. Two great rivers of India viz., Bhagirathi (called the Ganga beyond Deoprayag) and the Yamuna form the main drainage of district Uttarkashi. Yamuna rises from west of Bandarpunch peak with rivers Tons, Aglar, Pabar being its important

Figure-2.1: Catchment area of river Bhagirathi



tributaries. The Bhagirathi has its origin from Gangotri Glacier. Its main tributaries are Janhavi and Bhilangana. It flows westerly for about 40km and then turns south across the axis through a deep gorge where the stream bed is about 7000 ft asl. From here tortuous course is southerly to the plains, about 120km distance. Along its catchment area, many rivulets locally called as *Gads* form different watersheds. Some of the rivulets, which form important watersheds, include Jadhganga, Kankora, Jalandhari, Pilangana, Duggada, Bhatwari, Sainj and Assiganga. Of these, Duggada and Bhatwari, were selected for the Intensive Study. The two watersheds selected for intensive study lie in the administrative block Bhatwari. In block Bhatwari there are 94 villages, of which 92 are inhabited and 2 have been recently abandoned.The number of villages in the intensive study localities are eight and all are inhabited. The altitudinal gradient of the two watersheds varies from 1700-3600m asl. (Figures-2.2 and 2.3).

2.2.2.Climate: The climate of the district is largely temperate monsoonal type. Three seasons viz., rainy (mid June-September), winter (October-March) and summer (April-June) are well defined. Winters are severe due to frosts and snowfall in the upper and middle altitudes.

For the present study rainfall data were gathered from Tehsil Bhatwari, where a rain gauge has been set by the Government authorities while for recording the temperature during the study period a minimum-maximum thermometer was set at the base camp. The monthly rainfall at Bhatwari for the period of 1996 to 1998 is shown in Figure-2.4. Maximum annual rainfall for the upper catchment of river Bhagirathi was recorded in the year 1986 whereas minimum annual rainfall was recorded during the year 1995 (Figure-2.5). Average monthly temperature from 1996 to 1999 is shown in Figure-2.6. The highest temperature of 30.86^{0}C was recorded in the month of June whereas lowest temperature 3.6^{0}C was recorded during the month of December and January. Relative humidity was highest nearly 90% in the monsoon and the lowest during the pre-monsoon months when it may drop to even less than 40%.

Figure-2.2: North facing- Duggada watershed

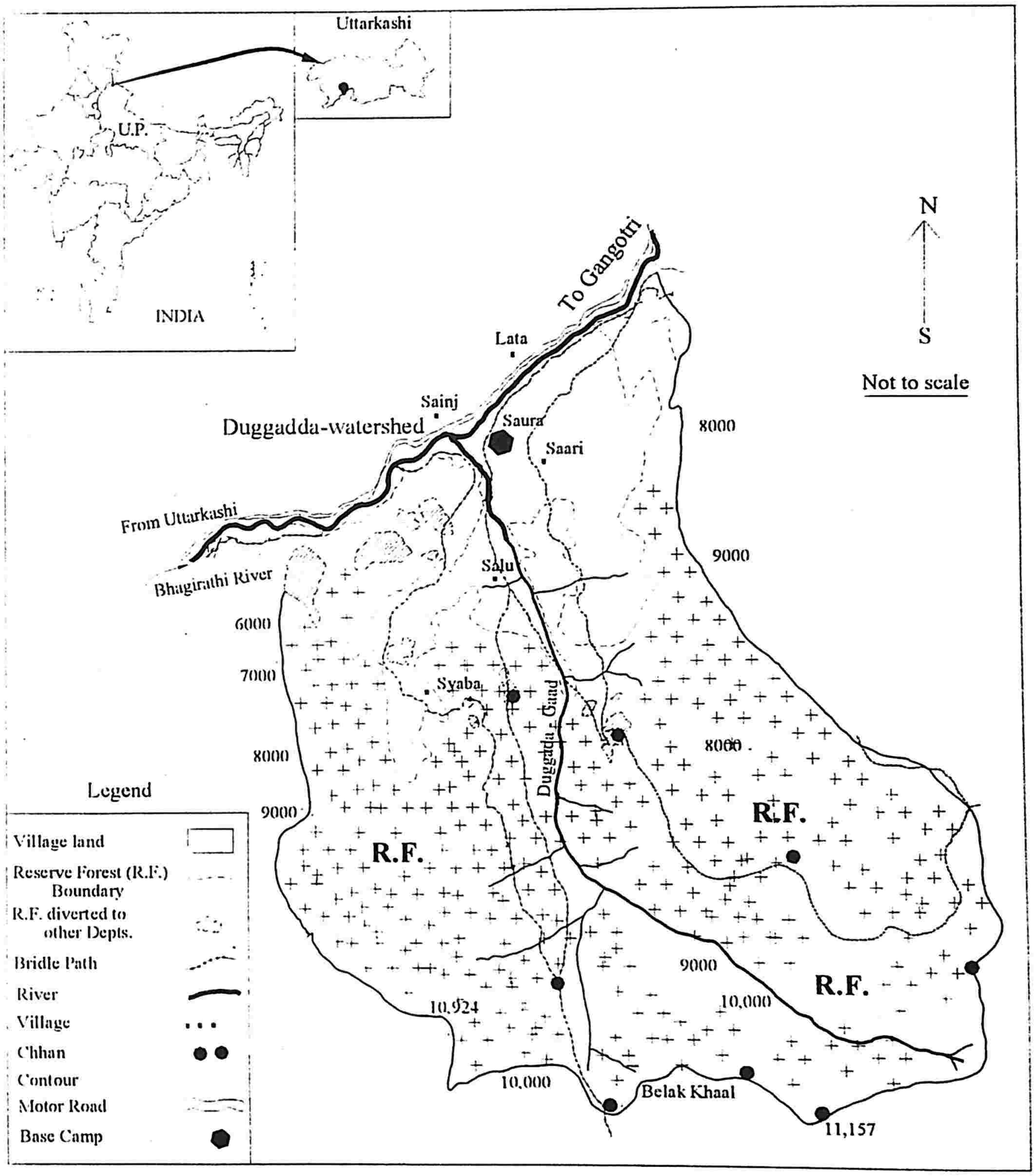


Figure-2.3: South facing-Bhatwari watershed

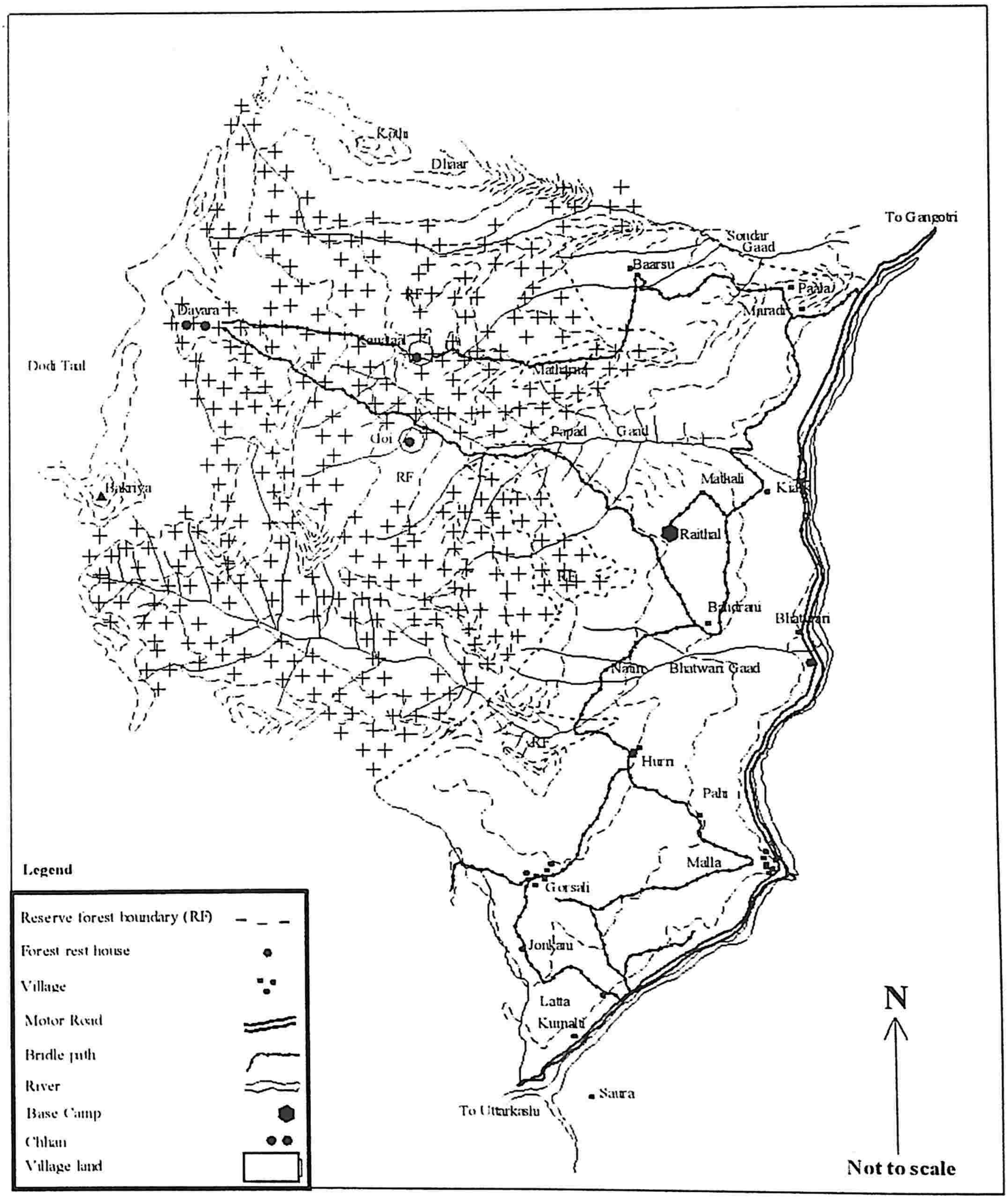


Figure- 2.4: Monthly rainfall in intensive study sites
(Source: Tehsil Bhatwari)

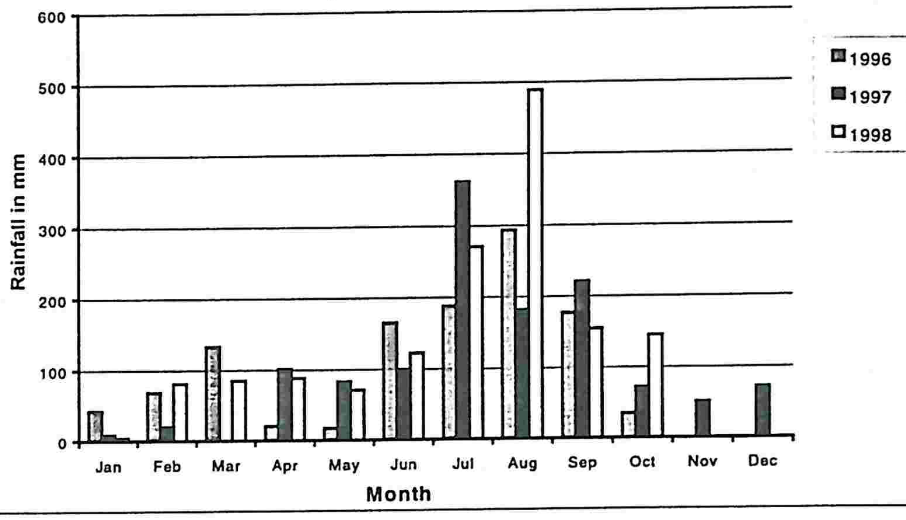


Figure-2.5: Annual rainfall for the upper catchment of river Bhagirathi (Source: Tehsil Bhatwari)

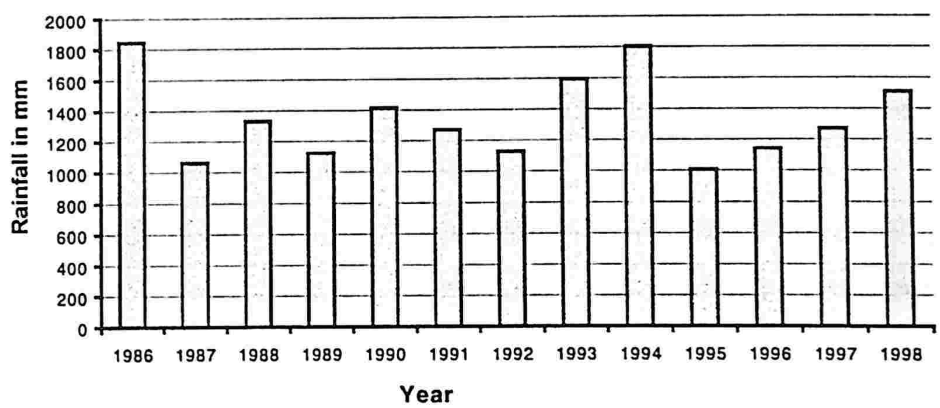
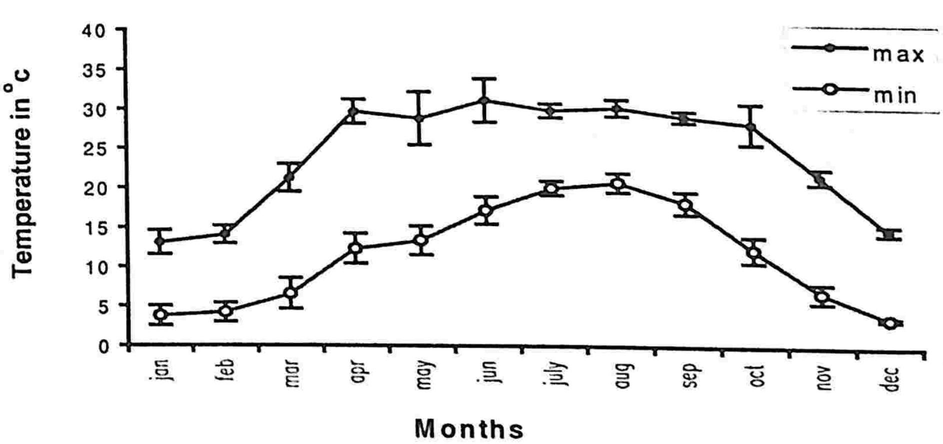


Figure-2.6: Mean monthly temperature during 1996 to 1999 at Bhatwari



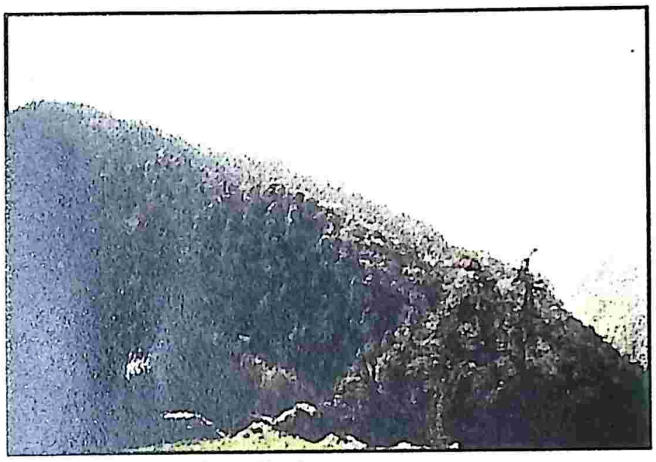
2.2.3 Geology and Soil: Geologically the Uttarkashi district may be divided into two major belts the northern and the southern, demarcated by the river Sainj. The former one is occupied mainly by the higher ranges and snow covered peaks and consists entirely of high grade metamorphic rocks such as slates, quartzites, marble and various type of micaceous schists and gneisses, whereas the southern belt comprises chiefly of sedimentary and low grade metamorphic rocks such as limestones, quartzite, slates and sericite biotite schists (Wadia 1975, Saklani 1993).

The quality of the soil is determined by the kind of rocks in the subsoil. In Himalaya very shallow skeletal to very deep soils are found. The surface soil or the upper layer of a soil profile is richer in organic matter and darker in colour. The profile characteristics of soil vary from place to place. Soils on steep slopes (>30^0) are shallow due to erosion and mass wasting processes and have very thin surface horizons. Texturally, they are medium to coarse depending on the type of material from which they have been derived. Soils in general are acidic except those developed from limestone which are neutral to slightly alkaline. Valley soils are developed from the colluvium and alluvium brought down from the slopes and deposited in valleys. The soils, therefore, are coarse textured unless the surrounding hills are of shale rocks (Ghildiyal 1981). Entisols or young soils are generally present in the terraces and along channels on the colluvial and alluvial materials. Less developed soils or Incepticols are common on the surface of the slopes whereas brown forest soils are medium to heavy textured, deep, moderately well drained, rich in organic matter and acidic in nature. In the alpine areas either meadow soil or soil rich in morainic contents are found.

2.2.4 Forest: The Uttarkashi district is spread over 8016 sq. km. Of this nearly 88% area is administered by the Uttaranchal (erstwhile Uttar Pradesh) forest department, most of which (4,633.73 sq. km.) falls under Uttarkashi forest division. Administratively this is further divided into two subdivisions, five ranges and 39 beats. Out of the total area managed by the forest department *ca.* 49.9% is covered with snow while 7.65% is rocky, 0.86% is open, *ca* 16.67% is under alpine vegetation and rest (24.92%) is covered by forests. The following categories of forests according to Champion and Seth's

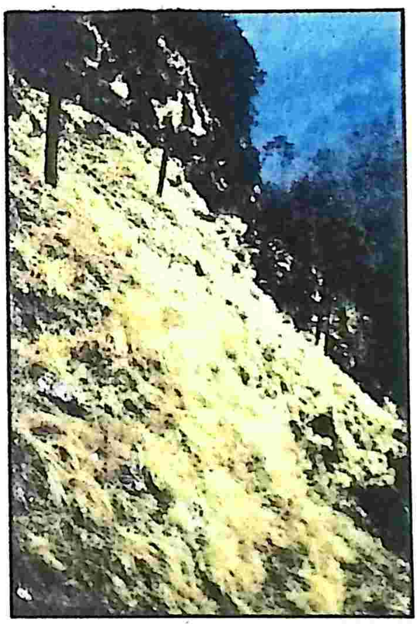
Scrub

Chir pine

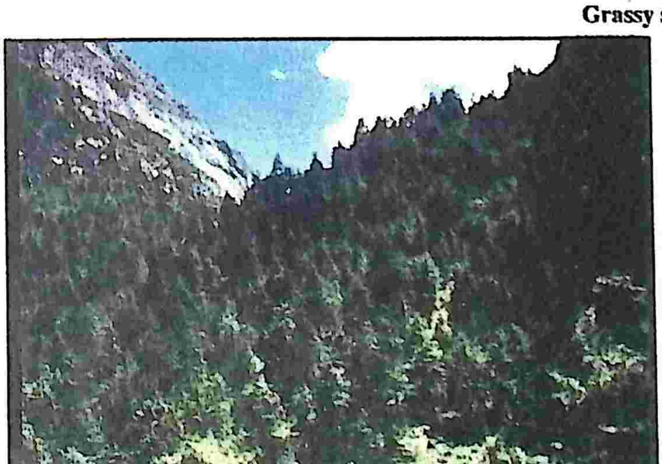


Broadleaf

Mixed broadleaf



Grassy slopes



Conifer

Alpine meadows

Plate-2: Vegetation types in study area

classification (1968) are found in the study area Subtropical Pine Forest, Himalayan Moist Temperate Forest, Himalayan Dry Temperate Forest, Sub-Alpine forest, Moist Alpine Scrub and Dry Alpine Scrub (described in section-2.1.3). The forests of intensive study areas selected for the present study lie in Taknaur and Mukhem range having *ca* 3,731.87 sq km and 232 sq km area respectively. The lower valleys are dominated by chir pine (*Pinus roxburghii*) covering an area of 405.68 sq km. The timberline is formed by Kharsu oak (*Quercus semecarpifolia)* covering 144.71 sq km. The largest area falls under alpine pastures 798.34 sq km (Plate-2.1). The forests of the area meet the demands of fuel, fodder, leaf-litter and non-timber forest products for the local people. Overexploitation, especially near the habitation has converted the oak forests into scrub. Presence of *Chaks* (agricultural land amidst the forest) has also increased the pressures on forests. A total of 325 *chaks* covering an area of 98.71 sq km occur in the forests. During the summer months, herds of buffaloes and cattle are housed in temporary huts called *Chhans,* in the subalpine and alpine meadows, (locally called *kharaks*). Forests, which are relatively inaccessible and away from habitation, are in good state.

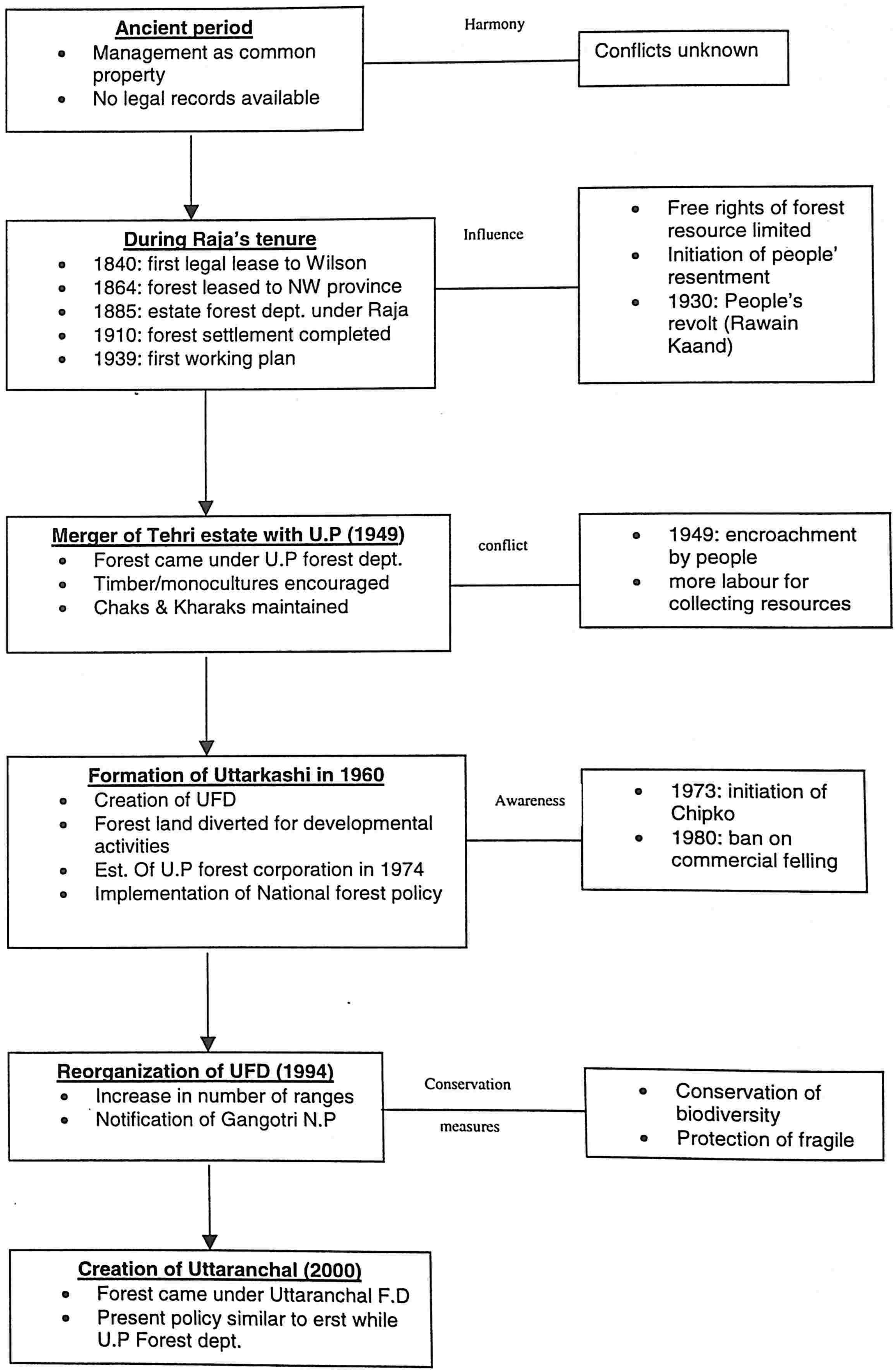
2.2.5 Fauna: The varied topography and diverse forests serve as good habitat for various faunal species. Important ungulate species found in the study area are sambar, goral, barking deer, wild pig, Himalayan musk deer, serow, Himalayan tahr and bharal. Tahr and bharal are found in the higher reaches of Gangotri and Gaumukh whereas sambar, barking deer, wild pig and goral are seen in the mixed broad-leaved forests with an under growth of hill bamboo (vern. *Ringal*) and adjacent grassy slopes. Musk deer and serow are confined to relatively undisturbed and inaccessible patches at higher altitudes. Some of the carnivorous species inhabiting these forests include Asiatic black bear, brown bear, common leopard and red fox. The small mammals, frequently seen, are pale weasel (*Mustela sibirica*), Himalayan yellow throated marten (*Martes flavugula*) and flying squirrels (*Petaurista petaurista albiventer*). Pheasants such as monal, kaleej, jungle fowl and koklas form the important component of the avifauna in the study area.

2.3 Past History of Forest Management

The local inhabitants in the study area are primarily agropastoralists. They have been using the forests and forest products since their advent in the region. The traditional practices of resource use, perhaps due to low human densities and extensive forests, were sustainable. Although, written rules and regulations pertaining to management of natural resources prior to 1840 are not available, certain practices of conservation such as reverence of sacred trees and system of rotational grazing exist among the local communities. The villagers set aside certain areas for hay production (locally, *Ghasni*) where livestock grazing is not permitted and hay collection is allowed only after certain dates (*Rakeeta*). Unlike many parts of India, the land and forests of Uttarkashi and Tehri were owned by the then ruler (*Raja*) of erstwhile Tehri Garhwal. The local people (subjects) were given several concessions and were allowed collection of free timber, fuelwood, fodder and leaf litter for cowsheds. The only pressures on the forests, before the beginning of commercial forestry were from the practice of *Nayabad* and *Pula* and the sources of revenue were mainly agricultural and milk products (Atkinson 1882). A brief outline of the history of forest management in the study area is given in Figure-2.7 In the year 1840 these forests were leased to Mr. Wilson on contract who exploited them for commercial purposes resulting in much deterioration. This aroused a need for scientific management of these forests that led to the establishment of forest department under the control of ruler. For the management of the forests, the state constituted its own department with four ranges and 23 beats under a conservator of forest (Raturi 1938). Deodar plantations were started in suitable localities, all deodar and chir forests under regeneration were fire protected, shifting cultivation was prohibited and breaking up of forest land for new cultivation (*katil* farming) without previous permission stopped. Later, Pt. Keshvanand, a forest officer, demarcated almost all the deodar (*Cedrus deodara*), sal (*Shorea robusta*) and papri (*Buxus wallichiana*) forests, large area of chir and small patches of Ban oak (*Quercus leucotrichophora*) forests near Tehri between 1897-1899. They further imposed prohibition on felling of trees without permits and hammer marking, curtailment of grazing and checks were also introduced on extension of cultivation in wastelands. Pt. Keshavananad was succeeded by Pt.

Sadanand who proposed removal and modification of irksome restrictions on villager's forest requirement, demarcation of forest from wasteland and felling to be reduced to an amount to meet the cost of management only. A new era in forest conservancy began with the advent of Pt. Ram Datt Raturi. He divided the forests into three classes viz., reserved, protected and civil. The first two were under the forest department while the third was to be controlled by the civil authorities (Working Plan 1949). After the annexation of Tehri state with Uttar Pradesh (U.P) in 1949 the forests came under the control of U.P forest department. The primary aim of the forest department continued to be bringing forests to a maximum state of productivity. In case of revenue forests e.g deodar, kail, chir the immediate objective was to produce timber trees so as to get maximum commercial timber. This led to monocultures with low biodiversity but high economic returns. Along the common boundaries of chir with ban and other broad-leaved species removal of broad leaved species was encouraged so as to stock these areas with Chir. Commercial exploitation and restrictions of the villagers rights on the forests led to social unrest which gave rise to "Chipko" movement and initiation of *Van mahotavsa* (Shiva and Bandhyopadhyay 1986). The villagers resented the Gujjars being given permission to graze large number of buffaloes in the high altitude forests. The re-organization of the erstwhile Tehri Garhwal in 1960 led to the formation of another district Uttarkashi and consequently the forests were brought under the control of Uttarkashi Forest Division. This Forest Division, earlier, had five ranges, which (after reorganization in 1994) was divided into six ranges for better management. Recently, Gangotri National Park covering an area of *ca* 2390 sq. km, lying in the Gangotri range has been notified. The primary aim of the park is to promote biodiversity conservation in the region (Working Plan 1996). With the declaration of new state Uttaranchal in year 2000 the forests came under the jurisdiction of Uttaranchal Forest Department.

Figure-2.7: Chronology of past forest management practices in Bhagirathi valley



CHAPTER-3

General Methods

CHAPTER- 3

General Methods

The overall aim of the present study was to assess the current conservation status of forests in the upper catchment of river Bhagirathi. This necessitated collection of both primary and secondary data from the study area. Various parameters of vegetation and abiotic factors were collected, analysed and correlated to meet the study objectives. Figure-3.1 shows a general methodological approach adopted for the study. General approach of field sampling i.e. collection of primary data and collation of secondary information is described below:

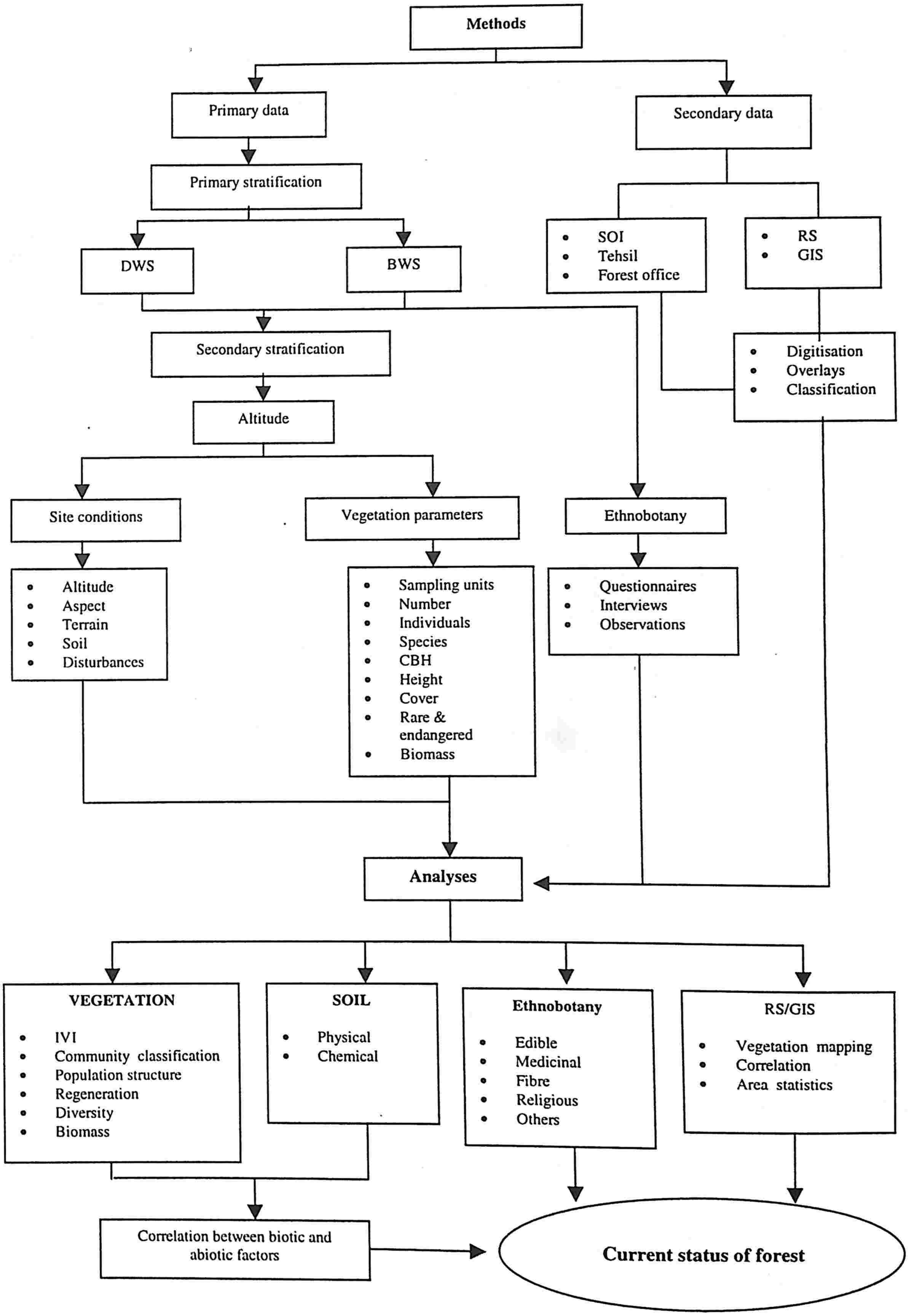
3.1 Field work and collection of primary data

The fieldwork pertaining to the present study was conducted during October 1996 to July 1999.Various steps involved in the field sampling include

3.1.1 Stratification: A reconnaissance survey of the upper catchment of river Bhagirathi was carried out in January 1996. Based on the survey two intensive study sites (ISS) *viz.*, Dugadda Watershed (DWS) and Bhatwari Watershed (BWS) were selected. The sites were representative of the area in terms of vegetation, landuse, altitude and aspect. DWS had an altitude ranging from 1700 to 3600m with north facing slopes while BWS had south facing slopes with an altitudinal range of 1800 to 3600m. The fieldwork for DWS was started in July 1996 and was completed in February 1998 while fieldwork for BWS was undertaken during March 1998 to July 1999. The basis of secondary stratification was altitude (Chapter 4).

3.1.2 Sampling units: At every 100m rise in elevation one hectare plots were permanently marked for sampling vegetation and terrain features. For trees, 10X10m square quadrats (n=10) and for shrubs 5X5m square quadrats (n=10) were randomly laid. The size and number of sampling units were determined by species area curve and running mean method respectively (Misra 1968). The plants were identified using floras (Naithani 1984-85, 1995,

Figure-3.1: Outline of general methodology adopted for the present study



Hajra and Balodi 1995, Polunin & Stantion 1984) in the field. However, the plants, which could not be identified in the field, were collected and brought to headquarters. These were then identified using voucher specimens available at the herbaria of Wildlife Institute of India (WII), Forest Research Institute (DD) and Botanical Survey of India (BSD).

3.1.3 Estimation of above ground biomass: Dominant shrub species of different circumference at ground level (CGL) were harvested in the field and their fresh weight was noted (Chapter 5). Later after 20 days their sun dried weight was noted following Misra (1968).

3.1.4 Soil: The soil samples were collected from permanently marked one hectare plots in different forest types in the same season. Three sample plots of 30X30X30 cm each were dug randomly within each plot to collect soil. An area of 30 X 30 cm was cleared after removing litter and humus. The soil was collected from three strata 0-10cm, 10-20cm and 20-30 cm. The samples of each stratum from the three plots were mixed to minimise biases. The samples were collected in airtight polybags and labeled. Later, the samples were brought to the laboratory at headquarters for analyses which was done following Jackson (1973) and Saxena (1987) (Chapter 4).

3.1.5 Ethnobotanical surveys: The ethnobotanical surveys were conducted using questionnaires and informal interviews (Chapter 6). Data were collected on plant parts used, quantity and preparation following Jain and Mudgal (1999) and Martin (1995).

3.2 Secondary data

The Forest Working Plans (1986-95, 1996-2005), District gazetteer and other records were consulted to collect and collate information on the number of ranges, various forest types, their area and distribution. Past history of forest management in the study area was extracted from the Forest working plans and District Gazetteer while past rainfall and climate data were collected from the Block office and Tehsil.

The Survey of India (SOI) toposheets were used for extracting information on various themes such as contours, road network and landuse. Remote Sensing (RS) data of IRS 1C, LISS-III for the month of November was acquired from National Remote Sensing Agency (NRSA) Hyderabad for vegetation classification.

3.3 Analyses

3.3.1 Soil analyses: The chemical analyses of soil were performed in the laboratory to find pH, percent Nitrogen, Phosphorus and Potassium. Physical properties such as water holding capacity were recorded following Jackson (1973) and Saxena (1987). The soil characteristics and other abiotic factors were correlated with data on vegetation parameters to determine their influence on the plant distribution using CANOCO (Ter Braak 1986, 1987 Chapter 4).

3.3.2 Vegetation structure and composition: The structural aspect of vegetation such as density, frequency, abundance and dominance of constituent species were determined following Misra (1968). The relative values of density, frequency and dominance were used for calculating importance value index (IVI) following Curtis and McIntosh (1950). The A/F ratio was analyzed following Whitford (1949) so as to interpret the distribution pattern of species. Individuals with circumference at breast height (CBH) ranging between 10.5-31.5 cm were treated as saplings while individuals with CBH below 10.5 were treated as seedlings (Singh & Singh 1992). The girth class distribution was used for determining the regeneration potential and population structure of the dominant tree species (Saxena *et al.* 1985).

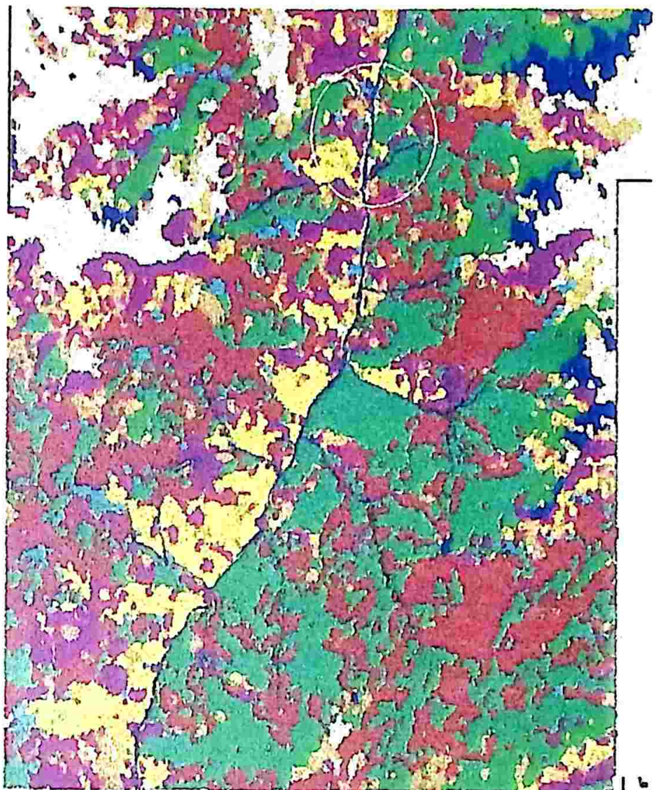
The plant communities for woody vegetation were classified using computer software TWINSPAN (Two Way Indicator Species Analyses, Hill 1979). Bray and Curtis (1957) Polar Ordination was used to determine the similarity between different communities (Chapter 4). Species diversity, evenness and richness were calculated using computer package "STATECOL" (Statistical Ecology, Ludwig and Reynolds 1988). The diversity, evenness and richness (Magurran 1988) were compared between different communities and the two ISS (Chapter 4).

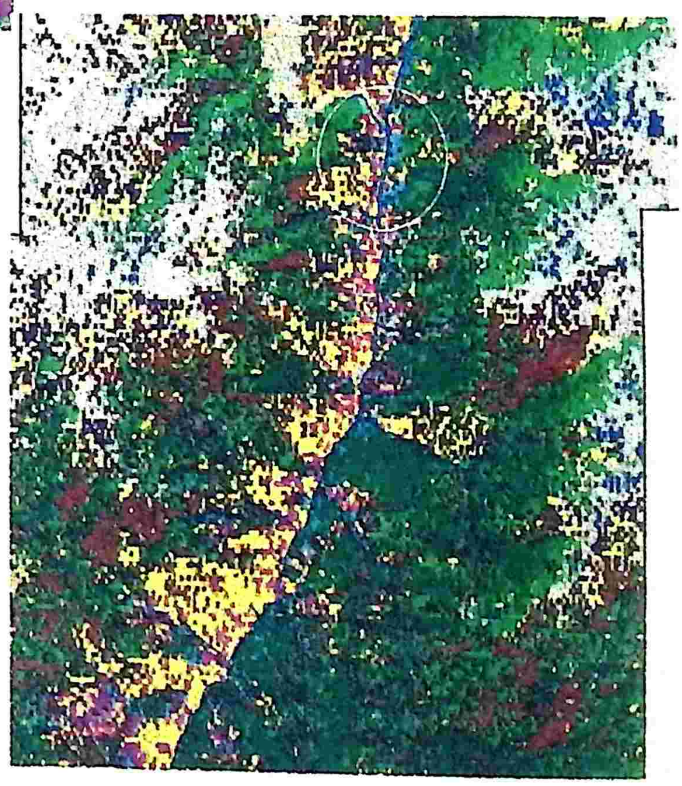
3.3.3 Estimation of above ground biomass: For calculation of above ground standing biomass of the tree species regression equations developed by Rana *et al.* 1989, Singh & Singh (1992) and Adhikari *et al.* (1995) for similar forests in Kumaun Himalaya were used. For shrubs regression equations between dry weight and CGI were developed to calculate their above ground biomass (Chapter 5).

3.3.4 Ethnobotany: Information collected through questionnaire surveys was segregated into different categories *viz.,* edible plants, medicinal plants, fibre yielding plants and religious plants (Chapter 6).

3.3.5 Vegetation mapping and classification: Remote Sensing (RS) and Geographical Information System (GIS) were used for mapping different vegetation types. Digital data of IRS 1C LISS-III for the month of November 1998 was acquired from NRSA. After rectification and enhancement, the Area of Interest (AOI) was extracted which was later processed using ERDAS Imagine ver 8.3. to obtain classified maps of the area. Different themes from SOI toposheets were digitised to generate spatial database in ARC/INFO ver 7. From the digitised contours, digital elevation model (DEM) was generated at an interval of 80m. From DEM slope and aspect maps were derived. To refine the classified map DEM was used to segregate species with similar spectral reflectance. Finally vegetation map with 12 classes was generated and analysed for area statistics using ARC/VIEW ver 3.1.

CHAPTER-4





Vegetation Classification and Mapping

CHAPTER- 4

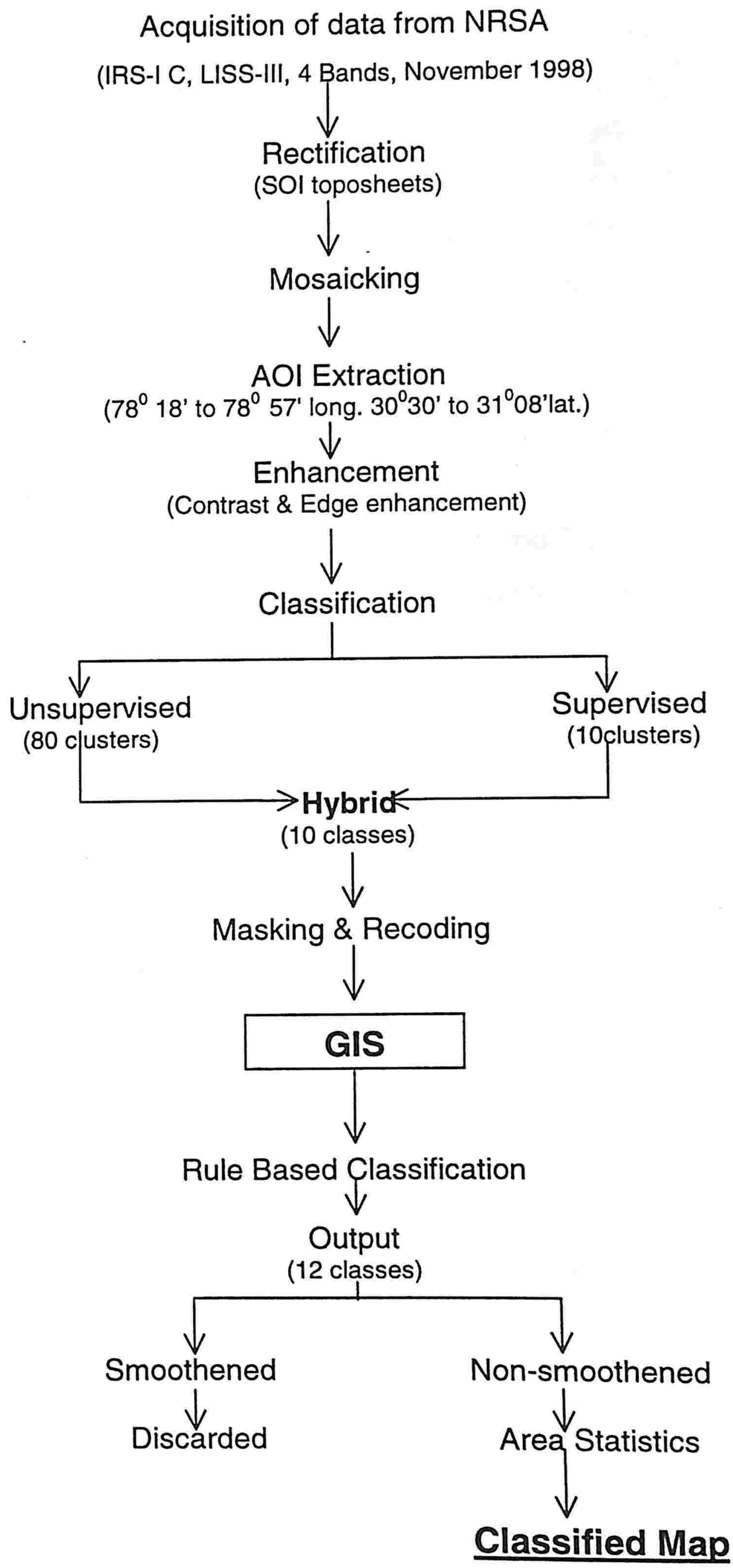
Vegetation Classification and Mapping

4.1 Introduction

Mapping of natural resources is essential for their conservation and management (Skole and Tucker 1993, Franklin *et al.* 1994, Defries and Townshend 1998, Innes and Koch 1998). The use of Remote Sensing (RS) for natural resource mapping began with the launch of Landsat-1 in 1972 (Vans Es 1974, Bryant *et al.* 1980, Hobbs *et al.* 1989). However, in India the use of RS for vegetation mapping is very recent. With the launch of series of Indian Remote Sensing (IRS) satellites (Kasturirangan *et al.* 1992, Rao 2000) gathering information about remote and inaccessible areas became easier (Roy *et al.* 1996). The complexity and inaccessibility of Himalayan terrain inhibits intensive field surveys where RS as a tool can help in exploring such ecologically important and inaccessible areas (Fleming 1988, Sahai & Kimothi 1994-95, Ghosh *et al.* 1996). Vegetation mapping is important for preparing inventories, for extrapolating field observations and for long term monitoring (Mueller-Dombois 1984). The fragility of Himalaya, recent developments coupled with low productivity of land calls for the proper management of its natural resources (Gupta *et al.* 1993). Several studies such as Vans Es (1972, 1974), Tiwari (1978), Negi (1980), Tiwari *et al.* (1992), Sahai & Kimothi (1994), Pant & Kharkwal (1995) and Das *et al.* (1996) have been done to classify forest and landuse types in parts of Garhwal Himalaya. However, Bhagirathi valley in the Western Himalaya is one such area where natural resources have been exploited since the time of Britishers (Raturi 1938) but their status has not been well documented. Studies done by Philip and Ravindran (1998) and Saraf *et al.* (1999) in this valley are limited to glacier and snow cover mapping. Hence, this study was initiated with an aim to document and map the current status of forests in the area for their proper conservation and management. Broad objectives of the study were:

- To classify and map different vegetation types
- To relate the vegetation types with abiotic factors

Figure- 4.1: An outline of the methods for vegetation classification



4.2 Methods

A brief outline of the methods followed is given in Figure-4.1

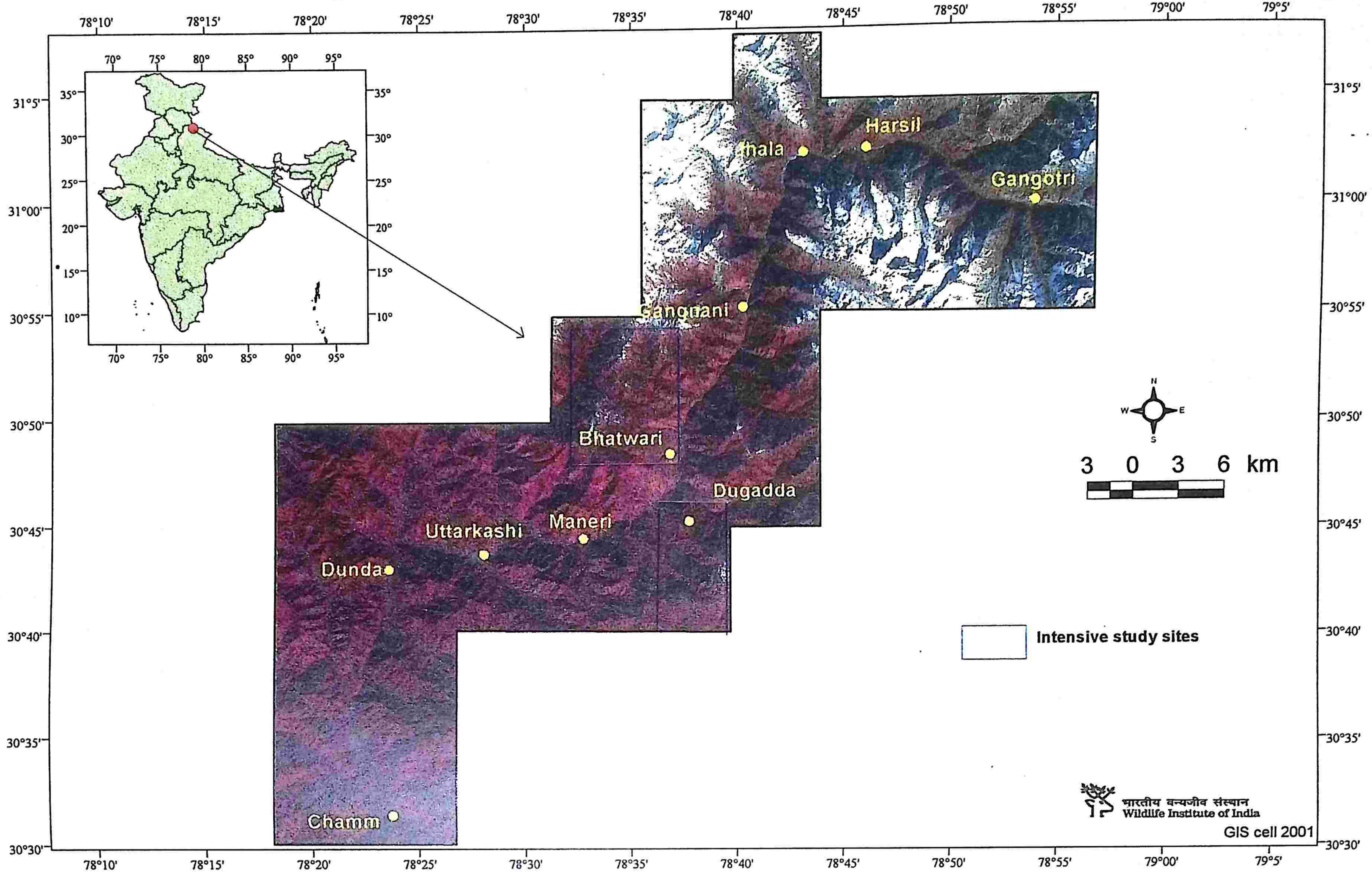
4.2.1 Data used: Season plays an important role in RS as it affects the variability of ground features (Adinarayana and Ramakrishna 1996, Ehrlich and Lambin 1996). For the present study digital data of IRS-IC, LISS-III (Figure-4.2) with a resolution of 23.5 m in BIL format was acquired from National Remote Sensing Agency (NRSA) for November 1998 as during this time the contrast between snow and forest is very sharp (Tiwari *et al.* 1996). Besides, Survey of India (SOI) toposheets viz., 53J/5, 53J/6, 53J/9, 53J/10,53J/13, 53J/14, 53I/12 and 53I/16 of the scale 1:50,000 were also used to extract Area of Interest (AOI) and various themes such as contours, drainage, landuse and road network. Forest Working Plan (Prasad and Johri 1985) and District Gazetteer (Anon 1970) were also consulted.

4.2.2. Hardware and Software used: Analyses was carried out in SUN Microsystem, workstations. ERDAS IMAGINE ver. 8.3 was used for digital image processing (DIP) of satellite data. ARC/INFO ver. 7.0 and ARC/VIEW ver. 3.1 was used for digitization of various themes in GIS, calculation of area statistics and hardcopy outputs of the final maps. Contours were digitized at an interval of 80 m, which were later used to prepare a digital elevation model (DEM) of the study area. From DEM, aspect, and slope maps were derived.

4.2.3. Image processing*:* After acquisition of raw digital data several processes following Jensen (1996) were run to get the final output.

Rectification: The present study area covered two scenes (Path & Row: 97/49 and 96/49). Both the scenes were geometrically rectified using 40 ground control points (GCPs) each from SOI toposheets. Rectification involves conversion of geometry of an image (rows and columns) to planimetric coordinates (latitude and longitude). First order affine transformation was performed for geocoding with a root mean square (RMS) error of 0.1, which was below the threshold limit of 0.5. Nearest neighbourhood algorithm was used for resampling, as it does not alter the original pixel value

Figure-4.2: False Colour Composite of Bhagirathi catchment (AOI)



Mosaicking: Rectified scenes were mosaiced to obtain the complete study area.

Extraction of AOI: The intensive study area was extracted from the mosaiced scene using coordinates 78^0 15' –79^0 long. $30^0$30'-$31^0$08'lat. as a subset.

Enhancement: Linear contrast stretch was applied to the raw image. Later after extracting the AOI, 3X3 kernel was used for edge enhancement to highlight sharp features.

Classification: Classification of RS data involves assigning each pixel on the image a ground class based on its spectral reflectance (Lillesand and Kiefer 1994). Enhanced image was classified, both unsupervised and supervised clustering were used for classifying vegetation. types. Classification was performed using maximum likelihood classifier as it has been proven very efficient for vegetation mapping (Bolstad and Lillesand 1991, Reddy and Reddy 1996). Later a hybrid approach was used.

Unsupervised classification: The classification uses ISODATA algorithm for differentiating spectral reflectance of various objects. For the present classification, 80 clusters and 15 iterations were specified. Iteration is the maximum number of times the ISODATA utility will recluster the data. Convergence threshold was set to 0.95. It is the maximum percentage of pixels whose cluster assignments can go unchanged between iterations. Later these 80 classes were merged into 10 distinct classes *viz.,* chirpine (areas with more than 75% chirpine), other conifer such as *Pinus wallichiana, Cedrus deodara, Abies pindrow, Picea smithiana* (areas with more than 75% conifers) broadleaf (areas with more than 75% broadleaf species such as oaks, maples, horsechestnut, laurels) broadleaf-conifer mixed (areas with both broadleaf and conifer species in almost equal proportions), scrub (areas with more than 75% scrub), grassland (areas with more than 75% grasses), habitation, water, rocks & boulders and snow.

Supervised classification: The output of unsupervised classification at the scale of 1:50,000 was taken to the field for ground truth. Seven homogeneous training sets were selected for each class and their coordinates were recorded using Global Positioning System (GPS). Spectral signatures of different classes were evaluated. Later 35 locations were used for supervised classification and the rest were kept for accuracy assessment.

Hybrid classification: Combination of unsupervised and supervised classification was used to overcome the lacunae of both the methods. Both the classification schemes could not delineate shadow, waterbody and clouds and hence hybrid approach was used. The classification errors were not due to mixed pixels but due to similar spectral reflectance of these features as has also been pointed by Janssen *et al.* (1990). Later maps were refined and for misclassified pixels of shadow and water masking and recoding were done. The delineation of chirpine from other conifers was still not possible; likewise, differentiation of alpine scrub and pastures from low valley scrub and grasslands was also very difficult. Therefore, the map was exported to GIS for rule based classification. The utility of hybrid and rule based classification has been well demonstrated by Sader *et al.* (1995), Treitz and Howarth (2000).

Rule based classification: Altitude was used as a criterion to differentiate different conifers, grasslands and scrub. Chirpine in the study area was found to occur below 2300m. Similarly, alpine pastures and scrubs were confined above 3200 (personal survey). These ecological features were used to develop certain rules for their accurate classification. The rules so developed were:

- Conifers resembling chirpine above 2200m were considered as other conifers
- Other conifers below 2300m were converted to Chirpine
- Grasslands and scrub above 3200m were reclassed as alpine pastures and alpine scrub respectively.

Terrain features play an important role in improving classification (Woodcock *et al.* 1994). Of all the terrain features DEM is highly used (Shasby and Carneggie 1986, Roy and Pujar 1998, Elumnoh and Shrestha 2000). In the present study DEM was broken into two zones based on above-mentioned

Figure-4.3: Delineation of Chirpine and Other Conifers using DEM

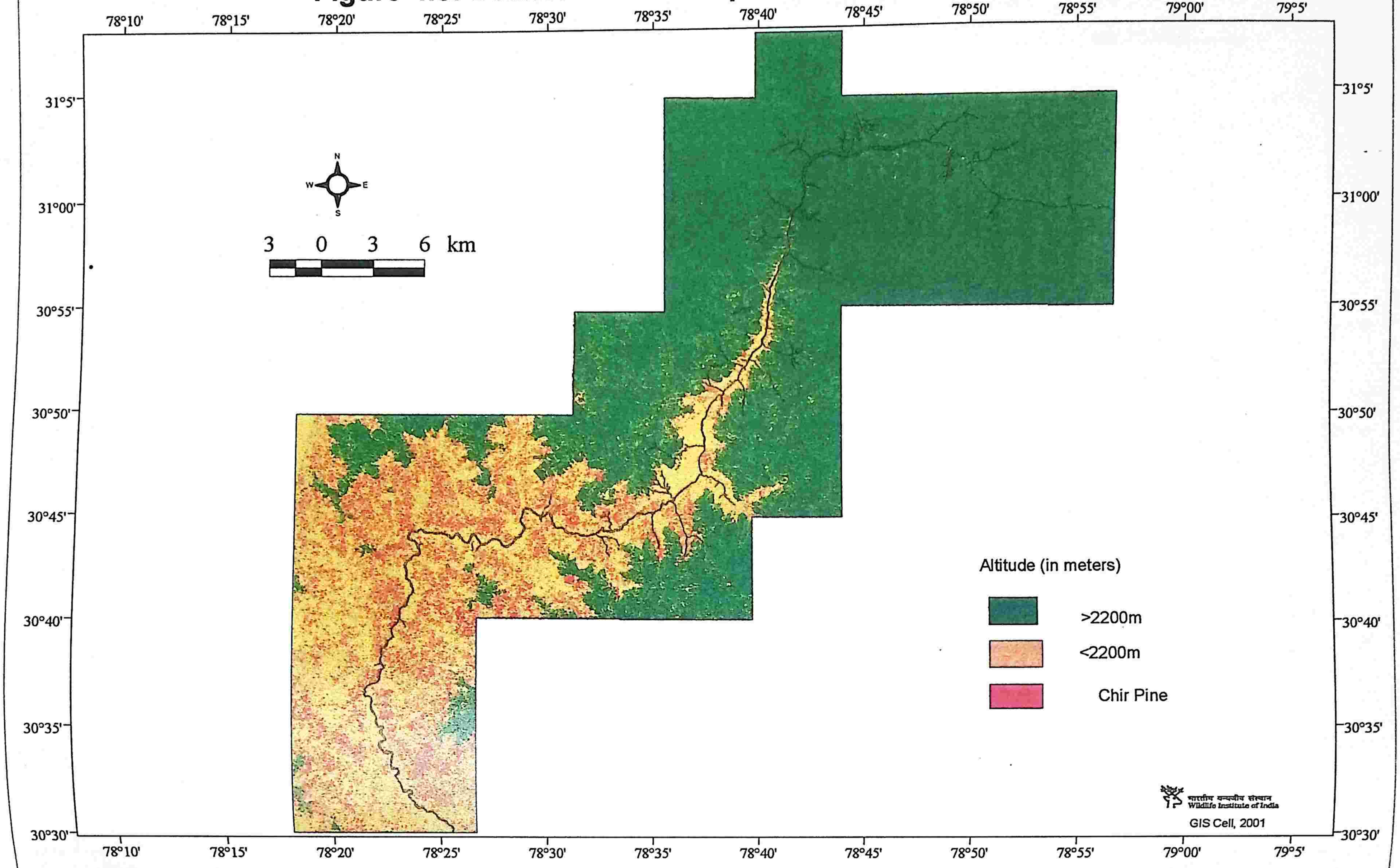
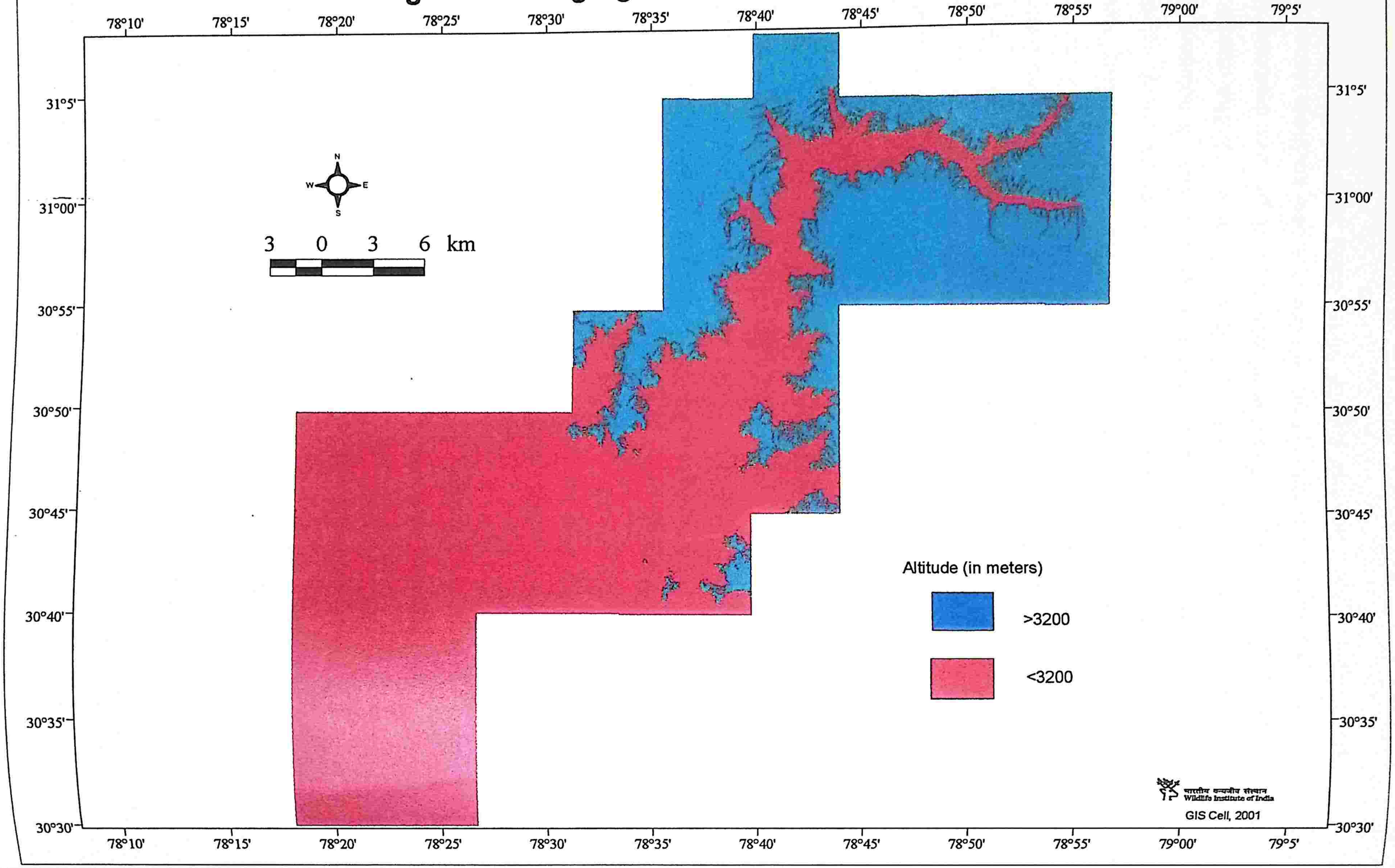


Figure-4.4: Segregation of DEM into two zones



ecological rules (Figures- 4. 3 and 4.4) and the final map having 12 classes was prepared.

Smoothening: The output obtained from rule based classification was pixellated and hence a 3X3 window smoothening was applied. Nearest neighbour algorithm was used. However, after smoothening it was found that certain important forest patches were merged with the surrounding forest types. Mapping of, these small patches of forests were important for their ecological monitoring and hence smoothened map was discarded.

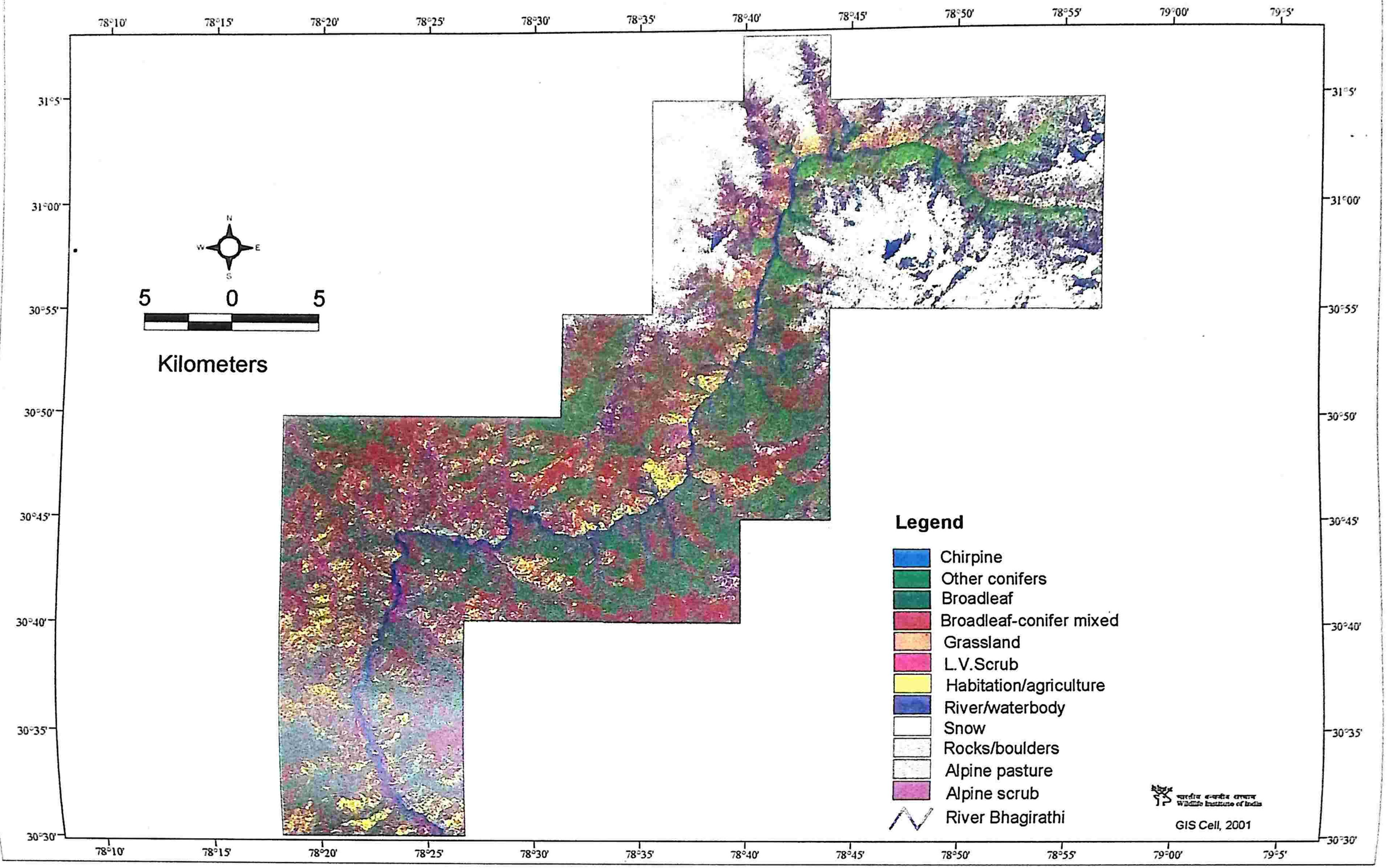
Area statistics was calculated from the non-smoothened map and it was used for further analyses.

4.2.4 Analyses: Area under different altitude, aspect and slope categories was calculated in ARC/VIEW. The slope (in degrees) was divided into six classes. Category I (0-15), II (15-30), III (30-45), IV (45-60), V (60-75) and VI (>75). Five categories of aspect (flat, north, east, south and west) were considered for calculating area. Similarly the entire altitudinal gradient (279 – 6600 meters) was divided into six zones. Zone I (279-981), II (982-1683), III (1684-2386), IV (2387-3088), V (3089-3790) and VI (>3790). Vegetation classes delineated were then correlated with these environmental variables.

4.3 Results

The results of the study indicated that the area of AOI was 205065.6 hectares. It could be well differentiated into eight forest classes and four non-forest classes. Eight different forest types are chirpine, other conifers, broadleaf, broadleaf-conifer mixed, grassland, low valley scrub, alpine pasture and alpine scrub (Figure-4.5). Broadleaf-conifer mixed forest dominated the area occupying 24.62 % of the total study area followed by broadleaf forest (10.53%) and low valley scrub (10.38%). The non-forest category included habitation/agricultural land, water/riverbody, snow and rocks & boulders and together occupied 27.6% of the total study area (Table-4.1). The maximum study area lied between 1684-2386m altitudinal range and therefore this range had the maximum forest cover. In case of aspect southern slopes had the maximum area, however highest forest cover was found on northern

Figure-4.5: Vegetation classification of Bhagirathi catchment (1998)



slopes. The relationship between different forests and environmental variables (altitude, aspect and slope) is given below.

Table- 4.1: Area under different forest types

Forest	Area (ha)	% area
Chirpine	11457.28	5.58
Other conifers	13640.96	6.65
Broadleaf	21612.16	10.53
Br-con mixed*	50504.96	24.63
Grassland	6334.72	3.09
L.V.scrub	21300.48	10.38
Alpine pasture	11402.24	5.56
Alpine scrub	12072.32	5.88
Non-forest	56740.48	27.67
Total	**205065.6**	**100**

* Broadleaf-Conifer mixed

4.3.1 Distribution of vegetation in different altitudes: In Himalaya altitude plays a major role in the distribution of vegetation. The vegetation map when overlaid on DEM in GIS revealed that maximum area was under zone III, followed by zone VI while the least was under Zone I. However, forest cover in zone VI was comparatively very less while zone III and IV had higher forest cover (Figure-4.6).

In zone I L.V. scrub occupied the maximum area (34.76%) followed by broadleaf-conifer mixed (19.76%) and chirpine (11.6%) while in zone VI alpine pastures (11.4%) dominated the area followed by alpine scrub (9.12%) and conifers (1.17%). In the mid elevation zones III and IV broadleaf forest had good representation (Table-4.2). Distribution of different forest types revealed that chirpine had maximum distribution in zone II, other conifers had in zone IV while broadleaf and broadleaf-conifer mixed had higher distribution in middle elevation zones. Lower valley grassland covered maximum area in zone IV whereas alpine pastures covered maximum area in zone V.

Figure-4.6: Digital elevation model of Bhagirathi catchment

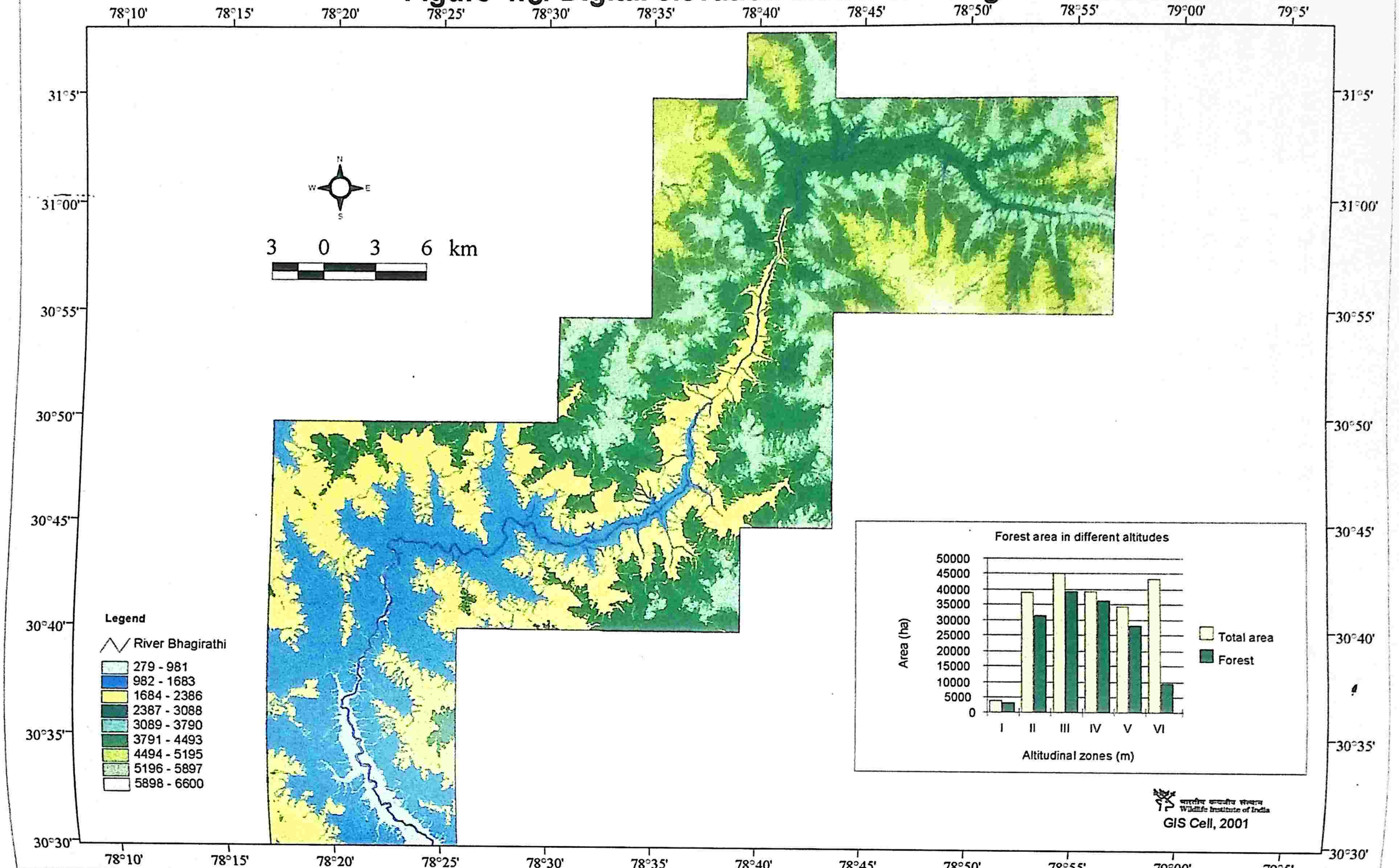


Table- 4.2: Area (ha) under different forest in different altitudinal zones

	I*	II*	III*	IV*	V*	VI*	Total
Chirpine	474.24	5964.16	5018.88	0	0	0	**11457.28**
Other conifers	0	0	1422.72	7390.72	4316.16	511.36	**13640.96**
Broadleaf	243.2	4848	7675.52	6711.04	2024.32	110.08	**21612.16**
Br-con mixed	805.76	11665.28	17029.76	15089.28	5792	122.88	**50504.96**
Grassland	220.8	1281.28	1396.48	2743.68	692.48	0	**6334.72**
L.V Scrub	1417.6	7828.48	6593.28	4527.36	933.76	0	**21300.48**
Alpine pasture	0	0	0	0	6453.12	4949.12	**11402.24**
Alpine scrub	0	0	0	0	8106.88	3965.44	**12072.32**
Non Forest	916.48	7154.56	6035.84	2850.56	6002.56	33780.48	**56740.48**
Total	**4078.08**	**38741.76**	**45172.48**	**39312.64**	**34321.28**	**43439.36**	**205065.6**

*Zone I (279-981), II (982-1683), III (1684-2386), IV (2387-3088), V (3089-3790) and VI (>3790)

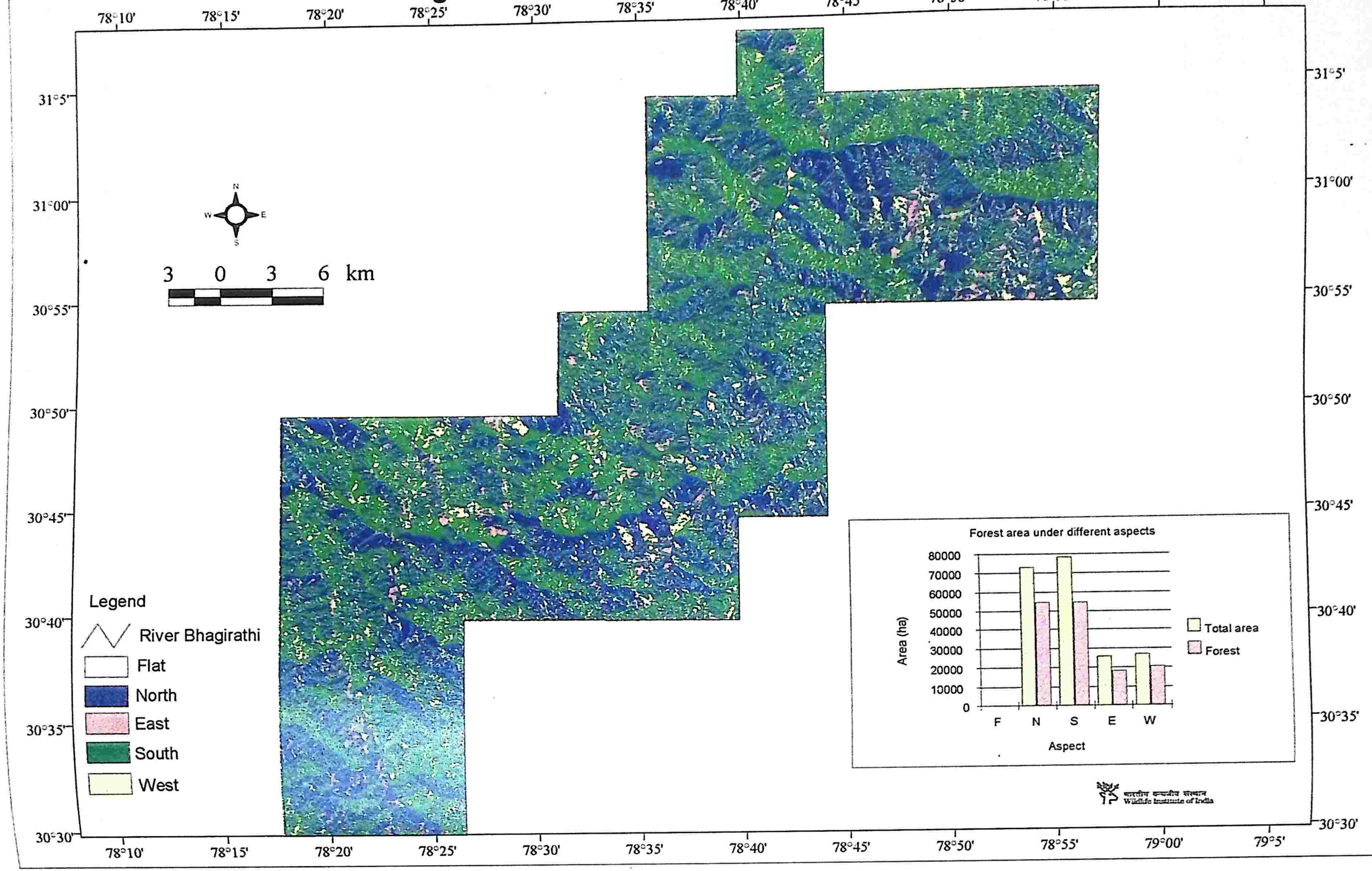
4.3.2 Distribution of vegetation in different aspect: After altitude, aspect plays the most important role in structure and composition of forest. Of all the aspects, maximum area was in southern aspect and minimum in flat whereas forest cover was maximum in northern aspect and minimum in flat (Figure-4.7). In the flat regions maximum area was covered by scrub (24.5%) and minimum by alpine pastures (1.45%). In all the aspects maximum area was covered by broadleaf-conifer mixed forest. However, in the southern aspect grassland and L.V. scrub (4.15% and 13% respectively) occupied a good proportion of the area whereas broadleaf forest occupied a good proportion (16%) in northern aspects.

Distribution of different forest types revealed that conifers and broadleaf had maximum distribution in northern aspect while broadleaf-conifer mixed, grassland and scrub had maximum distribution in southern aspect. Chirpine had almost equal distribution in northern and southern aspect. All the forest types had minimum distribution in flat areas (Table-4.3).

Table- 4.3: Area (ha) under different forest in different aspects

	Flat	North	South	East	West	Total
Chirpine	47.36	4342.4	4259.84	1269.12	1538.56	**11457.28**
Other conifers	60.8	6449.92	3456	1498.24	2176	**13640.96**
Broadleaf	71.68	12268.8	3874.56	2118.4	3278.72	**21612.16**
Br-con mixed	149.12	17223.04	19310.72	6650.24	7171.84	**50504.96**

Figure-4.7: Aspect map of Bhagirathi catchment



Grassland	52.48	1673.6	3248	697.6	663.04	**6334.72**
L.V Scrub	183.68	5121.92	10192	3073.92	2728.96	**21300.48**
Alpine pasture	10.88	3511.04	5101.44	1338.24	1440.64	**11402.24**
Alpine scrub	21.76	3923.2	4900.48	1619.2	1607.68	**12072.32**
Non Forest	152.32	18272.64	23895.68	8016	6403.84	**56740.48**
Total	**750.08**	**72786.56**	**78238.72**	**26280.96**	**27009.28**	**205065.6**

4.3.3 Distribution of vegetation in different slopes: The affect of slope on vegetation was very distinct. Minimum area was under slope category VI while maximum was under category III followed by II and so was the forest cover (Figure-4.8).

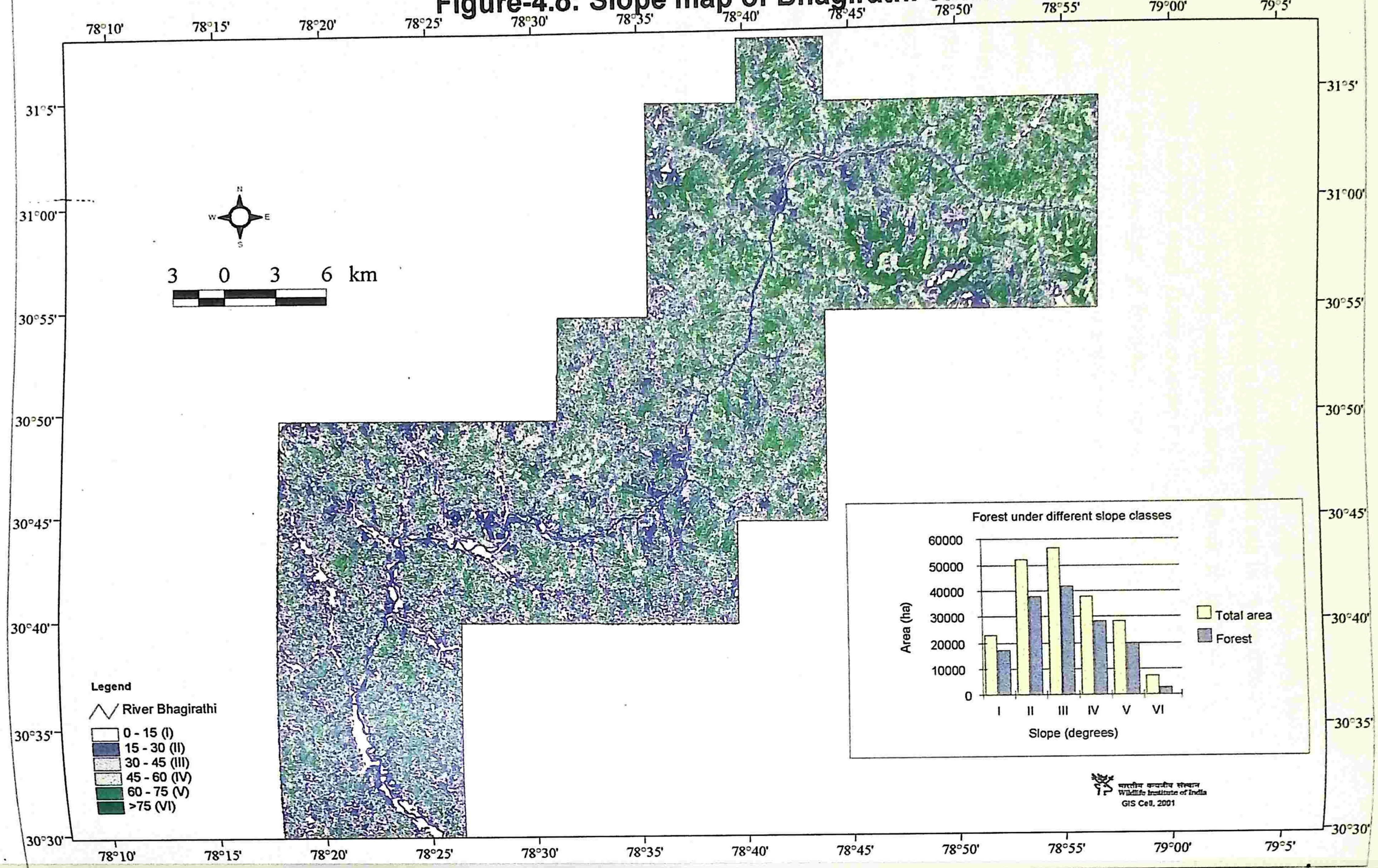
In category I broadleaf-conifer mixed had highest forest cover (24.9%) followed by scrub (18.5%) and so was the case in category II. Alpine pastures (2.55%) occupied minimum area in this category. On the other hand, broadleaf forest had higher area in category III (11.1%) (Table-4.4).

Forest distribution revealed that chirpine occupied maximum area in category II and minimum in category V. Other conifers, broadleaf, broadleaf-conifer mixed and grassland covered maximum area in category III. However, alpine pastures covered minimum area in category I. Low valley scrub covered maximum area in category III and minimum in category VI (Table-4.4).

Table- 4.4: Area (ha) under different forest in different slope categories

	0-15	16-30	31-45	45-60	60-75	>75	Total
Chirpine	1532.16	3365.76	3322.88	2040.32	1128.96	67.2	**11457.28**
Other conifers	1304.96	3302.4	3856.64	2797.44	2007.04	372.48	**13640.96**
Broadleaf	2144	5443.84	6268.8	4293.76	3102.72	359.04	**21612.16**
Br-con mixed	5747.84	14346.24	14629.12	9081.6	6014.08	686.08	**50504.96**
Grassland	922.24	1507.84	1698.56	1224.32	832.64	149.12	**6334.72**
L.V. scrub	4282.24	6080	5397.76	3304.32	2026.24	209.92	**21300.48**
Alpine pasture	588.16	1836.8	3217.28	2726.4	2341.76	691.84	**11402.24**
Alpine scrub	771.2	2116.48	3385.6	2756.48	2328.96	713.6	**12072.32**
Non-forest	5770.88	13790.72	14835.2	9463.04	8596.48	4284.16	**56740.48**
Total	**23063.68**	**51790.08**	**56611.84**	**37687.68**	**28378.88**	**7533.44**	**205065.6**

Figure-4.8: Slope map of Bhagirathi catchment



4.4 Discussion

The application of RS and GIS was found highly useful for mapping vegetation types at a broad scale. The area covered by flat regions in the present study was less (0.36%) and it was found that scrub dominated these areas (24.48%). These areas were usually inhabited and therefore had a greater area under non-forest category. The distribution of scrub (19.29%) and grassland (10.67%) was more in southern slopes because these slopes are warmer and are often burned for fresh and nutritious grasses (Singh & Singh 1987, Polunin & Stantion 1984). The forests were usually more distributed in the northern slopes. However, chirpine had considerable distribution in southern slopes also. The reason behind this could be the ability of chirpine to establish itself even in the poor nutrient substratum and also due to its fire resistant nature (Singh *et al.* 1984). Similarly gentler slopes had more scrub while the steeper slopes were covered with grasses. However, coniferous species such as *Juniperus* can grow on very steep slopes (Singh & Singh 1992). Therefore steeper slopes had more distribution of conifer species. The broadleaf forests were more confined to middle slope categories.

It was found that in the lowest altitude (zone I) the forests were degraded and had dominance of scrub (Figure-4.9), because these were inhabited by people while higher altitudes had dominance of grassland and scrub. The mid-elevational range had higher area under forest.

On comparison of the results of RS data and field data (coming chapters) it was found that they compliment each other. Southern slopes had less area under forest and only four communities could be distinguished whereas on the northern slopes ten distinct communities were identified. Again it was found through RS that the mid-elevational forests had comparatively good forest cover and were relatively undisturbed as was also found in the field study. However, mapping of different forest communities (segregated by TWINSPAN) in intensive study sites was not possible due to poor resolution of image. Such problems can be overcome by using high resolution data. In the present study it was found that forest in middle altitude zone lying in 30^0-45^0 slopes are most important for conservation (Figure-4.10).

Figure-4.9: Degraded areas in Bhagirathi catchment

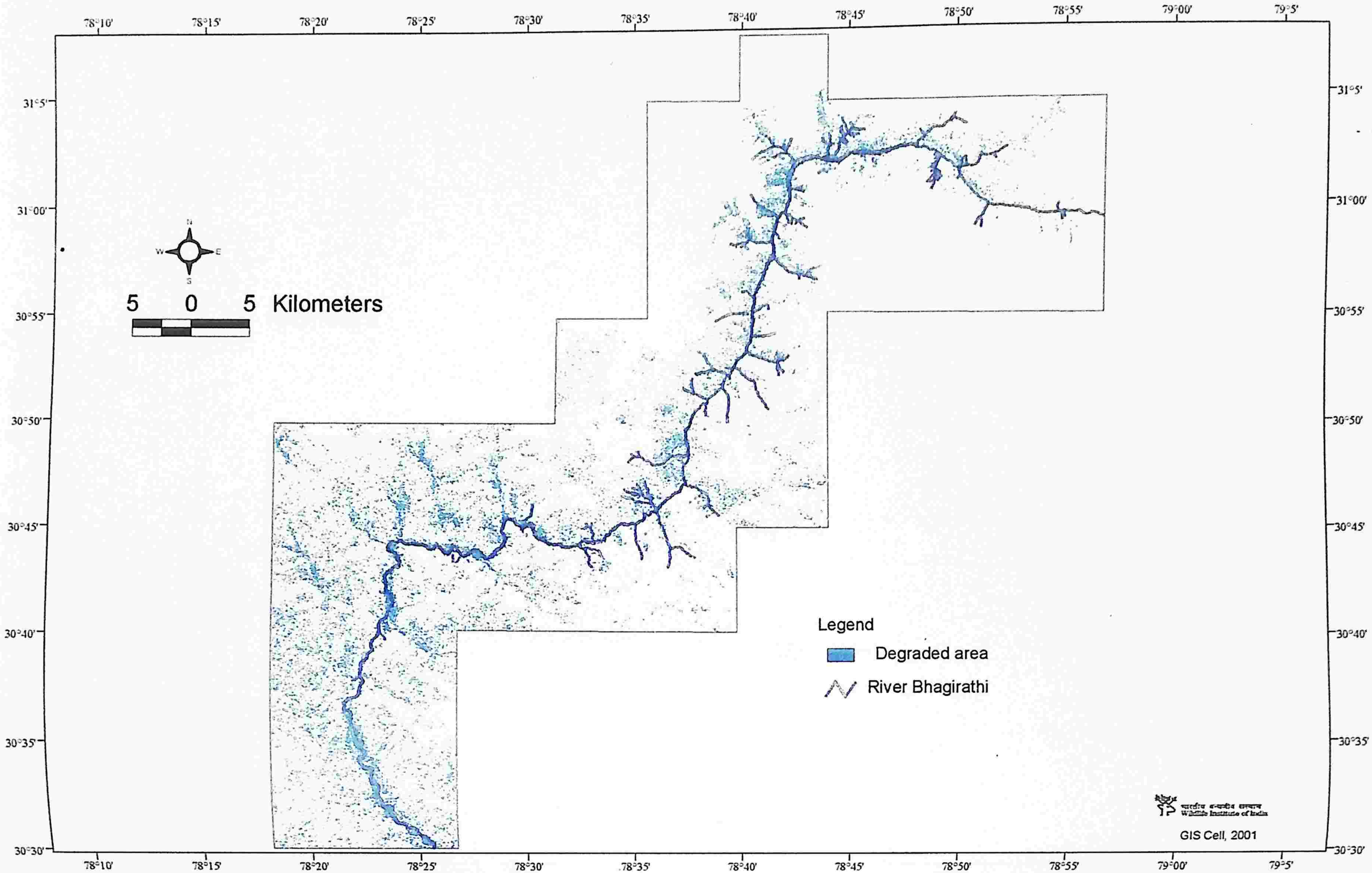
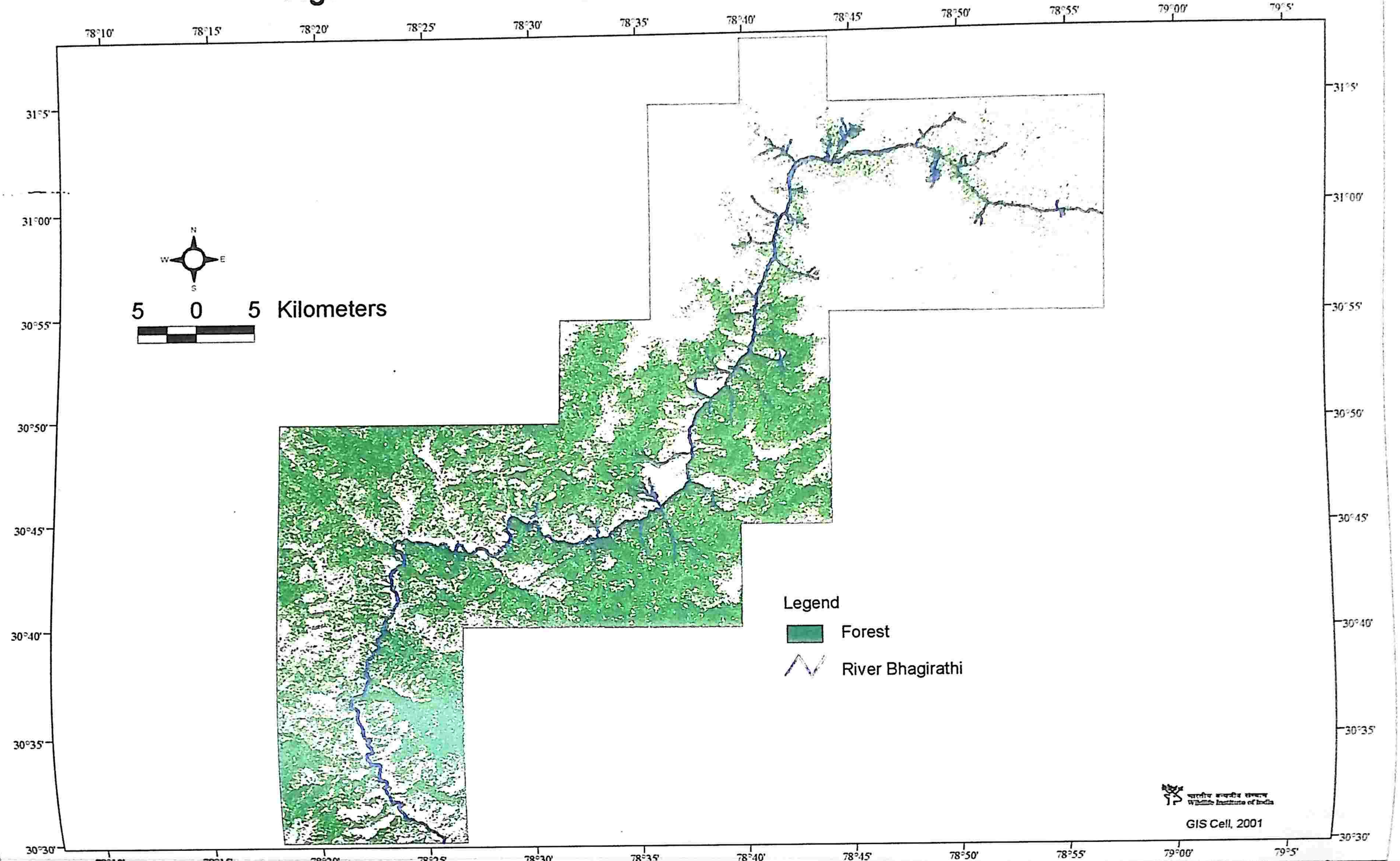


Figure-4.10: Areas important from conservation point of view



Thus, field knowledge coupled with RS/GIS can be effectively used for mapping large and inaccessible areas. It can also be used for continuously monitoring and updating existing forest maps, which could well be utilized for the management and conservation of highly fragile mountain watersheds.

CHAPTER-5

Vegetation Structure and Composition

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Vegetation Structure and Composition

5.1 Introduction

The structure and composition of the vegetation reflect the ecosystem properties and ecological conditions of an area that form the bases for further scientific studies and management of an area (Lindenmayer & Franklin 1997). The constituent elements of vegetation i.e. plant species and their assemblages also form the component of the biodiversity of a region that depends on various factors such as altitude, aspect, soil, geology, topography, orography and anthropogenic pressures. Many plant species, therefore, serve as indicators of site specific conditions and have been used for site evaluation (Rowe 1956, Barnes *et al.* 1998). Information on these parameters at spatio-temporal scale also helps in conservation planning and restoration of degraded ecosystems.

The high rates of deforestation, increasing landslides, siltation of rivers and other associated problems in the Himalayan region has caused concern among large number of environmentalists (e.g., Price 1998, Ives & Messerli 1989). Anthropogenic pressures on the Himalayan forests, especially in the North West and Western region, have completely modified their structure (Paliwal 1984) converting the forests into scrub vegetation or monocultures (Singh & Singh 1995). The high rate of deforestation in the region has also led to invasion of exotic weeds such as *Lantana camara, Parthenium hysterophorous* and *Xanthium strumarium* in the lower region and preponderance of thorny, unpalatable bushes in the middle elevations affecting the structure, composition, biomass and productivity of the forests. The stability of the Himalayan slopes, the livelihood of the villagers and the native fauna depend on the health and productivity of the ecosystem. This chapter deals with the structure and composition of the forest along the altitudinal and human use gradient in the upper catchments of river Bhagirathi. Diversity of woody species and the factors effecting their regeneration are also dealt with.

The major objectives of the study were:

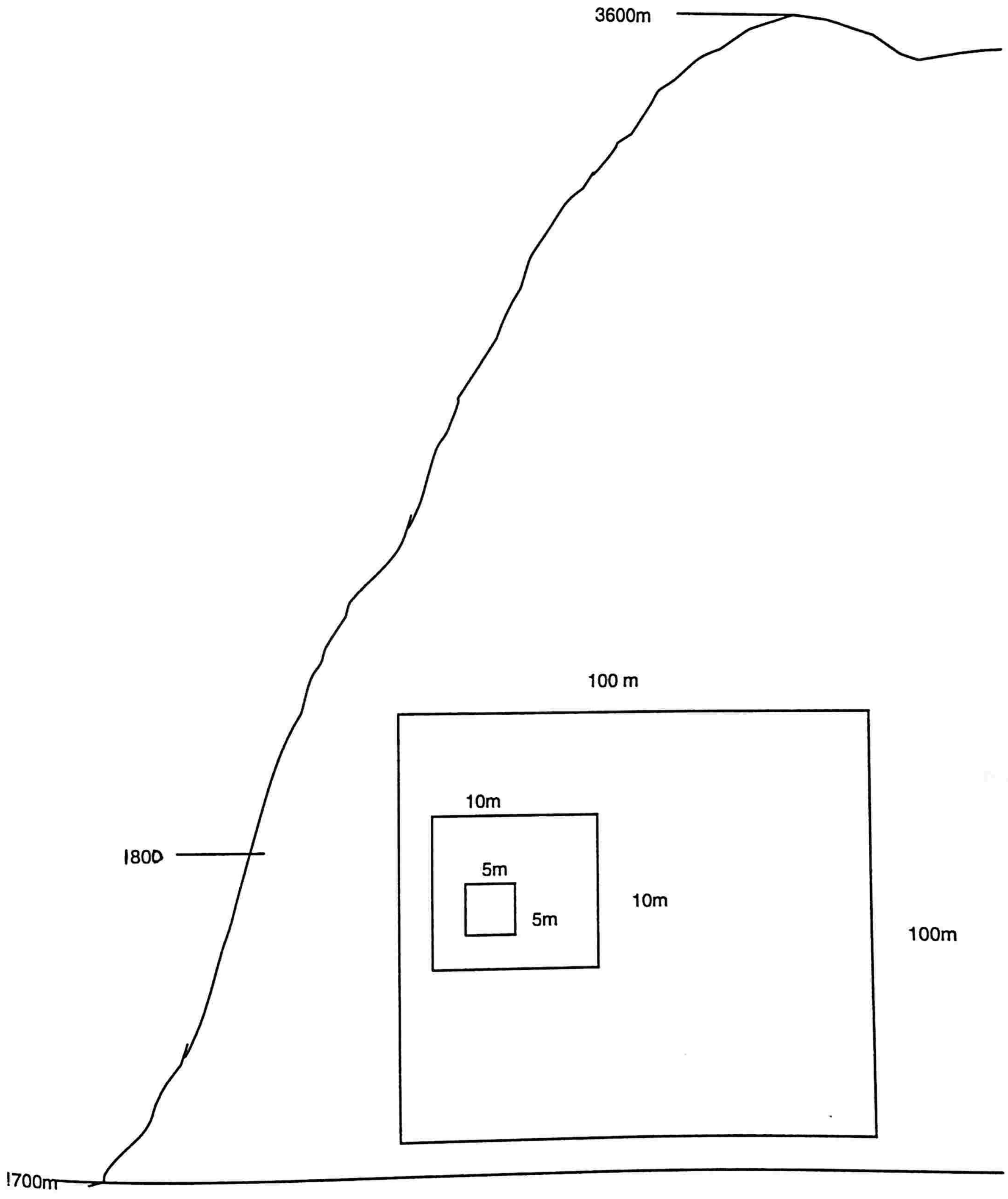
- To study the structure and composition of forests along an altitudinal gradient
- To study the effects of major abiotic factors on the forest composition
- To study the regeneration status of various tree species in the area.

5.2 Methods

5.2.1: Field Methods: After an initial reconnaissance of the study area two intensive study sites were selected viz., (i) the Saura-Belak (1700-3600m, North facing), and (ii) Bhatwari-Dayara (2000-3600m, South facing) in order to get a representation of the larger area. The secondary stratification was made based on altitude so as to include all the vegetation types occurring in the area. All the strata were sampled randomly. The trails going to the various forest types were walked and at every 100m rise in elevation, which was determined using altimeter, one hectare plots were marked 50m away from the pre-existing trail (Figure-5.1). The woody vegetation was quantified within these plots. For trees 10X10m (n=10) quadrats were laid and vegetation parameters such as species, individuals, Circumference at breast height (CBH, 1.37 m above ground) and crown cover were noted, nested within these 5X5m (n=10) quadrats were laid for shrubs and the same parameters as for trees were noted. Instead of CBH, CGL (Circumference at ground level) was noted for shrubs.

The size and the number of sampling units were determined by species area curve and running mean method respectively (Mueller-dombois & Ellenberg 1974). Individuals with CBH <10.5 cm were treated as seedlings and those between 10.5-31.5 were treated as saplings (Saxena & Singh 1982). The environmental variables noted in each plot were altitude, aspect, terrain, soil and disturbances in the form of grazing, lopping, cutting and fire incidences.

Figure-5.1: Layout of sampling plots



At every 100m rise in altitude such plots were permanently marked

5.2.2 Data Analyses: Data collected in the field were analyzed for density, frequency, dominance and abundance following Misra (1968). The relative values of frequency, dominance and density were used for determining IVI (importance value index) (Curtis & McIntosh 1950). The Shannon and Wiener diversity index, evenness and richness values were computed using software package "STATECOL" (Ludwig & Reynolds 1988). The abundance to frequency ratio (A/F) was used to represent the distribution pattern of the species (Curtis & Cottam 1956).

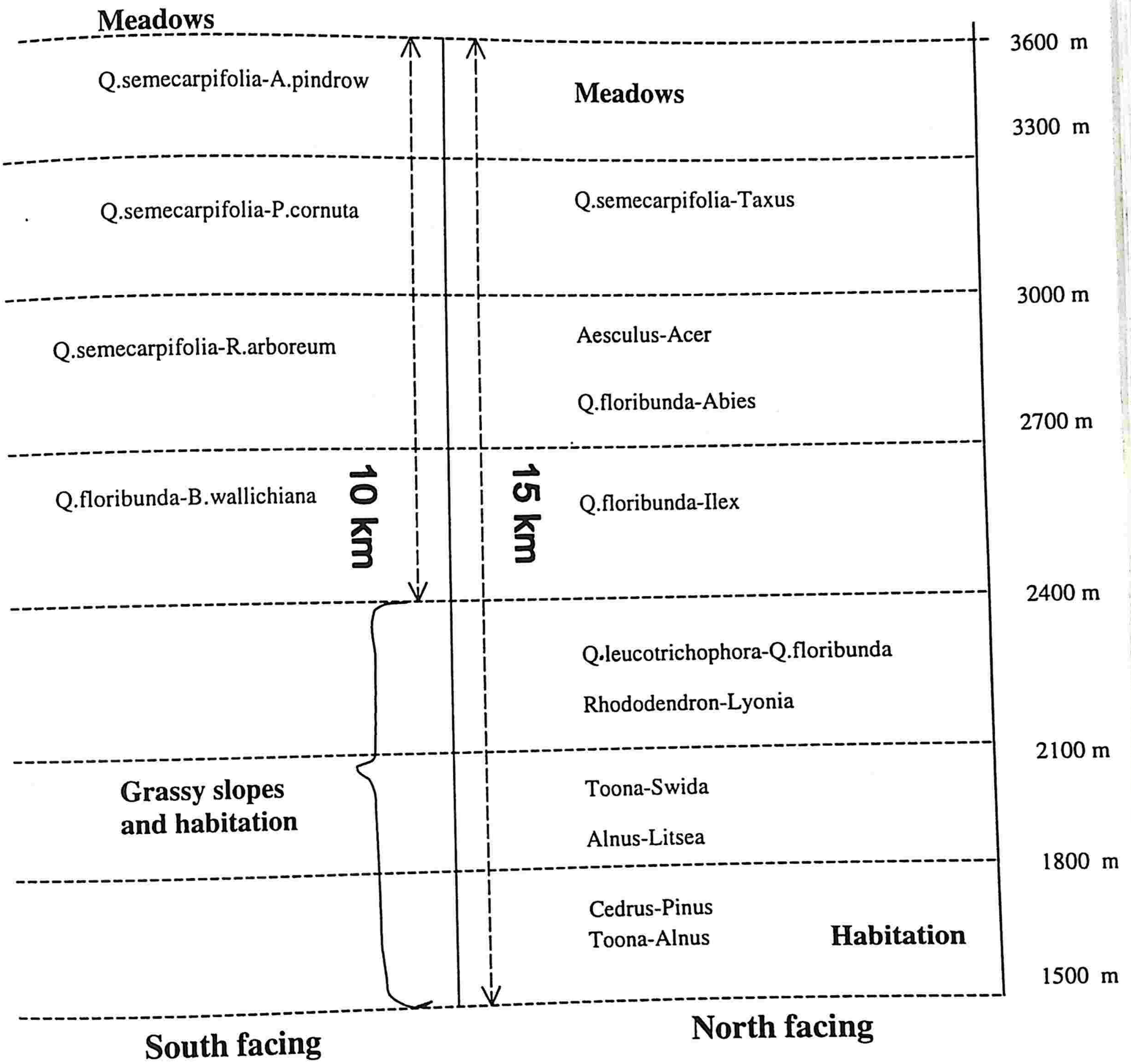
The density values of the species were used for community classification by "TWINSPAN" (Hill 1979). Bray & Curtis (1957) polar ordination was used to find out the percent similarity between the different plant communities. The similarity between the two sites was calculated both by qualitative and quantitative indices (Magurran 1988). Simple statistics such as correlation was applied to find the relationship between tree density and shrub density along an altitudinal gradient. To detect differences in the density of dominant species at the two ISS t-Test was used following Zar (1984).

The biotic and abiotic factors were correlated using "CANOCO" (Ter Braak 1986, 1987) so as to find out the major abiotic factors responsible for species distribution.

5.3 Results

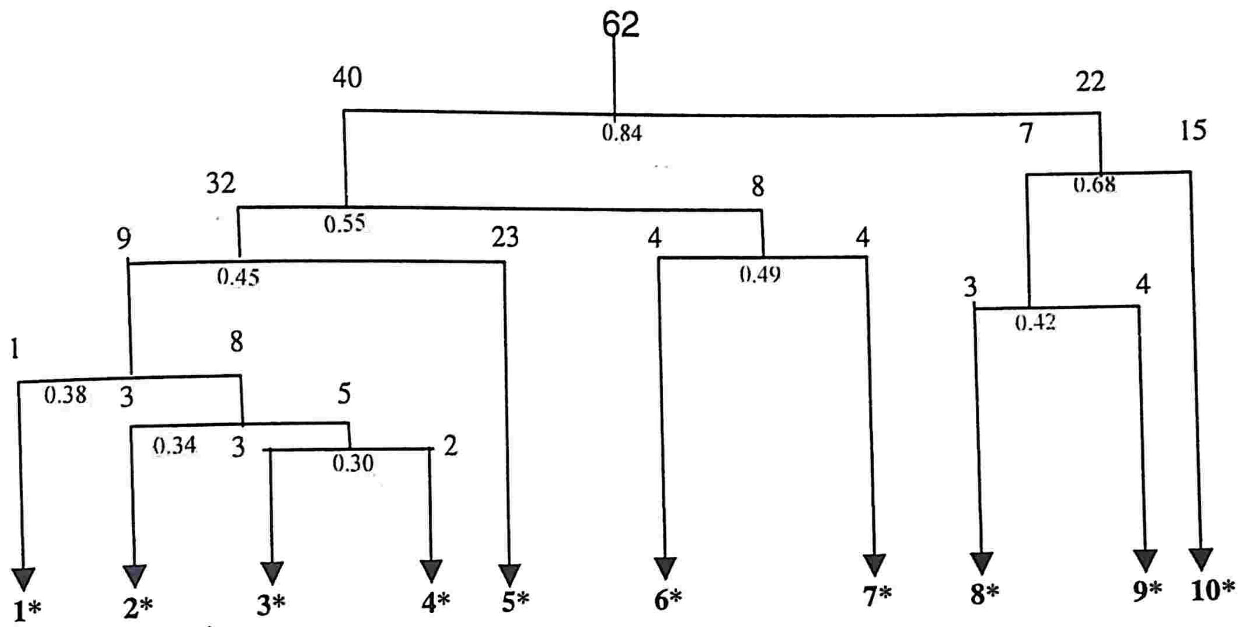
5.3.1 Community classification: A total of 75 plots (each measuring one hectare) were sampled and analyzed for community classification using TWINSPAN. Even though of its limitations (Hill 1979) it is one of the best available computer packages for community classification. A general distribution of different communities in both the ISS is given in Figure-5.2.

Figure-5.2: Diagrammatic representation of communities along an altitudinal gradient in the study area



5.3.1.1 Duggada watershed (North facing): A total of ten communities were identified based on TWINSPAN results (Figure-5.3).

Figure-5.3: Dendrogram of plant communities in DWS



*Communities

Community 1: Cedrus-Pinus: The community occurred at lower elevations (1600-1700m asl) and was represented by a single plot. The even age of the coniferous species and the occurrence of *C. deodara* at such low elevations indicated plantation of these species. This was later confirmed by the working plan by Johri and Prasad (1986). The total tree density of the community was 590 individuals/ha with deodar alone accounting for 490 individuals having an IVI value of 214. The total basal area of the community was 60.04 m^2/ha (Table-5.1). The total shrub density within this community was 200/ha with *Inula cappa* having the highest density 88/ha and IVI 117.58. The A/F ratio showed that the shrub species were contiguously distributed (Table-5.2).

Table-5.1: Density, frequency, IVI, A/F ratio and basal area of different tree species in community 1

Species	Density/ha	Frequency	IVI	A/F ratio	Basal area
Cedrus deodara	490	20	214	0.225	50.77
Pinus roxburghii	90	100	44.7	0.05	9.1
Fraxinus micrantha	10	10	26.3	0.1	0.17

Table-5.2: Density, frequency, IVI and A/F ratio of different shrub species in community 1

Species	Frequency	Density/ha	IVI	A/F ratio
Berberis lycium	30	52	75.26	0.14
Cyathula tomentosa	20	16	51.17	0.1
Inula cappa	40	88	117.58	0.13
Spiraea canescens	30	36	52.91	0.1
Zanthoxylum armatum	10	8	29.96	0.2

Community 2: Toona-Alnus: The community was located along the *Saura gad* (rivulet) between 1650-1800 m asl. The total tree density of the community was 507.8/ha with *Toona sinensis* having the highest density 213/ha and IVI 124.9 followed by *Alnus nepalensis* having 126/ha and 60.8 density and IVI respectively (Table-5.3). The total basal area of the community was 62.8 m^2/ha. The shrub density of the community was 371.6/ha with *Berberis* having the highest density 65.2/ha and IVI 68.24 (Table-5.4). The shrub species were contiguously distributed whereas in case of trees 50% of the species were contiguously distributed and the remaining species randomly.

Table-5.3: Density, frequency, IVI, A/F ratio and basal area of different tree species in community 2

Species	Density/ha	Frequency	IVI	A/F ratio	Basal area
Alnus nepalensis	126±29.68	40±15.27	60.82±30.9	0.04	14.5
Toona sinensis	213±98	73.3±14.5	124.9±35.3	0.03	32.5
Celtis australis	13±4	20±5.8	14.1±4.7	0.07	0.4
Euonymus tingens	3±3	3.3±3.3	2.8±2.8	0.01	0.32
Lyonia ovalifolia	6.7±6.7	3.3±3.3	3.21±3.21	0.1	0.13
Pinus roxburghii	63±26	30±11.55	44.1±13.73	0.1	11.9
Pyrus pashia	13.3±3	13.33±0	8.92±2.44	0.08	0.62
Rhododendron arboreum	3.3±3	3.3±3.3	2±2	0.03	0.25
Rhus punjabensis	6.6±3	10±5.8	10±5.4	0.1	0.04
Swida macrophylla	53.3±27	23.3±14.5	24.8±16.17	0.06	1.24
Ulmus wallichiana	3.3±1.6	6.7±3.3	4±2	0.06	0.5
Albizia julibrissin	3.3±3.3	3.3±3.3	2.6±2.6	0.03	0.4

Table-5.4: Density, frequency, IVI and A/F ratio of different shrub species in community 2

Species	Frequency	Density/ha	IVI	A/F ratio
Artemisia sp.	3.3	12	2.96	0.1
Berberis lycium	60	65.2	68.24	0.04
Caesalpinia decapetala	30	82	65.73	0.06
Debregeasia hypoleuca	36.6	36	52.45	0.16
Deutzia staminea	13.3	21.2	16.4	0.3
Prinsepia utilis	40	49.2	51.27	0.07
Rubus ellipticus	10	22	14.17	0.06
Rubus niveus	16.6	36	21.8	0.1
Spiraea canecsens	3.3	24	5.75	0.2
Urtica parviflora	3.3	24	4.6	0.2

Community 3: Alnus-Litsea: The community occupying the altitudinal range between 1800-1900m asl had an overall tree density of 563.2/ha with *A.nepalensis* having density of 100/ha and IVI 77.3. *Alnus nepalensis* is an early colonizer and usually occurs along the riverbanks. Although *Quercus leucotrichophora* had higher density than *Litsea umbrosa* the latter had a higher IVI value than the former (Table-5.5). The distribution pattern of the tree species was in the following order contiguous>random>regular. The total basal area of the community was 60.39 m^2/ha. The total shrub density within the community was 1069.2/ha with *Sarcococca* having the highest density (569.2/ha) and IVI (132.19). The shrubs were contiguously distributed and only *Rubus ellipticus* was randomly distributed (Table-5.6).

Table-5.5: Density, frequency, IVI, A/F ratio and basal area of different tree species in community 3

Species	Density/ha	Frequency	IVI	A/F ratio	Basal area
Alnus nepalensis	100±47	43.3±8.8	77.3±31.2	0.17	28.84
Carpinus viminea	66.6±26	36.7±12.1	33.8±11.5	0.036	3.1
Toona sinensis	56.6±27	30±17.32	30.9±17.34	0.06	7.2
Celtis australis	10±10	6.7±6.7	7.7±7.7	0.04	0.19
Fraxinus micrantha	10±10	3.3±3.3	2.7±2.7	0.01	0.19
Litsea umbrosa	90±28	50±20	48±11.5	0.1	5.5
Lyonia ovalifolia	16.7±8	10±5.8	7.45±3.9	0.11	1.73
Pyrus pashia	16.7±4	20±5.7	10.75±2.15	0.06	1.2
Quercus leucotrichophora	96.6±51	46.7±26	40.1±26	0.02	5.8

R.arboreum	20±10	23.3±14.5	15.31±9.14	0.01	2.71
Rhus punjabensis	6.6±3.4	6.7±3.3	4.8±2.6	0.2	0.1
Swida macrophylla	57±6	36.7±17.34	26.02±3.42	0.046	3.77
Ulmus wallichiana	3±3	3.3±3.3	1.4±1.4	0.03	0.06

Table-5.6: Density, frequency, IVI and A/F ratio of different shrub species in community 3

Species	Frequency	Density/ha	IVI	A/F ratio
Daphne papyracea	10	32	14.27	0.2
Debregeasia hypoleuca	3.3	16	17.44	0.13
Desmodium triflorum	6.6	76	57.55	1.26
Elsholtzia fruticosa	10	240	17.83	0.22
Prinsepia utilis	16.6	44	32.37	0.1
Rubus ellipticus	6.6	16	3.91	0.03
Rubus niveus	3.3	16	2.25	0.13
Sarcococca saligna	50	569.2	132.19	0.65
Urtica parviflora	10	60	22.17	0.05

Community 4: Toona-Swida: The community had dominance of deciduous tree species and occupied an altitudinal range between 1900-2000m asl. The total tree density of the community was 530/ha. *T. sinensis* had an IVI value of 86.9 while *Swida* had a value of 42.35. The A/F ratio clearly indicates that the tree species were distributed in regular>random>contiguous order (Table-5.7). The total basal area of the community was 58.5 m^2/ha. The shrub density in the community was 672.4/ha with *Sarcococca* having the highest density (298/ha) and IVI (103.46). The shrub species were more contiguously distributed when compared to random distribution (Table-5.8).

Table-5.7: Density, frequency, IVI, A/F ratio and basal area of different tree species in community 4

Species	Density/ha	Frequency	IVI	A/F ratio	Basal area
Alnus nepalensis	5±5	5±5	8.5±8.5	0.05	3.8
Carpinus viminea	15±15	15±15	7.9±7.9	0.02	0.4
Toona sinensis	150±20	80±0	86.9±11.7	0.024	20.5
Celtis australis	10±10	10±10	4.3±4.3	0.025	3.2
Fraxinus micrantha	10±10	10±10	9.6±9.6	0.025	4.35
Llitsea umbrosa	45±45	30±30	22.7±22.7	0.012	4.35
Lyonia ovalifolia	35±35	30±30	19.3±19.3	0.03	2.7

Pyrus pashia	55±30	35±15	24.53±12	0.04	3.6
Quercus leucotrichophora	45±10	45±5	26.4±6.14	0.022	3.25
Rhus punjabensis	15±15	5±5	2.1±2.1	0.1	0.55
Swida macrophylla	70±16	55±5	42.35±2.7	0.03	7.75
Symplocos chinensis	35±5	30±0	16.34±.0.27	0.035	1.4
Ulmus wallichiana	10±10	5±5	4.8±4.8	0.1	1.05
Albizia julibrissin	30±5	30±10	16.51±1.49	0.085	1.6

Table-5.8: Density, frequency, IVI and A/F ratio of different shrub species in community 4

Species	Frequency	Density	IVI	A/F ratio
Berberis lycium	20	64	37.66	0.062
Caesalpinia decapetala	15	44	34.23	0.061
Debregeasia hypoleuca	5	16	10.34	0.2
Deutzia staminea	20	40	23.88	0.15
Elsholtzia fruticosa	35	130	55.42	0.27
Prinsepia utilis	20	52	23.02	0.04
Rubus niveus	5	0.4	2.77	0.05
Sarcococca saligna	60	298	103.46	0.21
Spiraea canescens	10	28	9.1	0.087

Community 5: Rhododendron-Lyonia: The community occupied an altitudinal gradient of 2000-2200 m asl with *R.arboreum* being the dominant tree species. The total tree density of the community was 717.1/ha. The difference in the density and IVI values of *R.arboreum* and *Lyonia ovalifolia* was negligible. It is interesting to note the reoccurrence of *Pinus roxburghii,* even though the density value *of Q.leucotrichophora* was greater than *Pinus roxburghii*, the latter had a higher IVI value (Table-5.9). The total basal area of the tree species in the community was 68.97 m^2/ha. The A/F ratio clearly indicates that most of the tree species were either randomly or regularly distributed while majority of the shrub species were contiguously distributed. The total shrub density of the community was 769.8/ha with *Spiraea canescens* having the maximum density and IVI (Table-5.10).

Table-5.9: Density, frequency, IVI, A/F ratio and basal area of different tree species in community 5

Species	Density/ha	Frequency	IVI	A/F ratio	Basal area
Aesculus indica	0.4±0.4	0.43±0.43	0.15±0.15	0.004	0.04
Alnus nepalensis	23.6±13	13.47±4.56	13.9±6.4	0.06	3.16
Carpinus viminea	12±7	6.1±3.3	4.4±2.6	0.025	0.64
Toona sinensis	17±7	5.65±2.42	3.9±1.55	0.046	0.59
Cedrus deodara	12±12	1.7±1.7	1.8±1.8	0.003	0.44
Celtis australis	0.4±0.4	0.43±0.43	0.17±0.17	0.004	0.46
Fraxinus micrantha	0.4±0.4	0.43±0.43	0.27±0.27	0.004	0.45
Ilex dipyrena	1±1	0.43±0.43	0.32±0.32	0.013	0.45
Llitsea umbrosa	3.5±2	1.3±.95	1.5±1.1	0.014	0.45
Lyonia ovalifolia	176±22	71.7±4.3	65.2±4.8	0.04	11.64
Machilus odoratissima	4.8±1	2.6±1.9	2.04±1.6	0.005	0.4
Pinus roxburghii	111.3±31	41.3±7.7	57.2±12.9	0.044	21.3
Pyrus pashia	20±5	13.9±3.1	8.94±2.32	0.049	1.35
Quercus leucotrichophora	124±34	56.52±7.4	54.7±9.7	0.047	11.8
Quercus floribunda	0.4±0.4	0.43±0.43	1.7±1.7	0.004	0.036
Rhododendron arboreum	179±29	66.1±5.64	69.5±6.2	0.054	14.51
Rhus punjabensis	8.7±4	6.96±2.9	4.30±1.8	0.039	0.24
Swida macrophylla	10±3	7.4±2	4.9±1.4	0.06	0.67
Symplocos chinensis	7,8±3	9.57±2.3	4.6±1.3	0.049	0.17
Ulmus wallichiana	4±1	2.6±0.93	1.64±0.6	0.043	0.15
Albizia julibrissin	0.4±0.4	0.43±0.43	0.18±0.18	0.004	0.023
Ficus palmata	0.4±0.4	0.43±0.43	0.23±0.23	0.004	0.004

Table-5.10: Density, frequency, IVI and A/F ratio of different shrub species in community 5

Species	Frequency	Density/ha	IVI	A/F ratio
Artemisia	2.17	46	5.1	0.19
Berberis lycium	17.39	62	36.2	0.15
Caesalpinia decapetala	2.17	16	7.67	0.056
Daphne papyracea	12.17	63.2	22.9	0.03
Debregeasia hypoleuca	1.74	16	9.8	0.008
Desmodium triflorum	4.78	31.12	16.3	0.075
Deutzia staminea	3.04	28	9.83	0.04
Elsholtzia fruticosa	1.74	49.2	4.69	0.082
Inula cappa	3.04	32	7.46	0.041
Prinsepia utilis	1.74	25.2	3.64	0.053
Rubus ellipticus	5.65	17.48	10.39	0.063

Rubus niveus	6.52	78.8	20.72	0.284
Rhus cotinus	0.43	8	0.65	0.009
Rosa brunonii	1.74	32	6.72	0.03
Sarcococca saligna	3.91	132	10.93	0.19
Spiraea canescens	25.65	132.8	113.96	0.28

Community 6: Q.leucotrichophora-Q.floribunda: The community occupying the altitudinal range 2100-2350m asl had the dominance of oak species. The oak species are regarded as the climax species in the Himalaya. The tree density of the community was 1046.5/ha. The density of *Q.leucotrichophora* was 312/ha whereas *Q.floribunda* had a density of 102/ha but the difference in the IVI values was very low. The IVI values of both the species were 78.5 and 71.3 respectively closely followed by *R.arboreum* with density 125/ha and IVI 62.48. The total basal area of the community was 93.83m^2/ha (Table-5.11). The total shrub density of the community was 826.2/ha of which *Sarcococca* contributed 424/ha but it was *Daphne*, which had the highest IVI 123.38. The shrubs were contiguously distributed (Table-5.12).

Table-5.11: Density, frequency, IVI, A/F ratio and basal area of different tree species in community 6

Species	Density/ha	Frequency	IVI	A/F ratio	Basal area
Alnus nepalensis	7.5±3.6	12.51±4.9	10.15±4.1	0.14	3.5
Carpinus viminea	12.5±12.5	7.5±7.5	4.6±4.6	0.014	2.13
Cedrus deodara	30±16	15±8.7	7.7±4.7	0.02	3
Euonymus tingens	5±5	5±5	2.6±2.6	0.016	0.6
Ilex dipyrena	5±2	5±2.9	2.16±1.3	0.06	0.43
Lyonia ovalifolia	110±39	57.5±10.3	28.1±6.02	0.039	7.86
Machilus odoratissima	27.5±27.5	12.5±12.5	10.6±10.6	0.15	1
Quercus leucotrichophora	312±68	87.5±9.46	78.5±10.7	0.07	32.53
Quercus floribunda	102±23	60±0	71.35±6.57	0.215	24.6
Rhododendron arboreum	125±47	80±10	62.48±8	0.07	17.23
Swida macrophylla	2.5±2.5	2.5±2.5	1.1±1.1	0.03	0.06
Symplocos chinensis	7.5±5	10±5.8	3±1.7	0.016	0.13
Lindera pulcherrima	300±189	7.5±7.5	4.64±4.64	0.4	0.76

Table-5.12: Density, frequency, IVI and A/F ratio of different shrub species in community 6

Species	Frequency	Density	IVI	A/F ratio
Daphne papyracea	42.5	182.8	123.38	0.25
Desmodium trif. um	2.5	12	5.07	0.075
Sarcococca saligna	20	424	78.19	0.324
Spiraea canescens	17.5	208	93.36	0.23

Community 7: *Q.floribunda-Ilex:* With the increase in altitude one species of oak is replaced by another. The dominant tree species here was *Q.floribunda* with 172/ha and 77.6 density and IVI values respectively. The community occupied an altitudinal range between 2300-2500 m asl. The total tree density of the community was 926.7/ha and the total basal area 96.66 m^2/ha. The tree species were either contiguously or randomly distributed (Table-5.13). The total shrub density of the community was 1191.2/ha with *Sarcococca* having the maximum density and IVI. The shrub species were contiguously distributed (Table-5.14).

Table-5.13: Density, frequency, IVI, A/F ratio and basal area of different tree species in community 7

Species	Density/ha	Frequency	IVI	A/F ratio	Basal area
Abies pindrow	67.5±58	17.5±14.36	25.15±23.6	0.06	9.75
Acer spp.	17.5±4	12.5±6.45	4.63±3.8	0.08	0.78
Aesculus indica	12.5±6	15±6.5	12.98±5.8	0.05	7.64
Buxus wallichiana	2.5±2.5	2.5±2.5	0.5±0.5	0.03	0.05
Carpinus viminea	17.5±8	22.5±13.14	8.46±4	0.05	2.24
Euonymus hamiltonianus	42.5±17	27.5±16	11.4±7.4	0.09	0.7
Euonymus tingens	27.5±9	17.5±6.3	8.42±3.18	0.029	0.59
Ilex dipyrena	110±41	62.5±4.8	37.13±12.3	0.04	2.54
Juglans regia	50±31	10±7.1	9.4±8.3	0.14	1.23
Llitsea umbrosa	27.5±10	27.5±13.7	8.8±4.7	0.04	0.59
Lyonia ovalifolia	10±4	27.5±0	6.97±3	0.08	1.35
Machilus odoratissima	105.5±41.7	50±23.5	24.43±11.7	0.09	3.28
Picea smithiana	1.2±1.2	10±10	6.4±6.4	0.01	3.8
Pyrus pashia	2.5±2.5	2.5±2.5	0.87±0.87	0.03	0.14
Q.floribunda	172±91	80±10	77.6±23	0.09	58.83
R.arboreum	10.5±7.4	7.5±4.78	6.25±4.8	0.03	1.93

Rhus punjabensis	2.5±2.5	2.5±2.5	0.65±0.65	0.03	0.16
Symplocos chinensis	17.5±7	17.5±7.5	7.1±3.8	0.047	0.24
Lindera pulcherrima	230±105	27.5±15.5	22.24±8.9	0.08	0.82

Table-5.14: Density, frequency, IVI and A/F ratio of different shrub species in community 7

Species	Frequency	Density/ha	IVI	A/F ratio
Daphne papyracea	37.5	80.8	98.71	0.139
Elsholtzia fruticosa	5	520	43.65	0.81
Rosa spp	2.5	56	39.38	0.35
Sarcococca saligna	42.5	534.4	118.28	0.279

Community 8: *Q.floribunda-Abies*: The change in the co-dominant species seems to have led to the formation of this community. The community occupied an altitudinal range between 2400-2700m asl. Here, *Q.floribunda* was the dominant tree species with density of 136.7/ha and IVI value of 82.7. *Abies pindrow* had a density of 123/ha and IVI 49. The total tree density of the community was 751.6/ha and the total basal area of the community was 151.7 m^2/ha (Table-5.15). The total shrub density of the community was 1973.2/ha with *Sarcococca* having the maximum density but *Elsholtzia* having the maximum IVI (Table-5.16). The shrub species were contiguously distributed.

Table-5.15: Density, frequency, IVI, A/F ratio and basal area of different tree species in community 8

Species	Density/ha	Frequency	IVI	A/F	Basal area
Abies pindrow	123±54	56.7±14.5	49.24±24	0.042	35.1
Acer spp.	80±14	50±5.8	28.5±5.5	0.035	6.71
Aesculus indica	23±8	20±5.8	20.1±7.9	0.06	13.7
Euonymus tingens	16.7±12	10±5.8	4.5±2.5	0.06	0.53
Ilex dipyrena	133.3±65	66.7±23.3	46.1±13.3	0.1	3.1
Juglans regia	3.3±3.3	3.3±3.3	1.7±1.7	0.03	0.31
Machilus odoratissima	13.3±13.3	16.7±16.7	6.14±6.14	0.042	0.83
Quercus floribunda	136±29	66.7±3.3	82.7±19.8	0.03	56.4
Quercus semecarpifolia	46.7±46.7	26.9±26.9	28.2±28.2	0.007	34.1
Rhododendron arboreum	13.3±13.3	6.7±6.7	4.7±4.7	0.05	0.5
Symplocos chinensis	20±10	13.3±6.7	6.25±3.3	0.05	0.33

Lindera pulcherrima	143±83	33.3±20.1	22.9±11.8	0.04	0.16

Table-5.16: Density, frequency, IVI and A/F ratio different shrub species in community 8

Species	Frequency	Density/ha	IVI	A/F ratio
Daphne papyracea	46.66	81.2	68.08	0.08
Elsholtzia fruticosa	30	790	124.16	0.68
Sarcococca saligna	40	1102	107.78	0.56

Community 9: Aesculus-Acer: This community, dominated by deciduous trees, occupied an altitudinal range between 2500-2700m asl. The tree density of the community was 564.5/ha. *Aesculus indica* had a density of 160/ha with IVI value of 83.12. The total basal area of the community was 139.7 m^2/ha (Table-5.17). The shrub density of the community was 1285/ha with *Elsholtzia* contributing 832/ha having an IVI value of 139.83. The distribution pattern of the species clearly indicates that the shrubs were contiguously distributed (Table-5.18).

Table-5.17: Density, frequency, IVI, A/F ratio and basal area of different tree species in community 9

Species	Density/ha	Frequency	IVI	A/F	Basal area
Abies pindrow	80±31	35±14.4	47.6±17.2	0.032	39.06
Acer spp.	157±24	70±10.8	69.2±23.8	0.04	14.79
Aesculus indica	160±34	80±9.12	83.12±10.12	0.031	34.96
Ilex dipyrena	2.5±2.5	2.5±2.5	1.8±1.8	0.025	0.13
Juglans regia	25±8	5±2.9	21.6±9.24	0.026	13.69
Lyonia ovalifolia	2.5±2.5	2.5±2.5	1.12±1.12	0.025	0.09
Picea smithiana	20±16	7.5±4.7	8.46±7	0.068	4.13
Quercus floribunda	62.5±32	40±14.1	40.85±18.6	0.046	26.17
Quercus semecarpifolia	17.5±17.5	10±10	10.9±10.9	0.009	5.45
R.arboreum	2.5±2.5	2.5±2.5	1.15±1.15	0.025	0.16
Symplocos chinensis	22.5±13	17.5±10.3	10±5.8	0.018	0.92
Taxus baccata	2.5±2.5	2.5±2.5	1.54±1.54	0.025	0.28
Lindera pulcherrima	10±5	5±2.8	2.9±1.7	0.02	0.001

Table-5.18: Density, frequency, IVI and A/F ratio different shrub species in community 9

Species	Frequency	Density/ha	IVI	A/F ratio
Daphne papyracea	20	48	39.66	0.3
Elsholtzia fruticosa	42.5	832	135.07	0.54
Sarcococca saligna	32.5	321	102.58	0.64
Viburnum cotinifolium	10	84	22.72	0.032

Community 10: Q.semecarpifolia-Taxus: The community forms the timberline in the area occupying the zone between 2700-3200m asl. The overall tree density of the community was 552.2/ha and the total basal area 140.21m^2/ha. The density and IVI values of *Q.semecarpifolia* were 296/ha and 159 respectively while that of *Taxus baccata* were 131/ha and 70 respectively. Tree species were generally randomly distributed in the community (Table-5.19). The shrub density of the community was 938.4/ha. *Sarcococca saligna* had the maximum density (504/ha) but *Viburnum had* the maximum IVI (124.21). The distribution of *Viburnum* was contiguous whereas the other species were randomly distributed (Table-5.20).

Table-5.19: Density, frequency, IVI, A/F ratio and basal area of different tree species in community 10

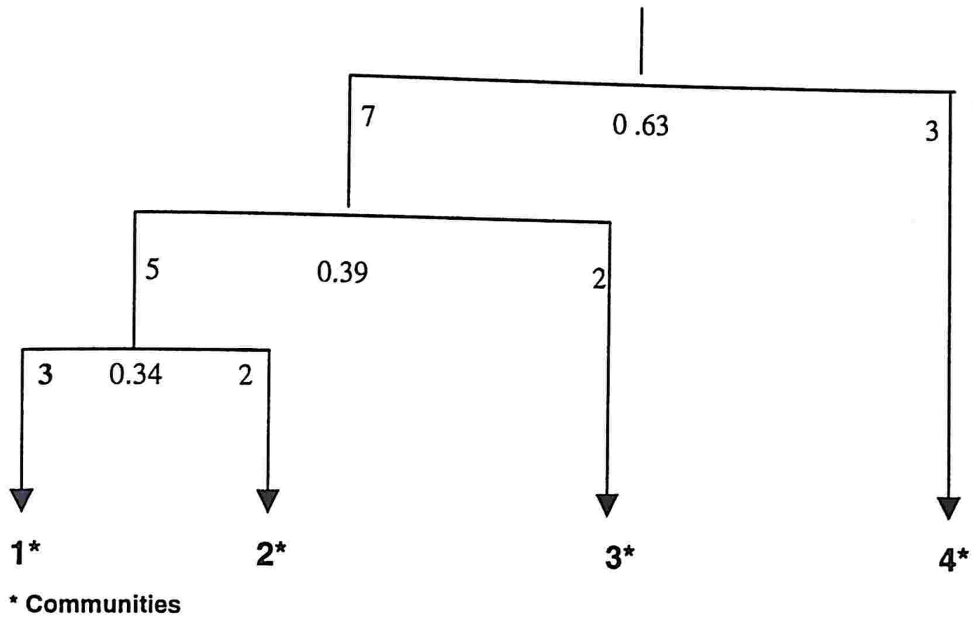
Species	Density/ha	Frequency	IVI	A/F	Basal area
Abies pindrow	76±27	34±9.7	45.5±12.9	0.1	26.25
Acer spp.	23.3±6	16.1±3.6	15.3±3.8	0.047	3.19
Aesculus indica	6±6	0.7±0.7	0.32±0.32	0.006	0.24
Quercus floribunda	7±7	4±4	3.1±3.1	0.002	1.16
Quercus semecarpifolia	295.3±30	86±4.1	159.2±16.5	0.04	80.12
R.arboreum	13.3±10	10±4.5	8.8±4.2	0.048	0.6
Taxus baccata	131.3±25	58.7±8.2	70.6±10.6	0.044	28.65

Table-5.20: Density, frequency, IVI and A/F ratio different shrub species in community 10

Species	Frequency	Density/ha	IVI	A/F ratio
Daphne papyracea	0.66	4	0.79	0.006
Elsholtzia fruticosa	2.6	324	8.76	0.03
Sarcococca saligna	3.3	504	10.43	0.033
Viburnum cotinifolium	30	106.4	124.21	0.16

5.3.1.2 Bhatwari watershed (South facing): A total of four communities were identified based on TWINSPAN (Figure-5.4).

Figure-5.4: Dendrogram of Plant communities in BWS



<u>*Community 1: Q. floribunda-Buxus wallichiana:*</u> The community occupied an altitudinal range between 2400-2700m. The density of the community was 666.67 with *B.wallichiana* and *Q.floribunda* having 263 and 90 individuals/ha with IVI values 90.68 and 85.23 respectively. The shrub density of the community was 1582/ha with *Berberis lycium* having the highest density 923/ha. The total basal area of the community was 76.5 ±22.15 m^2/ha (Table-5.21). The A/F ratio shows that most of the trees were randomly distributed whereas in the case of shrubs 50% were regularly distributed and the rest randomly (Table-5.22).

Table-5.21: Density, Frequency, IVI, basal area and A/F ratio of different Tree species in community 1

Species	Frequency	Density/ha	Basal area	IVI	A/ F
Acer spp	20±17.32	30±30	2.23	11.6±10.05	0.033
Buxus wallichiana	66.67±57.7	263.33±232	12.4	90.68±88.4	0.026
Cotoneaster acuminatus	6.67±11.5	6.67±11.54	0.32	2.72±4.72	0.016
Corylus jacquemontii	8.52±17.32	20±34.64	2.4	7.5±12.58	0.022
Carpinus viminea	6.67±11.54	6.67±11.54	0.18	2.57±4.46	0.016
Euonymus fimbriatus	6.67±11.54	6.67±11.54	0.08	2.47±4.28	0.016
Ilex dipyrena	46.67±35.11	80±88.8	2.3	25.98±18.9	0.049
Juglans regia	6.67±5.77	6.67±5.77	1.1	3.74±3.47	0.066
Lyonia ovalifolia	3.33±5.77	3.33±5.77	0.52	1.757±3.04	0.033
Pyrus vestita	3.33±5.77	3.33±5.77	0.56	2.05±3.5	0.033

Quercus floribunda	60±17.62	90±17.32	41.75	85.23±10.6	0.028
Quercus semecarpifolia	10±10	10±10	2.35	7.58±6.96	0.05
Rhododendron arboreum	30±43.58	73.33±110.15	6.72	25.65±34.9	0.077
Rhamnus virgatus	6.67±11.54	6.67±11.54	0.17	3.01±5.22	0.016
Symplocos chinensis	46.67±25.16	56.67±32.14	2.48	24.9±10.78	0.031
Taxus baccata	3.33±5.77	3.33±5.77	0.9	2.51±4.30	0.033

Table-5.22: Density, Frequency, IVI and A/F ratio of different shrub species in community 1

Species	Frequency	Density/ha	IVI	A/F
Berberis lycium	86.66	923	171.48	0.011
Cotoneaster bacillaris	13.33	63	13.35	0.055
Daphne papyracea	16.66	33	14.59	0.0145
Prinsepia utilis	43.33	400	55.39	0.0147
Rosa brunonii	13.33	120	22.73	0.0459
V.cotinifolium	10	43	22.43	0.0358

<u>Community 2: *Q.semecarpifolia-R. arboreum*</u>: This community occupying an altitudinal range between 2700-3000m had an overall tree density of 570±56.56 with *Q.semecarpifolia* having 155 individuals/ha and an IVI of 132.13. On the other hand *R. arboreum* had 100 individuals/ha and an IVI of 36.23 (Table-5.23.).The shrub density of the community was 825/ha (Table-5.24). The total basal area of the community was 165.12±26.83 m^2/ha. Majority of the tree species were contiguously distributed in this particular community, while the shrubs were regularly distributed.

Table-5.23: Density, Frequency, IVI, Basal area and A/F ratio of different tree species in community 2

Species	Frequency	Density/ha	Basal area	IVI	A/ F
Acer spp	70±0	190±14.2	21.56	70.18±8.46	0.038
Aesculus indica	5±7.07	10±14.12	2.48	4.71±6.66	0.1
Ilex dipyrena	15±7.07	15±7.07	0.5	8.1±3.58	0.075
Prunus cornuta	25±7.1	55±21.21	5.5	22.27±10.2	0.089
Pyrus vestita	5±7.07	5±7.07	0.28	2.92±4.13	0.05
Quercus semecarpifolia	80±0	155±7.1	125.5	132.13±12	0.024
Rhododendron arboreum	45±7.1	100±28.28	5	36.23±0.27	0.053
Symplocos chinensis	10±14.12	10±14.12	0.6	5.86±8.29	0.025
Taxus baccata	30±28.28	30±28.28	3.7	17.56±15.6	0.06

Table-5.24: Density, Frequency, IVI and A/F ratio of different shrub species in community 2

Species	Frequency	Density/ha	IVI	A/F
Cotoneaster bacillaris	5	5	4.83	0.005
Deutzia staminea	5	10	9.24	0.01
Rosa brunonii	20	135	37.34	0.008
V.cotinifolium	40	310	112.65	0.004
Viburnum sp.	50	365	135.92	0.003

Community 3: *Q.semecarpifolia-P.cornuta*: This community occupied an altitudinal range between 3000-3200m with *Q.semecarpifolia* being the dominant species. Its density and IVI were 205 and 142 respectively. Overall tree density of the community was 485±35 and the basal area 82.89m^2/ha (Table-5.25). The shrub density of the community was 1605/ha (Table-5.26). Most of the trees had random distribution while the shrubs were regularly distributed.

Table-5.25: Density, Frequency, IVI, Basal area and A/F ratio of different tree species in community 3

Species	Frequency	Density/ha	Basal area	IVI	A/ F
Acer spp	50±0	65±7.07	4.23	40.63±5.51	0.026
Abies pindrow	5±5	5±7.07	6.36	9.38±13.26	
Euonymus fimbriatus	5±5	5±5	0.14	3.57±5.06	0.05
Prunus cornuta	55±5	105±21.21	6.4	53.26±7.4	0.034
Pyrus vestita	10±10	10±14.14	2.21	8.32±11.7	0.025
Quercus semecarpifolia	60±14.14	205±7.1	59.47	142.1±21.2	0.062
Syringa emodi	35±21.2	75±49.5	1.93	32.45±17.27	0.072
Taxus baccata	10±0	15±7.07	2.15	10.27±3	0.15

Table-5.26: Density, Frequency, IVI and A/F ratio of different shrub species in community 3

Species	Frequency	Density/ha	IVI	A/F
Berberis lycium	30	215	30.31	0.0171
Rosa brunonii	5	10	3.16	0.01
V.cotinifolium	20	30	26.27	0.0018
Viburnum sp.	100	1350	240.24	0.013

Community 4: Q.semecarpifolia-A.pindrow: The community formed timberline in the area occupying zone between 3200-3400m. The overall tree density of the community was 546.67±127.35 individuals/ha (Table-5.27) while the shrub density was 1130/ha (Table-5.28) The basal area of the community was 127.33m^2/ha. The A/F ratio clearly indicates that majority of the tree species were randomly distributed while majority of the shrubs were regularly distributed.

Table-5.27: Density, Frequency, IVI, Basal area and A/F ratio of different tree species in community 4

Species	Frequency	Density/ha	Basal area	IVI	A/ F
Acer spp	10±8.16	10±8.16	0.28	7.22±6.95	0.05
Abies pindrow	33.33±30.6	70±70	16.35	42.57±42.1	0.027
Prunus cornuta	20±20	26.67±25.17	1.29	16.89±17.1	0.035
Quercus semecarpifolia	96.67±5.8	430±191.6	109.3	229.45±63.5	0.045
Rhododendron campanulatum	3.33±5.8	6.67±11.55	0.07	2.94±5.09	0.066
Syringa emodi	3.33±5.77	3.33±5.77	0.04	0.91±1.57	0.333

Table-5.28: Density, Frequency, IVI and A/F ratio of different shrub species in community 4

Species	Frequency	Density/ha	IVI	A/F
Berberis jaeschkeana	10	86	9.43	0.009
Cotoneaster microphylla	10	30	59.16	0.012
Piptanthus nepalensis	3.33	13	4.69	0.013
Ribes glaciale	10	36	3.33	0.004
Rosa webbiana	73.33	530	76.31	0.010
Viburnum cotinifolium	20	33	42.17	0.0009
Viburnum sp.	36.66	403	104.87	0.271

5.3.2 Species diversity: Even though the term diversity has long been used for explanation of ecological communities; a unanimous accepted definition is still awaited. Huberlbert (1971) said, "Diversity per se does not exist". Many workers like McIntosh (1967) considered that diversity should include both evenness and richness component. Evenness refers to the distribution of species in a community while richness is an indicator of the number of species in a community. Pielou (1969) described, "diversity however defined, is a single statistic in which the number of species and the evenness are confounded". Whittaker (1972) distinguished three levels of diversity, alpha diversity or the within habitat diversity, beta diversity or between habitat diversity and gamma diversity i.e. of the entire landscape and can be considered as composite of alpha and beta diversity.

Despite of differences in opinion about diversity amongst the ecologists, the diversity indices are still widely used as they are straightforward and are frequently seen as indicators of well being of an ecosystem (Magurran 1988). Recent work in this field include that of Raghubanshi *et al.* (1991) who have described nine hypotheses regarding patterns of diversity while Ritchie & Olff (1999) have employed spatial scaling laws to explain the relationship between diversity and productivity and have tried to predict the potential number of species in a community.

In the present study Shannon and Wiener's diversity index (H') has been used as it is simple to calculate, widely used and takes into consideration both the richness and evenness values of the species. Further the values obtained by this index can be used for comparison with other parts of Himalayan region where mostly Shannon and Wiener's diversity index (H') has been used.

5.3.2.1 Duggada Watershed:

<u>*Tree diversity*</u>: It was found that the maximum tree diversity was in *Q.floribunda-Ilex* community (Table-5.29) which is in the mid elevation zone where species common to both the lower and higher zones were present. The minimum tree diversity was in *Cedrus-Pinus* community, which was a plantation, the community also had lowest evenness value as it was a monoculture and hence the concentration of dominance was highest in this community. The maximum evenness value was in the *Toona-Swida* community as the species were evenly distributed with not much difference in their abundance values. The highest species richness was in the mid elevational *Rhododendron-Lyonia* community where again species common to both the higher and lower zones were present. The beta diversity for the tree species, which is defined as the rate of change of species along a habitat gradient, was found to be 2.81.

Table-5.29: Diversity, dominance, evenness and richness values of tree species in different communities

Community	Diversity	Dominance	Evenness	Richness
Cedrus-Pinus	0.51	0.71	0.46	3
Toona-Alnus	1.63	0.26	0.66	12
Alnus-Litsea	2.19	0.13	0.85	13
Toona-Swida	2.27	0.14	0.82	14
Rhododendron-Lyonia	1.96	0.18	0.63	22
Q.leucotrichophora-Q.floribunda	1.82	0.2	0.71	13
Q.floribunda-Ilex	2.32	0.13	0.78	19
Q.floribunda-Abies	2.09	0.14	0.84	12
Aesculus-Acer	1.89	0.19	0.73	13
Q.semecarpifolia-Taxus	1.26	0.35	0.64	7

Shrub diversity: The diversity, richness and evenness of the shrub species in different communities were calculated separately (Table-5.30). It was found that *Toona-Alnus* community had the maximum diversity and evenness but lowest concentration of dominance, as in this community the species were more evenly distributed which is indicated by the high evenness value. The *Q.floribunda-Ilex* community, which had the maximum tree diversity, had the low shrub diversity this may be due to the dense canopy of the tree layer inhibiting gregarious shrub growth. The community-9 had the lowest evenness value as the dominance was shared by few species. This is clearly evident from the concentration of dominance value, which was highest in this community. The beta diversity for the shrub species was found to be 2.64.

Table-5.30: Diversity, dominance, evenness and richness values of Shrub species in different communities

Community	Diversity	Dominance	Evenness	Richness
Cedrus-Pinus	1.35	0.3	0.83	5
Toona-Alnus	2.03	0.15	0.88	10
Alnus-Litsea	1.05	0.54	0.48	9
Toona-Swida	1.51	0.3	0.69	9
Rhododendron-Lyonia	1.98	0.21	0.71	16
Q.leucotrichophora-Q.floribunda	1.08	0.35	0.79	4
Q.floribunda-Ilex	0.96	0.47	0.69	4
Q.floribunda-Abies	0.87	0.46	0.78	3
Aesculus-Acer	0.5	0.77	0.36	4
Q.semecarpifolia-Taxus	0.94	0.44	0.68	4

5.3.2.2 Bhatwari watershed:

Tree diversity: The maximum diversity was in the *Q.floribunda-B.wallichiana* community where the dominance was minimum. The community also had the maximum richness probably because of unpalatable, thorny species coming up in the disturbed sites, which also accounted for its high diversity. The minimum diversity was in the timberline *Q.semecarpifolia-A.pindrow* community that had the highest dominance and the lowest evenness (Table-5.31). The reason could be the dominance by single species i.e. *Q.semecarpifolia*. The Beta diversity of tree species in BWS was 2.21.

Table-5.31: Diversity, dominance, evenness and richness values of tree species in different communities

Community	Diversity	Dominance	Evenness	Richness
Q.floribunda-Buxus wallichiana	1.96	0.21	0.71	16
Q.semecarpifolia-R. arboreum	1.68	0.23	0.77	9
Q.semecarpifolia-P. cornuta	1.54	0.27	0.74	8
Q.semecarpifolia-A.pindrow	0.76	0.64	0.42	5

Shrub diversity: The shrub diversity was highest in the *Q.semecarpifolia-A.pindrow* community, which had the minimum tree diversity. The minimum shrub diversity was in *Q.semecarpifolia-P.cornuta* community, which consequently had highest dominance value 0.72 (Table-5.32) The Beta diversity of the shrub species in BWS was 2.

Table-5.32: Diversity, dominance, evenness and richness values of shrub species in different communities

Community	Diversity	Dominance	Evenness	Richness
Q.floribunda-Buxus wallichiana	1.16	0.41	0.65	6
Q.semecarpifolia-R. arboreum	1.11	0.36	0.69	5
Q.semecarpifolia-P. cornuta	0.52	0.72	0.37	4
Q.semecarpifolia-A.pindrow	1.27	0.35	0.66	7

5.3.3 Similarity

5.3.3.1 Similarity between different communities in DWS: The similarity (Table-5.33) clearly indicates that the maximum similarity occurs between the communities at the two extreme ends of the altitude. In lower altitudes the maximum similarity occurs between *Toona-Alnus* and *Alnus-Litsea* community while at higher altitudes the maximum similarity is between the communities *Q.floribunda-Ilex* and *Q.floribunda-Abies.*

Table-5.33: Similarity between different communities in DWS

Community	1	2	3	4	5	6	7	8	9	10
1	100									
2	16.5	100								
3	17.4	39.2	100							
4	9.9	28	37.9	100						
5	22.2	28.1	31.1	29	100					
6	2.1	8.7	17.9	15.9	25.2	100				
7	0.64	5.2	11.4	14.9	11.5	25.1	100			
8	0	0.1	1.1	6.1	3.3	14.5	38.9	100		
9	0	0.08	0.18	5.6	0.38	7.7	21.7	31.2	100	
10	0	0.1	1.2	0	2.2	2.4	6.7	20.9	10.7	100

Community: 1= *Cedrus-Pinus*, 2= *Toona-Alnus*, 3= *Alnus-Litsea*, 4= *Toona-Swida*, 5= *Rhododendron-Lyonia*, 6= *Q.leucotrichophora-Q.floribunda*, 7= *Q.floribunda-Ilex*, 8= Q.floribunda-Abies, 9= Aesculus-Acer, 10= *Q.semecarpifolia-Taxus*

5.3.3.2 Similarity between different communities in BWS: It can be seen that the maximum similarity occurs between communities *Q. semecarpifolia-R. arboreum* and *Q. semecarpifolia-P.cornuta* (Table-5.34) These are the mid elevation transitional communities where species common to both the upper and lower zones are present.

Table-5.34: Similarity between different communities in BWS

Community	**1**	**2**	**3**	**4**
1	100			
2	15.7	100		
3	6.7	22.3	100	
4	1.7	21.1	15.8	100

Community: 1=*Q. floribunda-B. wallichiana*, 2=*Q. semecarpifolia-R. arboreum*, 3=*Q. semecarpifolia-P. cornuta* and 4=*Q. semecarpifolia-A. pindrow*

5.3.4 Population structure and regeneration: In studying the regeneration status of forest communities, population structure is a very useful measure as it helps in predicting the future composition of the forest by highlighting the regeneration behaviour and reproductive strategy of the different species (Saxena *et al.* 1985). The population structure of different species was prepared separately for different communities in both the ISS. By dividing them into 7 girth classes *Viz,* I= 31.5-61.5cm, II= 61.5-91.5 cm, III= 91.5-121.5cm, IV= 121.5- 151.5 cm, V = 151.5-181.5 cm, VI = 181.5-211.5 cm and VII > 211.5cm

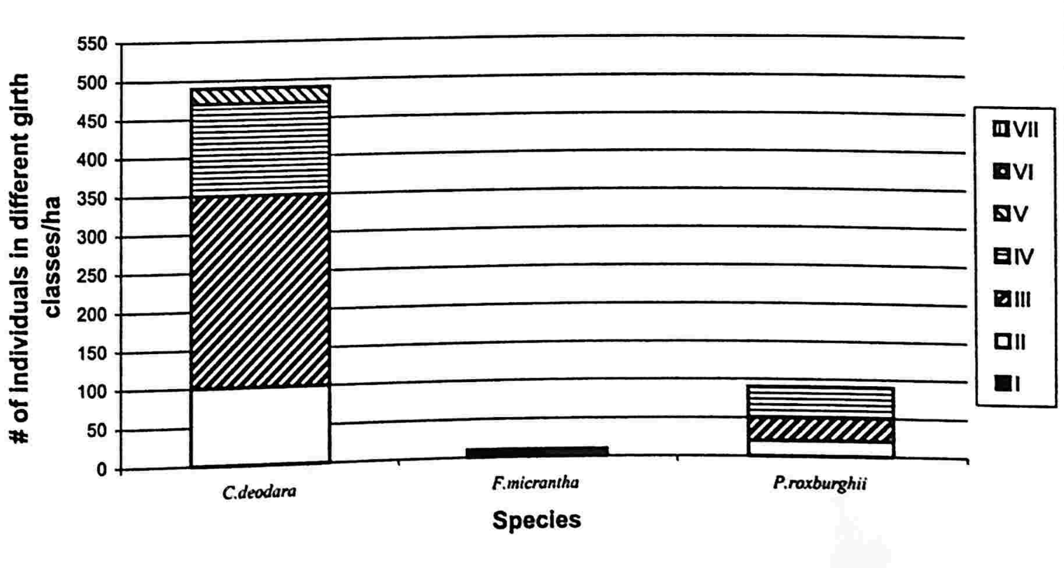
5.3.4.1 Dugadda Watershed

<u>Community 1: *Cedrus-Pinus* community:</u> The overall seedling density of the community was 70/ha and the sapling 38/ha (Table-5.35). The population structure of all the tree species occurring in the community is given in Figure-5.5. *Cedrus deodara* and *Pinus roxburghii* had most of the individuals in the medium girth class category while *Fraxinus micrantha* had all the individuals in the lower girth class. The seedling diversity of the community was 0.41 whereas in the case of sapling the diversity was 0.57.

Table-5.35: Seedling and sapling density/ha in *Cedrus-Pinus* community

Species	Seedling	Sapling
Cedrus deodara	10	10
Pinus roxburghii	60	28
Total	**70**	**38**

Figure-5.5: Population structure of tree species in *Cedrus-Pinus* community

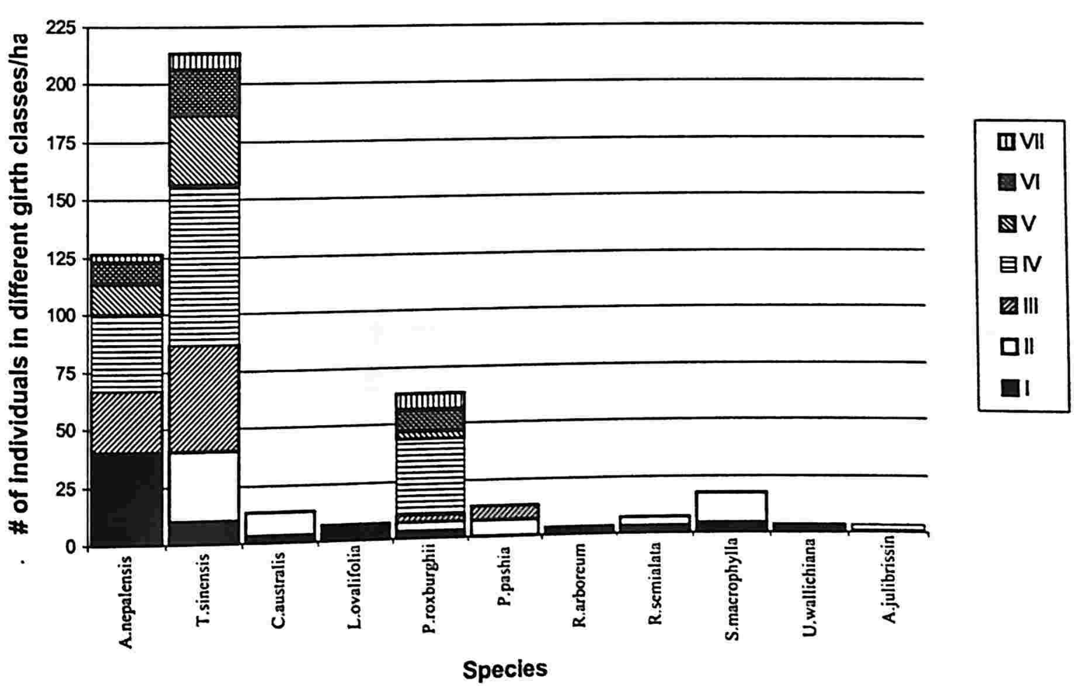


<u>*Community 2: Toona-Alnus community:*</u> The community had an overall seedling and sapling density of 66.6/ha and 73.4/ha respectively. *Toona sinensis* had the maximum seedling and sapling density (Table-5.36). For most of the species the density of individuals in the middle and higher girth class categories was higher (Figure-5.6). The seedling diversity was 1.44 whereas in case of saplings it was 1.6.

Table-5.36: Seedling and sapling density/ha in *Toona-Alnus* community

Species	Seedling	Sapling
Alnus nepalensis	10	6.7
Toona sinensis	33.3	33.3
Celtis australis	6.7	13.4
Lyonia ovalifolia	3.3	0
Pyrus pashia	0	6.7
Rhus punjabensis	10	3.3
Swida macrophylla	3.3	6.7
Ulmus wallichiana	0	3.3
Total	**66.6**	**73.4**

Figure-5.6: Population structure of tree species in *Toona-Alnus* community

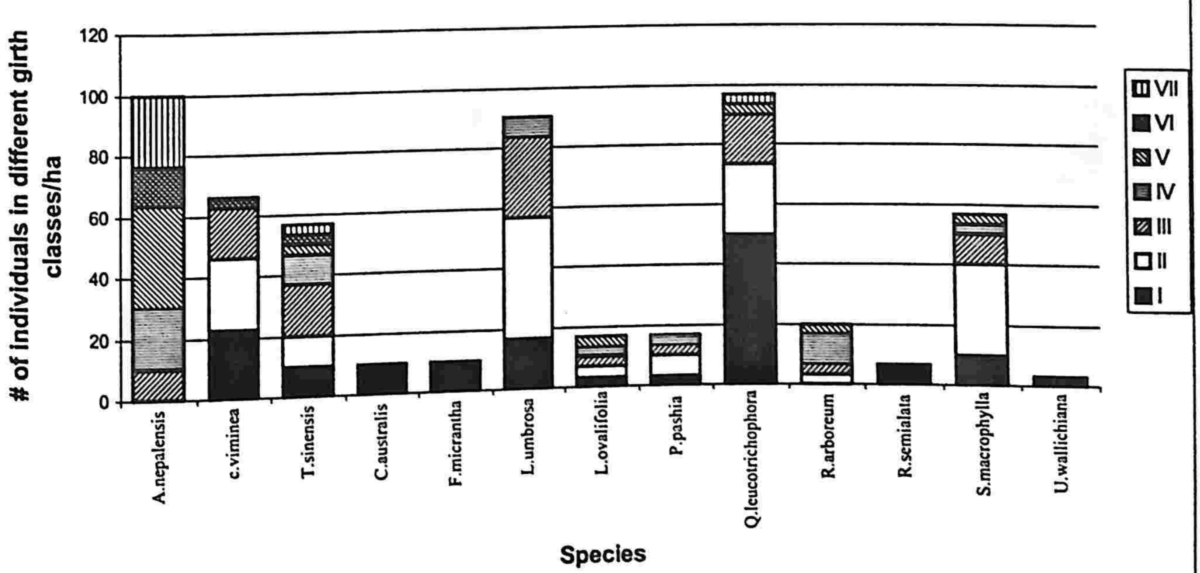


<u>*Community 3: Alnus-Litsea community*</u>: The community had three species in the seedling stage with a density value of 73.3/ha *Litsea umbrosa* alone contributed 66.7/ha (Table-5.37). The seedling diversity was 0.36 while the sapling diversity was 2.32. The population structure of the species is given in Figure-5.7, which clearly shows that while *Alnus* and *Toona* had higher number of individuals in the higher girth classes other species had most of the individuals in the lower and middle girth classes.

Table-5.37: Seedling and sapling density/ha in *Alnus-Litsea* community

Species	Seedling	Sapling
Alnus nepalensis	3.3	6.6
Carpinus viminea	0	6.6
Toona sinensis	0	13.4
Celtis australis	3.3	6.6
Fraxinus micrantha	0	3.3
Litsea umbrosa	66.7	6.6
Pyrus pashia	0	3.3
Q.leucotrichophora	0	16.7
Rhododendron arboreum	0	3.3
Rhus semialata	0	13.4
Swida macrophylla	0	6.6
Ulmus wallichiana	0	3.3
Total	**73.3**	**89.7**

Figure-5.7: Population structure of tree species in *Alnus-Litsea* community

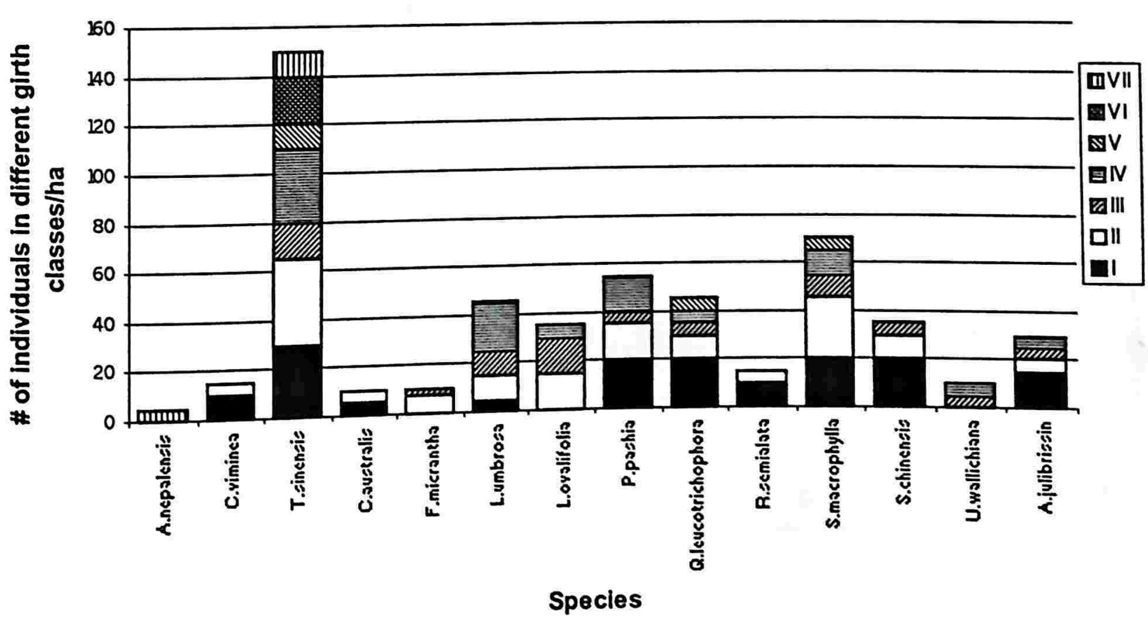


Community 4: Toona-Swida community: The community showed minimum regeneration with only 5 seedlings/ha and 45 saplings/ha. Only *Toona* represented the seedling strata with the concentration of being maximum (1) and diversity being the lowest (0). *Toona* also had the maximum sapling density 15/ha (Table-5.38) closely followed by other species. The sapling diversity was 1.69. The population structure of the species (Figure-5.8) clearly indicates that while majority of the species had higher number of individuals in the medium and lower girth class categories *Alnus nepalensis* had all the individuals in higher girth class.

Table-5.38: Seedling and sapling density/ha in *Toona-Swida* community

Species	Seedling	Sapling
Carpinus viminea	0	5
Toona sinensis	5	15
Celtis australis	0	7.5
Q.leucotrichophora	0	5
Rhus semialata	0	7.5
Albiz ia julibrissin	0	5
Total	**5**	**45**

Figure-5.8: Population structure of tree species in *Toona-Swida* community



Community 5: Rhododendron-Lyonia community: The community had the maximum richness in the seedling strata with a total of 11 species. The seedling density of the community was 162.83/ha with a diversity value of 1.49. The highest seedling density was of *Rhus semialata* 60.43/ha closely followed by *Q. leucotrichophora* 52.2/ha. The sapling density of the community was 73.5/ha with *Q. leucotrichophora* having the maximum sapling density 29.6/ha (Table-5.39). Sapling diversity was 1.86. The population structure (Figure-5.9) of the community revealed that while most of the species had individuals in low and intermediate girth class categories *Rhododendron, Lyonia* and *Q .leucotrichophora* had individuals in almost all the girth class categories.

Table-5.39: Seedling and sapling density/ha in *Rhododendron-Lyonia* community

Species	Seedling	Sapling
Aesculus indica	0	0.4
Alnus nepalensis	0.4	6.5
Carpinus viminea	0	0.4
Toona sinensis	0.4	0.8
Celtis australis	0	0.4
Lyonia ovalifolia	26.9	11.7
Pinus roxburghii	7.8	1.3
Pyrus pashia	0	1.7
Q.leucotrichophora	52.2	29.6
Q.floribunda	0.4	0
Rhus semialata	60.43	13
R.arboreum	11.3	3
Swida macrophylla	0.4	2.2
Symplocos chinensis	2.2	1.3
Ulmus wallichiana	0	0.8
Albizia julibrissin	0.4	0.4
Total	**162.83**	**73.5**

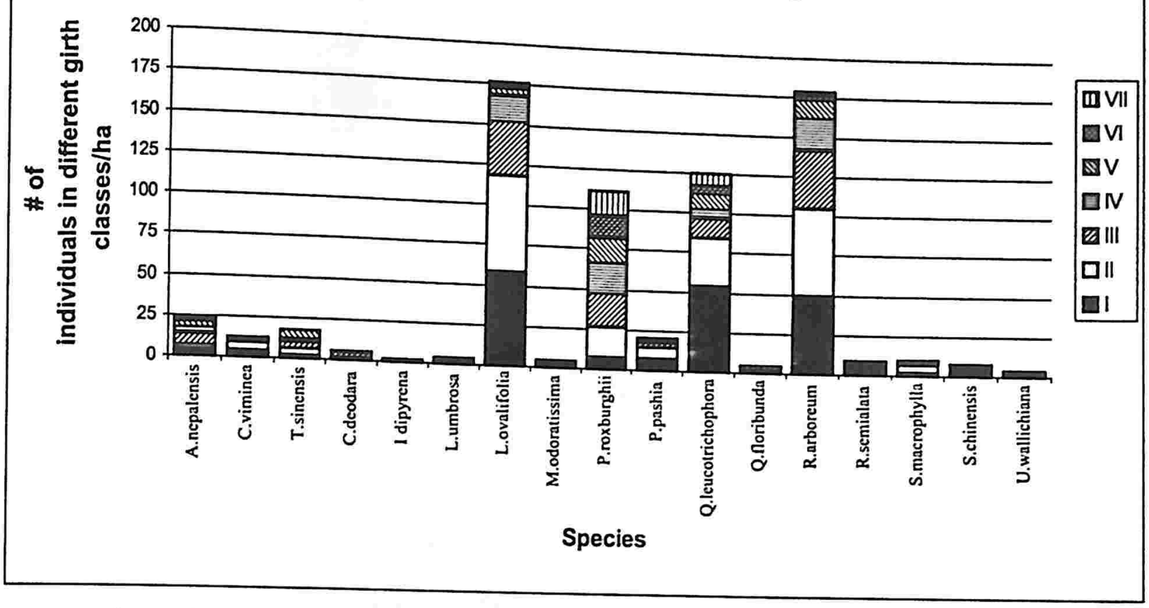
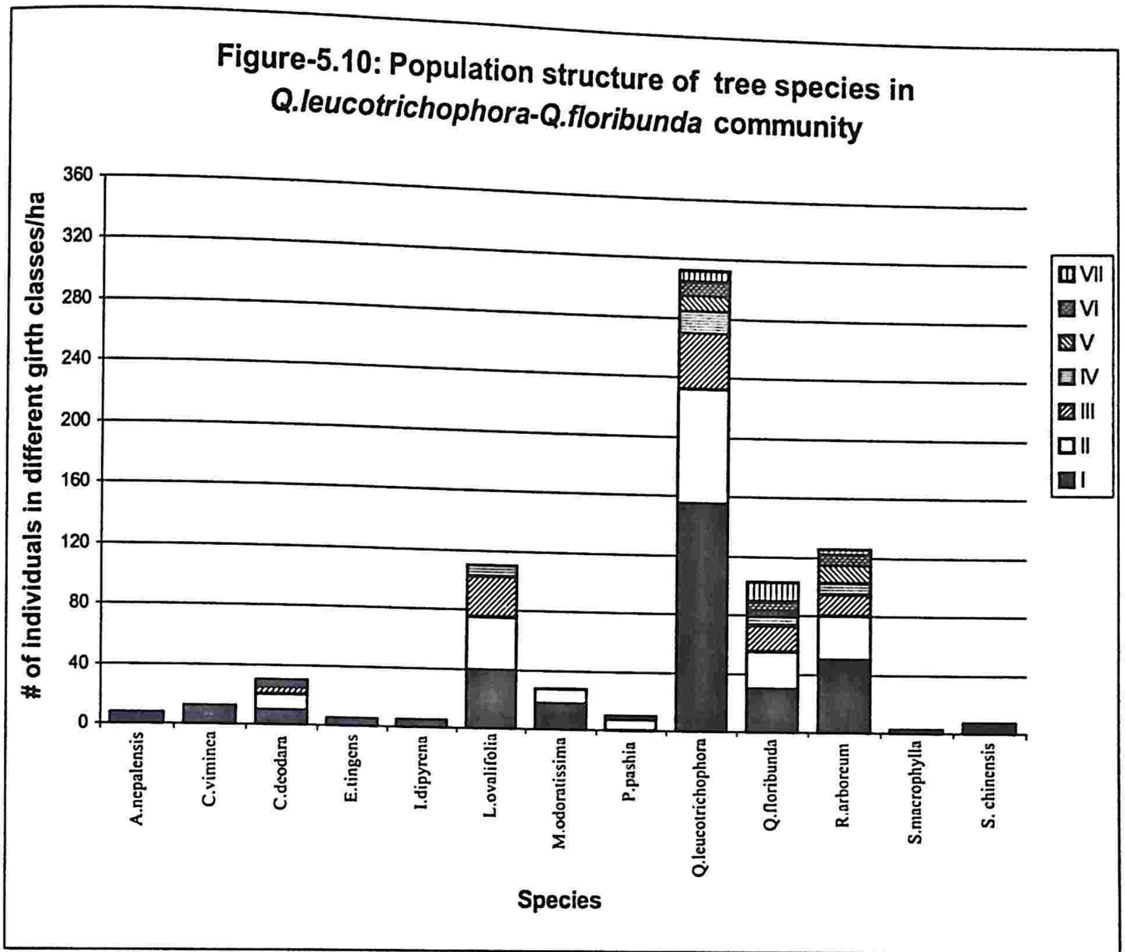


Figure-5.9: Population structure of tree species in *Rhododendron-Lyonia* community

Community 6: *Q.leucotrichophora-Q.floribunda* community: This mid elevational community had the maximum number of seedlings 1155/ha with *Q.floribunda* contributing 482.5/ha (Table-5.40). The seedling diversity of the community was 1.41 while that of the sapling was 1.68. The overall sapling density was 127.5/ha with *Q.leucotrichophora* having the maximum density 55/ha. The population structure of the species in the community is shown in Figure-5.10 where *Q.leucotrichophora* and *Q.floribunda* were present in almost all the girth classes, the other species were usually present in the lower and medium girth classes.

Table-5.40: Seedling and sapling density/ha in *Q.leucotrichophora-Q.floribunda* community

Species	Seedling	Sapling
Alnus nepalensis	22.5	5
Cedrus deodara	0	2.5
E.hamiltonianus	0	7.5
Lyonia ovalifolia	0	10
Machilus odoratissima	17.5	2.5
Pyrus pashia	0	2.5
Q.leucotrichophora	130	55
Q.floribunda	482.5	7.5
Lindera pulch rrima	300	0
R.arboreum	202.5	32.5
Symplocos chinensis	0	2.5
Total	**1155**	**127.5**



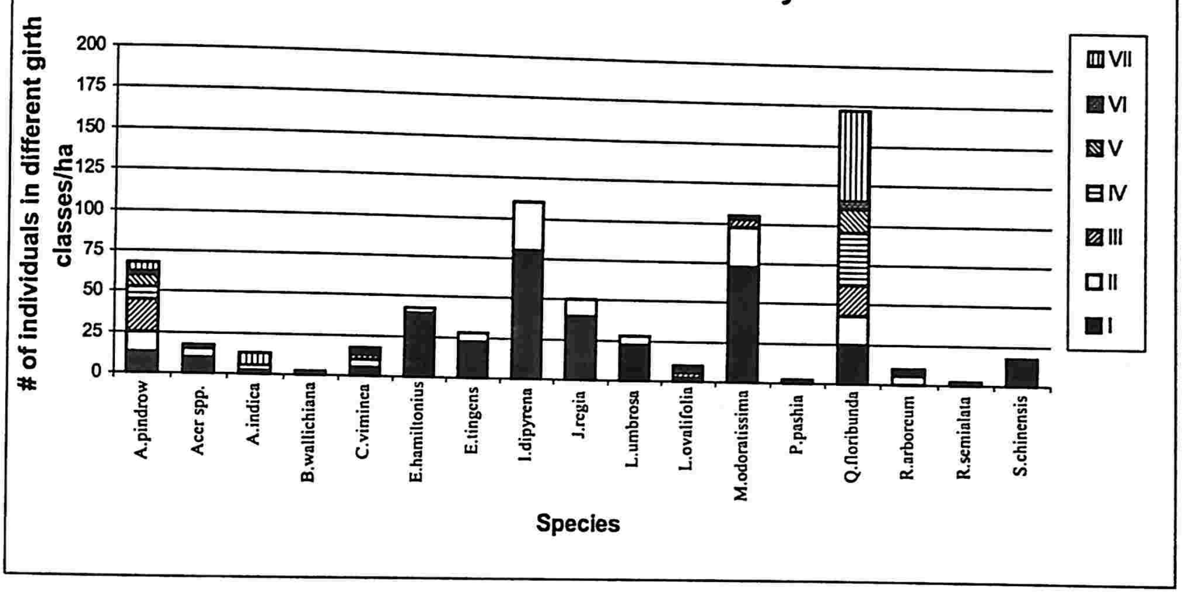
<u>*Community 7: Q.floribunda-Ilex community:*</u> The community had the maximum number of saplings 147.5/ha with *Machilus* contributing 40/ha and *Q.floribunda* 25/ha. The sapling diversity of the community was higher 2.28 while that of seedling was lower 1.08. The seedling density of the community was 550/ha with *Q.floribunda* alone accounting for 357.5/ha (Table-5.41). The population structure of the species in the community as shown in Figure-5.11 indicates that while *Q.floribunda* and *Abies* were represented in all the girth class categories, other species were distributed in the lower and medium girth class categories.

Table-5.41: Seedling and sapling density/ha in *Q.floribunda-Ilex* community

Species	Seedling	Sapling
Acer spp.	7.5	2.5
Buxus wallichiana	2.5	0
Carpinus viminea	0	5
E.hamiltonianus	0	22.5
E.tingens	0	5
Ilex dipyrena	27.5	10
Juglans regia	0	7.5
Litsea umbrosa	7.5	10
Lyonia ovalifolia	0	5

Lindera pulcherrima	115	15
Machilus odoratissima	30	40
Q.floribunda	357.5	25
R.arboreum	0	7.5
Symplocos chinensis	2.5	7.5
Total	**550**	**162.5**

Figure-5.11: Population structure of tree species in *Q.floribunda-Ilex* community

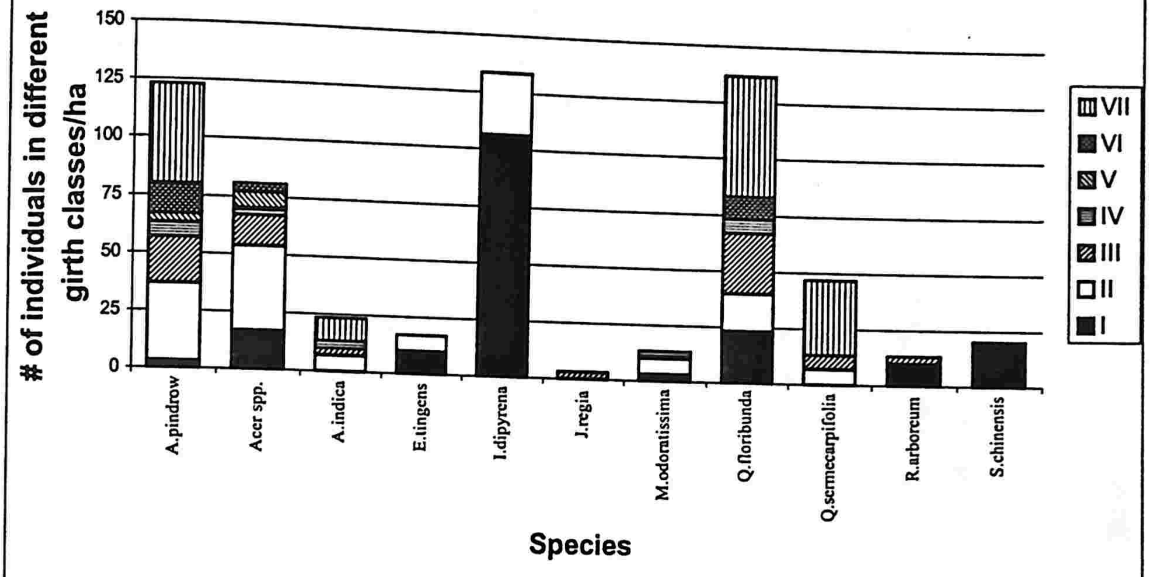


<u>*Community 8: Q.floribunda-Abies community:*</u> The community had only four species in the regenerating stage with a total of 229.6/ha and 43.3/ha seedling and saplings respectively. *Q.floribunda* accounted for 113/ha seedlings in the community whereas in the sapling strata it's density was 20/ha (Table-5.42). The seedling diversity was 0.69 while the saplings diversity was 1.12. The population structure (Figure-5.12) of the species in the community indicates that while *Q.floribunda*. *Abies* and *Acer* spp.had individuals in almost all the girth classes others had representation in the lower and medium girth classes.

Table-5.42: Seedling and sapling density/ha in *Q.floribunda-Abies* community

Species	Seedling	Sapling
Machilus odoratissima	0	3.3
Lindera pulcherrima	116.6	16.7
Symplocos chinensis	0	3.3
Q.floribunda	113	20
Total	**229.6**	**43.3**

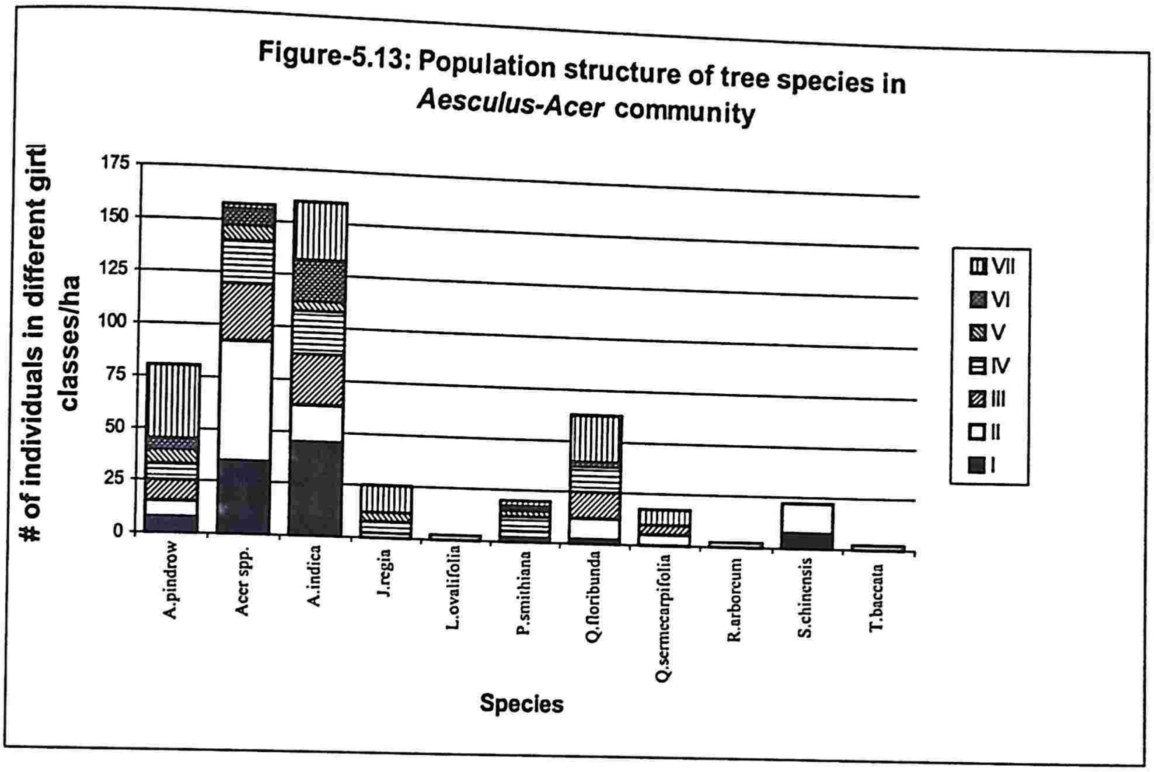
Figure-5.12: Population structure of tree species in *Q.floribunda-Abies* community



<u>*Community 9: Aesculus-Acer community:*</u> The community had an overall seedling and sapling density of 102.5/ha and 40/ha respectively with *Acer spp* having the maximum seedling density 82.5/ha and *Aesculus* having the maximum sapling density 25/ha (Table-5.43). The sapling diversity was higher 0.84 when compared to seedling diversity (0.49). The population structure of the species in the community (Figure-5.13) showed that the dominant species had representation in almost all the girth classes while the codominant species represented the lower and medium girth classes.

Table-5.43: Seedling and sapling density/ha in *Aesculus-Acer* community

Species	Seedling	Sapling
Acer spp.	82.5	12.5
Aesculus indica	20	25
Ilex dipyrena	0	2.5
Total	**102.5**	**40**



<u>*Community 10: Q.semecarpifolia-Taxus community:*</u> The community had the minimum sapling density 8.3/ha amongst all the communities. Of the entire sapling density *T.baccata* had the maximum sapling 2.8/ha. The sapling diversity of the community was 1.16. The seedling density of the community was 53.3/ha (Table-5.44). The diversity of the seedlings was lower 0.84 when compared to saplings. The population structure (Figure-5.14) for the species in the community shows that *Q.semecarpifolia, T.baccata* and *A.pindrow* represented themselves in all the classes while other species had few individuals in lower and medium girth classes.

Table-5.44: Seedling and sapling density/ha in *Q.semecarpifolia-Taxus* community

Species	Seedling	Sapling
Abies pindrow	0	2
Acer spp.	0	0.7
Ilex dipyrena	0	0.7
Q.semecarpifolia	18	1.4
R.arboreum	32	0.7
Taxus baccata	3.3	2.8
Total	**53.3**	**8.3**

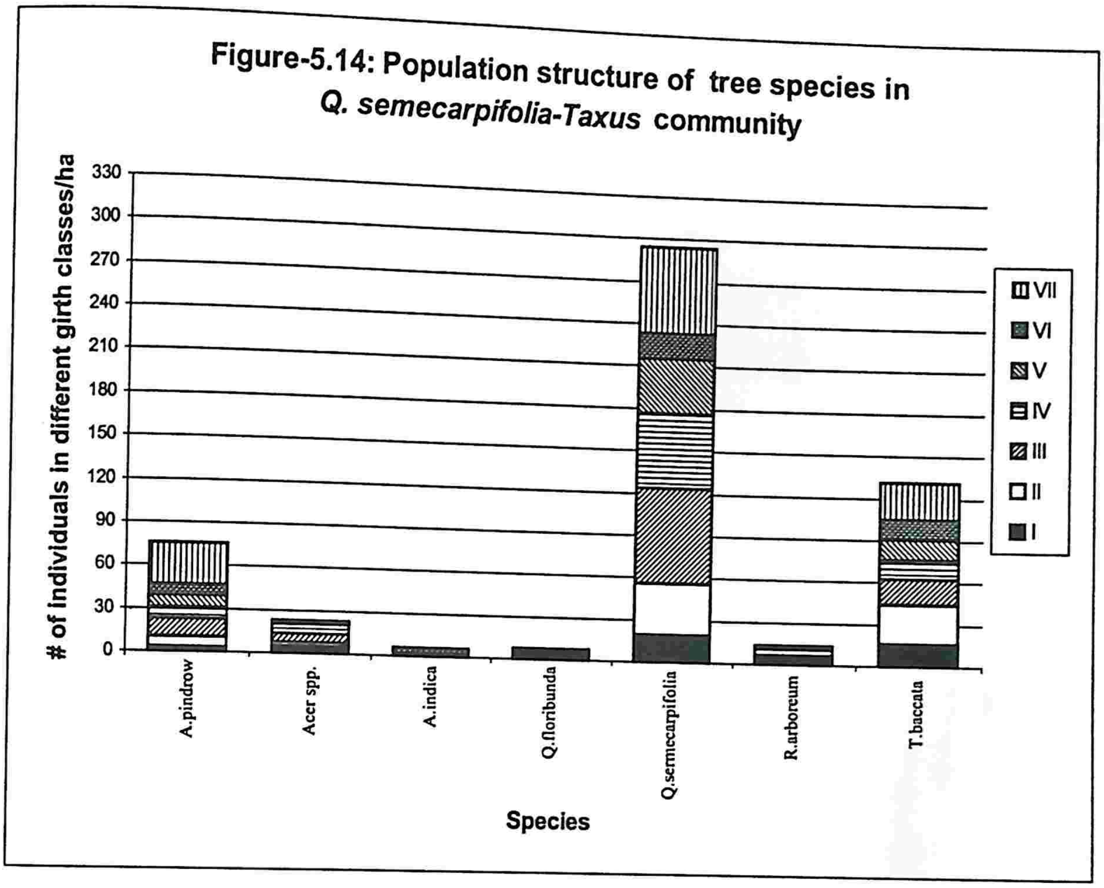


Figure-5.14: Population structure of tree species in
Q. semecarpifolia-Taxus community
# of Individuals in different girth classes/ha
330
300
270
240
210
180
150
120
90
60
30
0
A.pindrow
Acer spp.
A.indica
Q.floribunda
Q.semecarpifolia
R.arboreum
T.baccata
Species
VII
VI
V
IV
III
II
I

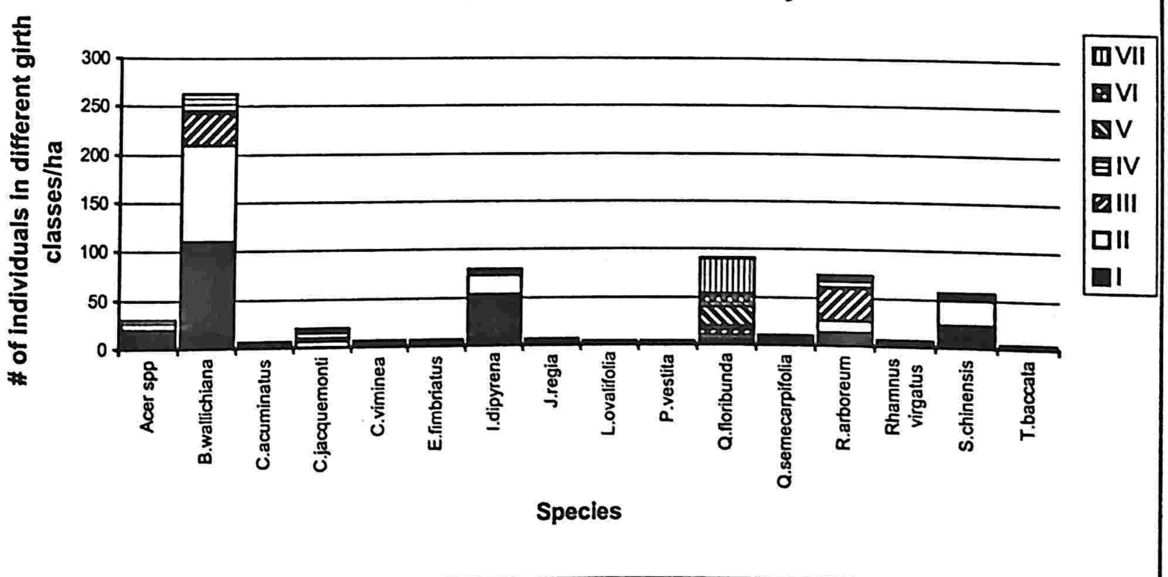
5.3.4.2 *Bhatwari Watershed*

<u>Community 1: *Q. floribunda-Buxus wallichiana* community:</u> The seedling and sapling density of the community was 1606.67 and 350/ha respectively (Table-5.45). The population structure of the tree species is given in Figure-5.15. *B.wallichiana*, *I.dipyrena* and *S.chinensis* had most of the individuals in lower girth class while others had majority of the individuals in medium and higher girth class. Seedling and sapling diversity of the community was 1.27 and 0.53 respectively.

Table-5.45: Seedling and sapling density/ha in *Q.floribunda-Buxus wallichiana* community

Species	Seedling	Sapling
Buxus wallichiana	426.66	303.33
Ilex dipyrena	283.33	23.33
Lyonia ovalifolia	6.66	0
Pyrus pashia	3.33	0
Quercus floribunda	740	0
Rhododendron arboreum	146.66	10
Symplocos chinensis	0	13.33
Total	**1606.67**	**350**

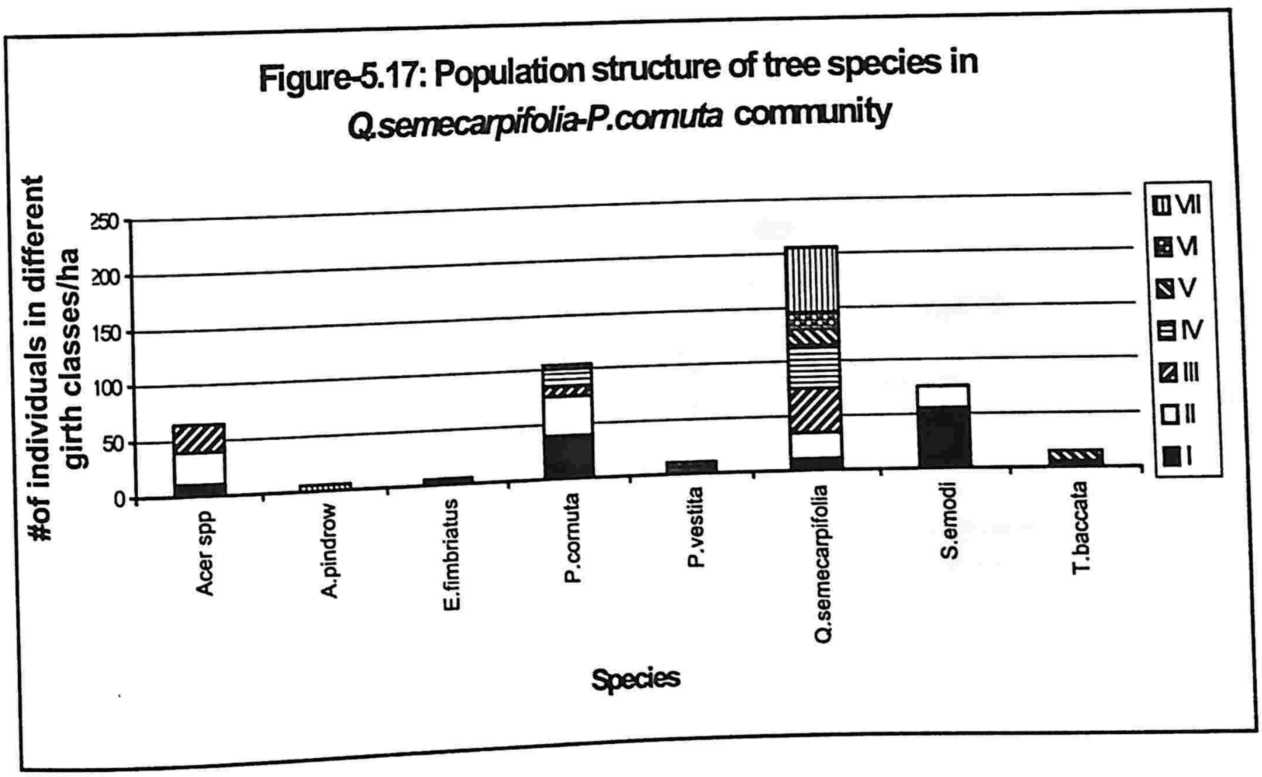
Figure-5.15: Population structure of tree species in *Q.floribunda-B.wallichiana* community



Community 3: *Q.semecarpifolia-P.cornuta* community: The community had four species in the regenerating strata. The seedling density of the community was 1320/ha of which *P.cornuta* had 665 individuals. *P.cornuta* also had the maximum sapling 10/ha while the total sapling density was 25/ha (Table-5.47). The seedling and sapling diversity of the community was 0.73 and 1.05 respectively. The population structure of tree species clearly reveals that *P.cornuta* and *S.emodi* had maximum individuals in the lower girth class others had more individuals in higher and medium girth class (Figure-5.17).

Table-5.47: Seedling and sapling density/ha in *Q.semecarpifolia-P.cornuta* community

Species	Seedling	Sapling
Abies pindrow	10	0
Prunus cornuta	665	10
Quercus semecarpifolia	555	10
Syringa emodi	0	5
Total	**1320**	**25**

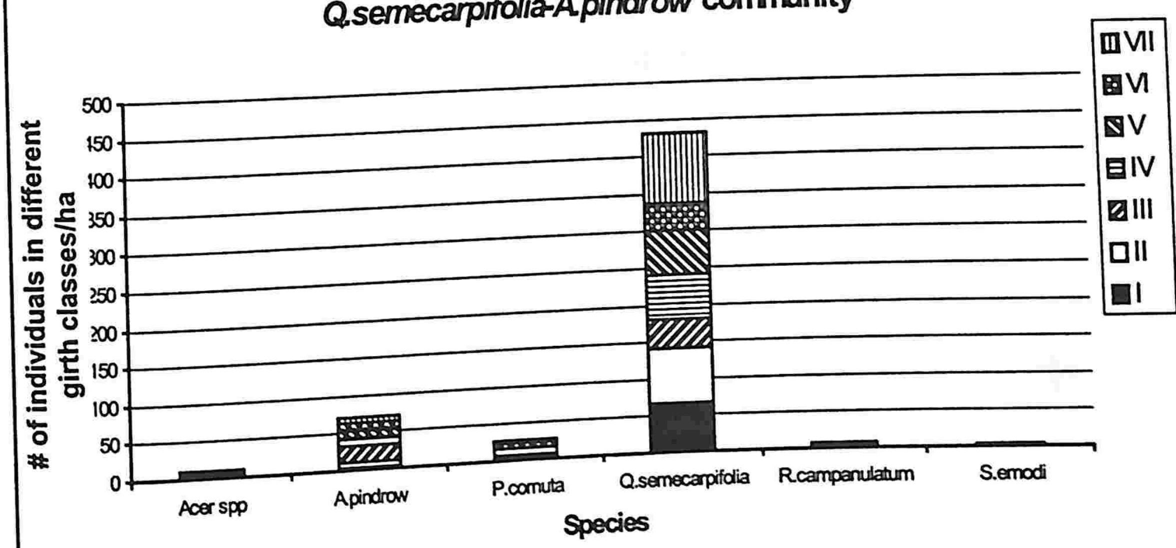


Community 4: Q.semecarpifolia-A.pindrow community: The community had maximum seedling density 2073.33/ha of which *Q.semecarpifolia* alone accounted for 1480/ha. The sapling density of the community was 60/ha (Table-5.48). Here also *Q.semecarpifolia* had the maximum contribution 26.67/ha. The population structure of tree species (Figure-5.18) clearly reveals that majority of the individuals were in higher or medium girth class. The seedling and sapling diversity of the community was 0.88 and 1.36 respectively.

Table-5.48: Seedling and sapling density /ha in *Q.semecarpifolia-A.pindrow* community

Species	Seedling	Sapling
Abies pindrow	203.33	3.33
Prunus cornuta	303.33	16.66
Quercus semecarpifolia	1480	26.66
Rhododendron campanulatum	86.66	6.66
Syringa emodi	0	6.66
Total	**2073.33**	**60**

Figure-5.18: Population structure of tree species in *Q.semecarpifolia-A.pindrow* community



5.3.5 Correlation between plant species distribution and abiotic factors: CCA was used for vegetation ordination. It is a direct gradient analysis, which correlates the species directly with environmental variables (Ter Braak 1986).

The results of CCA are shown in Figure-5.19 and the summary in Table-5.49.

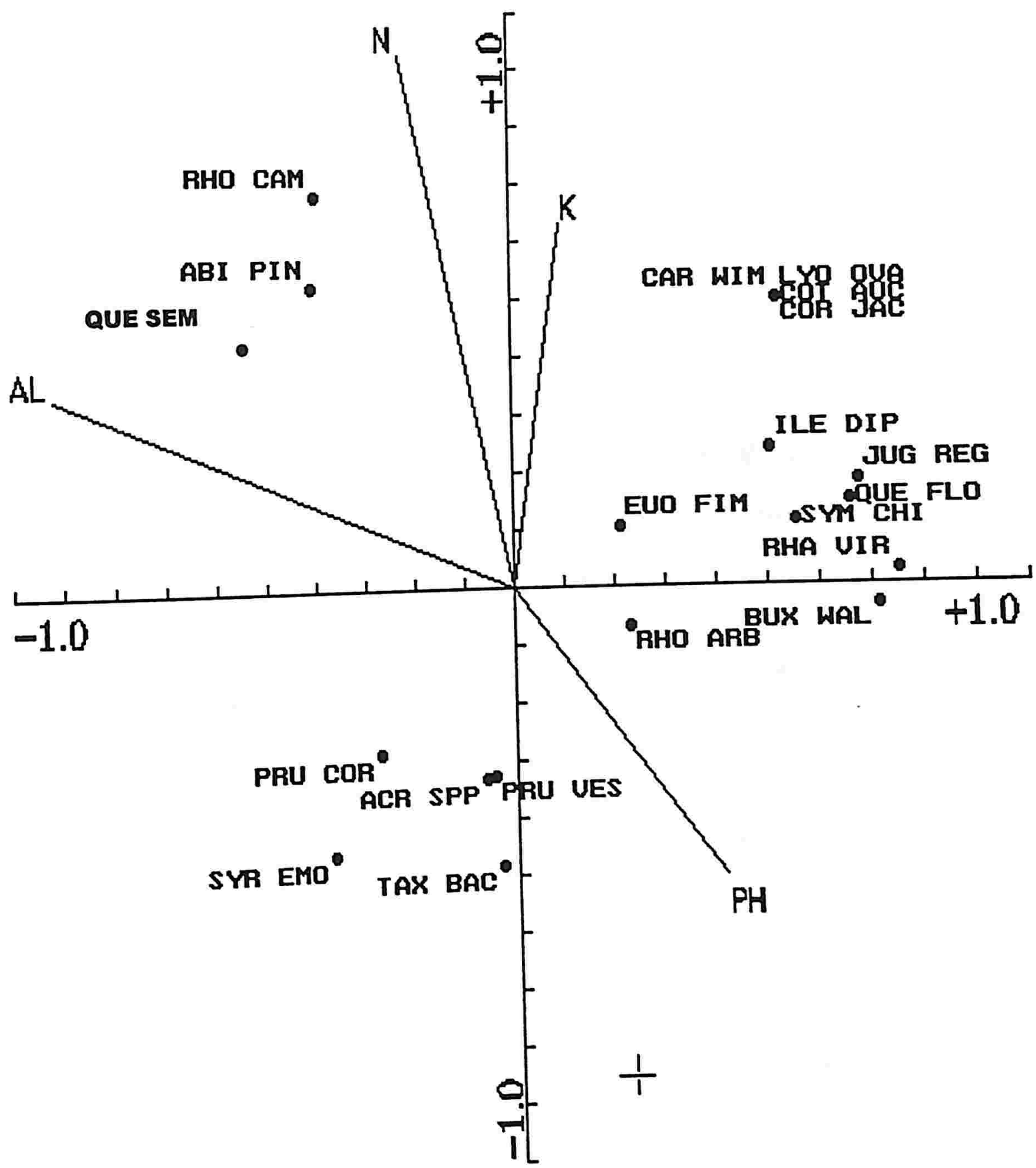
Table-5.49: Summary of CCA output

Parameters	Axis 1	Axis 2	Axis 3	Axis 4	
Eigen values	0.429	0-.273	0.196	0.098	
Species environment correlation	0.829	0.959	0.662	0.790	
Cumulative % variance					
a) of species data	21	34.3	43.8	48.6	
b) of species environment relation	40.7	66.6	85.1	94.4	
Sum of all unconstrained eigen values					2.048
Sum of all canonical eigen values					1.055
Interset correlations of environmental variables					
pH	-517	368	317	308	
Organic carbon	376	-828	-72	-116	
Nitrogen	382	-828	-67	-115	
Phosphorus	222	-709	100	-421	
Potassium	311	-507	225	323	
Altitude	163	-380	515	-288	

It can be seen that axis 1 of CCA is highly related to soil pH (interset correlation–517), axis 2 to available nitrogen, axis 3 with altitude and axis 4 with phosphorus. The figure-5.19 clearly indicates that pH and altitude were negatively correlated. In the figure arrows represent the environmental variables while points represent the species. The environmental variables with long arrows are closely related to species distribution in comparison to short arrows, which have less influence on species distribution.

Broad classification revealed that species such as *R.campanulatum, A.pindrow, Q.semecarpifolia, P.cornuta, S.emodi, T.baccata* were found at higher and medium altitudes (left hand side of diagram) while species such as *C.viminea, I.dipyrena, Q.floribunda, B.wallichiana, R.arboreum* were found at lower and mid-altitudes (right hand side of diagram). Species of *R.campanulatum, A.pindrow, Q.semecarpifolia* showed preference nitrogen rich areas (upper left of diagram) whereas *P.cornuta, Acer spp, S.emodi* were found in middle altitudes having low to medium pH (lower left of diagram). *C.viminea, L.ovalifolia, C.jacquemontii* showed preference for nitrogen and potassium rich sites (upper right side of diagram). Whereas *R.arboreum, B.wallichiana, R.virgatus* were found in high pH areas. Species such as *J.regia, Q.floribunda, S.chinensis* were found in middle elevation areas with high pH.

Figure-5.19: Ordination diagram showing species and environmental variables



5.4 Discussion

5.4.1: Vegetation structure and composition: There are various factors, which affect the vegetation structure and composition. Stability of the environment determines the climax vegetation whereas the edaphic factors bring about local variations in vegetation types, which are further attenuated by biotic factors (Dudgeon & Kenoyer 1925, Champion & Seth 1968).

In the DWS a total of ten communities were identified whereas in the BWS only four communities could be delineated based on TWINSPAN. The communities identified by TWINSPAN were distributed along an altitudinal gradient. The altitudinal gradient varied in the two study sites. In DWS (northern aspect) it ranged between 1700m-3200m while in BWS it was between 2400-3400m. In the BWS the communities were mainly dominated by *Q.semecarpifolia* and only a change in the codominant species led to the formation of new communities (Plate-5.1). On the other hand in the DWS, at the lower altitudes occurred the coniferous community *Cedrus-Pinus* that was a plantation. The under canopy was dominated by shrub species *Inula, Berberis* and *Zanthoxylum* as has also been reported by Gupta and Singh (1962) in the Tons valley of Garhwal. The density of the woody species was comparable comparable to that of Kumaun Himalaya (Saxena *et al.* 1985). The communities at still higher elevations located along the riverbanks and streams were dominated by deciduous species such as *Alnus, Swida* and *Toona*. The species of *Alnus* is an early colonizer and its symbiotic relationship with *Frankia* allows it occupy nutrient poor and freshly eroded sites usually along the banks of rivers and streams (Tiwari & Mishra 1995). The density of *Alnus* in it's community i.e *Toona-Alnus* and *Alnus-Litsea* was 123/ha and 100/ha which was low when compared to Alder forests of Kumaun Himalaya (Rikhari *et al* 1997). On the riverine areas species other than oaks were in dominance and although they are believed to be seral in nature their progression to climax does not take place (Mohan & Puri 1955). Oaks are regarded as the climax species in the Himalaya and with the rise in altitude one species of oak is replaced by another (Singh & Singh 1986). The oak species dominated the forests after 2000m although they were present after 1700m in *Rhododendron-Lyonia* community where *Q.leucotrichophora* (ban oak) was a co-dominant species. In slightly higher *Q. leucotrichophora*-

Q.floribunda community, *Q.leucotrichophora* had a density of 312/ha. Low-level oak species (*Q. leucotrichophora*) was not represented in any of the samples in BWS. Agricultural fields and habitation occupied the ecological zone of its occurrence (Plate-5.2). The density of *Q.floribunda* in its community was 90/ha, which was lower when compared to DWS. The mid-elevational oak *Q.floribunda* (moru oak) replaced ban oak at 2300m in DWS and was the dominant species in *Q.floribunda-Ilex* and *Q.floribunda-Abies* community where it had density values of 172/ha and 156/ha respectively. Pure stands of *Q.floribunda* seldom occur in Himalaya on account of favourable moisture conditions several broadleaf species such as *Aesculus, Ilex* and *Litsea* to grow in its association (Mohan & Puri 1955). At higher altitudes close to timberline *Q.semecarpifolia* (kharsu oak) replaced moru oak and had a density of 295/ha in DWS. In BWS *Q.semecarpifolia-A.pindrow* formed the timberline (Plate-5.3). The density of *Q.semecarpifolia* in the BWS (South facing) was higher compared to DWS (North facing) as has also been reported by Baduni and Sharma (1996).

The density of *Q.semecarpifolia* in the present study area was low when compared to that of Kumaun Himalaya (Adhikari *et al.* 1995). *Taxus* on the other hand had a density of 131/ha, which was higher when compared with results of Kumar *et al.* (1997) from Garhwal and Kalakoti *et al.* (1986) from Kumaun. In the present study area, the tree density increased with increase in altitude up to mid-elevation after which there was a decline in the tree density probably because of harsh climatic conditions at higher altitudes (Connell & Orias 1964). The shrub density also increased with altitude but decreased at the timberline where *V.cotinifolium* was the dominant species, which had higher diameter values (Plate-5.4). There was a very weak positive correlation (r=0.19) between tree and shrub density probably because of even distribution of *Sarcococca saligna*, an evergreen shrub with low diameter values. The basal area also increased with rise in the elevation and was highest in the timberline *Q.semecarpifolia-Taxus* community; in the DWS the reason for this could be the presence of large number of individuals in the higher girth class categories whereas in the BWS the highest basal area was in the mid elevational *Q.semecarpifolia-R.arboreum* community.

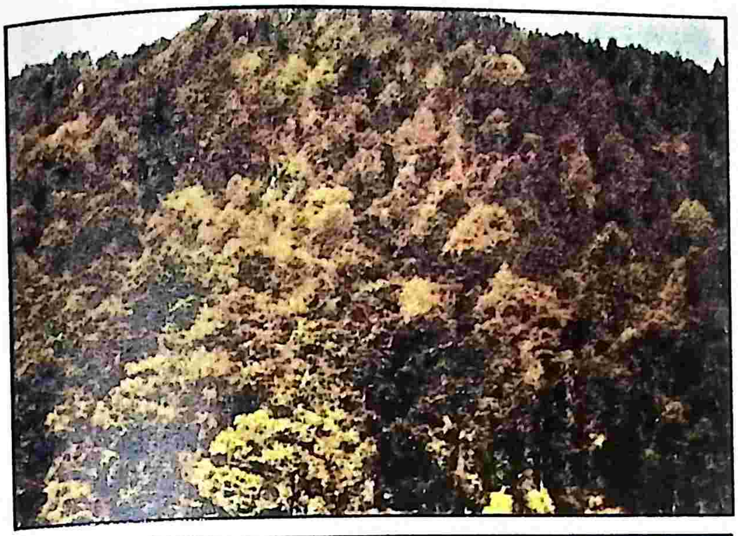


Plate-5.1: Brown oak dominated forests

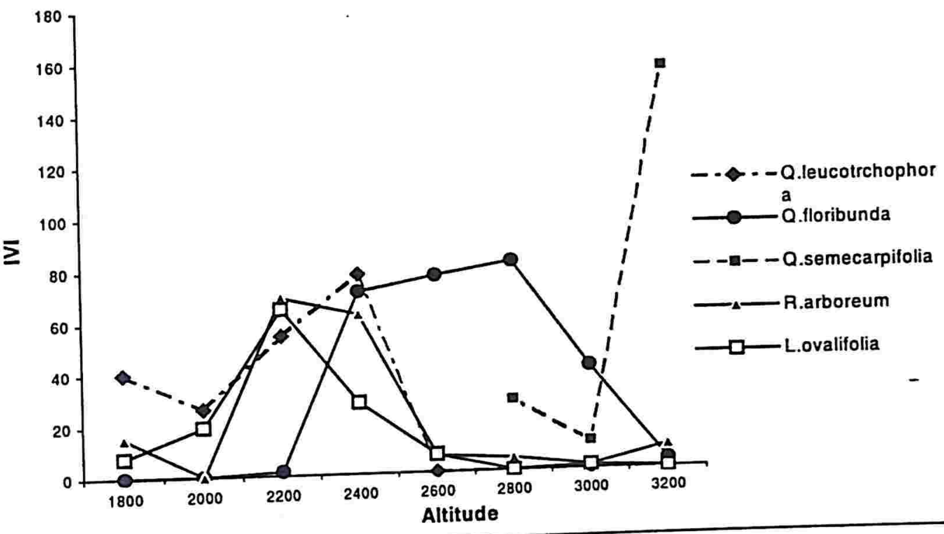
Plate-5.2: Agriculture fields on lower altitudes

Plate-5.3: Timberline communities

Plate-5.4: *Viburnum cotinifolium*-dominant shrub at higher altitudes

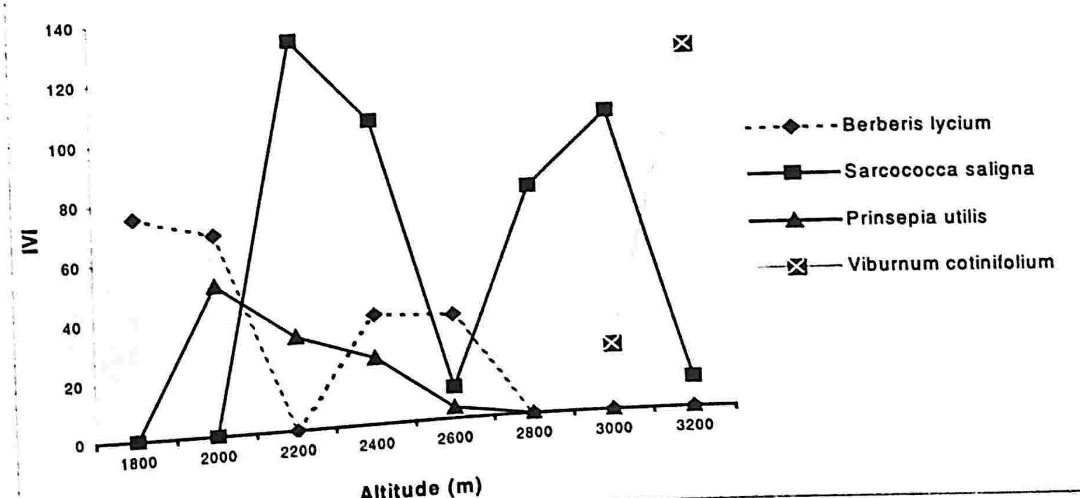
A general distribution of some common tree species along an altitudinal gradient is shown in Figures-5.20 At lower altitudes *Q.leucotrichophora* had the maximum IVI followed by *R. arboreum* and *L.ovalifolia.* The IVI of *Q. leucotrichophora* increases upto 2400 m after which there is a decline as the forests are dominated by *Q. floribunda.* The IVI of *Q.floribunda* increases upto 2800m after which it starts declining due to the dominance of *Q.semecarpifolia*, which forms the timberline in the area

Figure-5.20 : IVI of common tree species along an altitudinal gradient



In case of shrub species (Figure-5.21) it was found that the low altitude zones were mainly dominated by unpalatable thorny species such as *Berberis lycium* and *Prinsepia utilis* while the middle altitude zones were dominated by *Sarcococca saligna.* At higher altitudes *Viburnum cotînifolium* dominated the shrub strata.

Figure-5.21 : IVI of common shrub species along an altitudinal gradient



5.4.2 Species diversity: The overall tree diversity ranged from 0.51 to 2.32 in DWS while in BWS it ranged from 0.76 to 1.96. The shrub diversity in DWS ranged from 0.50 to 2.03 while in BWS it ranged from 0.52 to 1.27. The diversity was comparatively higher in DWS indicating better conservation status of forest. The beta diversity was also higher in DWS indicating that the rate of change of species along an environmental gradient was higher when compared to BWS. The species diversity increased up to the middle elevation after which there was a decline, where the unfavourable climatic conditions may have been the reason for low tree diversity (Simpson 1949, Connell & Orias 1964). However, the low tree diversity at higher elevations is compensated by high herbaceous diversity. The diversity values are comparable with those of Kumaun Himalaya (Singh *et al.* 1995, Saxena & Singh 1982) and other parts of Garhwal (Joshi and Tiwari 1990, Pangtey *et al.* 1987, Mehta *et al.* 1997, Rawat *et al.* 1999). The values fall within the range given by Risser & Rice (1971) for the temperate forests of the world. The values are low when compared to that of the tropical forests (Knight 1975, Pascal & Pelissier 1996) and upper montane *Quercus* forest of Costa Rica (Kappelle 1995). The diversity and the dominance were inversely related, as is usually the case where dominance shared by few species leads to reduction in diversity (Magurran 1988) (Figure-5.22). When diversity, dominance and density were analyzed for their interrelationship it was found that whereas diversity decreased with increase in tree density the concentration of dominance increased (Figure-5.23).

Figure-5.22: Relationship between concentration of dominance (Cd) and diversity (H')

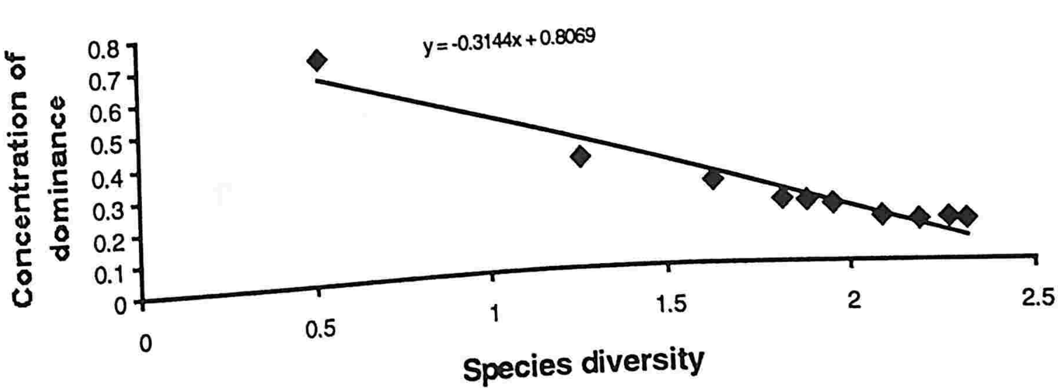
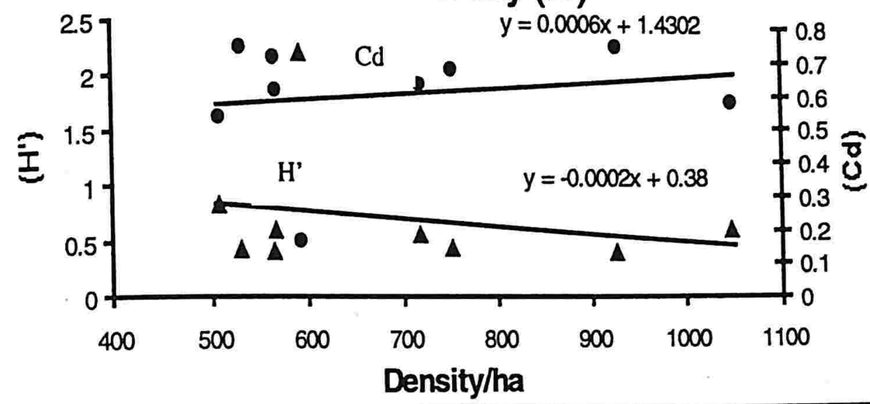


Figure-5.23: Relationship between density of trees/ha, concentration of dominance (Cd) and Diversity (H')



5.4.3 Similarity: The maximum similarity in DWS was found at the transitional zones. In the lower altitudes, species common to both the subtropical and temperate zones were present whereas in the higher altitudes species common to both the temperate and sub-alpine zones were present. In BWS the maximum similarity was found between *Q. semecarpfolia-R. arboreum* and *Q. semecarpifolia-P. cornuta* communities where species common to both the lower and higher zones were found.

The similarity between both the study sites (DWS & BWS) was calculated using both the qualitative and quantitative similarity indices. In case of qualitative measures the values obtained by Sorensen and Jacard's index were 0.54 and 0.37 respectively. As the qualitative indices use only the presence and absence data Sorensen's quantitative and Morista-Horn Index were also used. These measures gave a comparatively lower value i.e., 0.27 and 0.15 respectively indicating that the two areas varied much when analyzed based on the abundance value of each species.

5.4.4 Regeneration and population structure: In the DWS the number of seedlings and saplings increased towards the mid-elevation and were lower at both extremes. In the low altitude *Rhododendron-Lyonia* community *Q.leucotrichophora* was a co-dominant species, it appears that the repeated onslaught on this species might have led to its replacement by *Rhododendron* and *Lyonia*, which are usually the co-dominant species under

Q.leucotrichophora in other Himalayan regions (Singh & Singh 1995). Champion (1939), Upreti *et al.* (1985) have also pointed to the fact that the proportion of *Rhododendron* and *Lyonia* in the disturbed forests was very high when compared to the forests at undisturbed sites. These two species are unpalatable and the fuelwood obtained is of inferior quality hence they escape the onslaught when compared to *Q.leucotrichophora*, which is highly preferred for fuelwood and fodder. LeDuc & Havill (1998) have also reported the replacement of *Q. petraea* by its co-dominant species *Carpinus betulus* in England. Another striking feature of this community was virtually no differences between *Rhododendron* and *Lyonia* in terms of density and IVI values, while the former had a density of 179/ha the latter had 176/ha, similarly the IVI values of *Rhododendron* and *Lyonia* were 69.5 and 65.2 respectively. *Lyonia* also had higher number of individuals in the recruitment class and also a positive population structure so it is quite possible that *Lyonia* may replace *Rhododendron* in the coming time. On the other hand repeated lopping of *Q.leucotrichophora* individuals have converted them into scrubs thus limiting their growth as has also been pointed by Cottam (1949). The mid elevational community such as *Q.leucotrichophora-Q.floribunda* and *Q.floribunda-Ilex* had the maximum number of seedlings and saplings, as these are located in relatively undisturbed zone. The timberline community *Q.semecarpifolia-Taxus* seems to have the maximum difficulty in regeneration. Excessive grazing and trampling could be one of the major factors for its poor regeneration (Singh *et al.* 1997, Upreti *et al.* 1985).

In the BWS maximum seedlings and saplings were found in the timberline community. The sparse vegetation and the opening up of the canopy could have been the reason for their higher diversity and density as has also been pointed by Singh *et al.* (1997).

If instead the distribution of the dominant species for the entire altitudinal range is pooled for the DWS and BWS (Figures-5.24 and 5.25).

Figure-5.24: Girth class distribution of dominant tree species in DWS

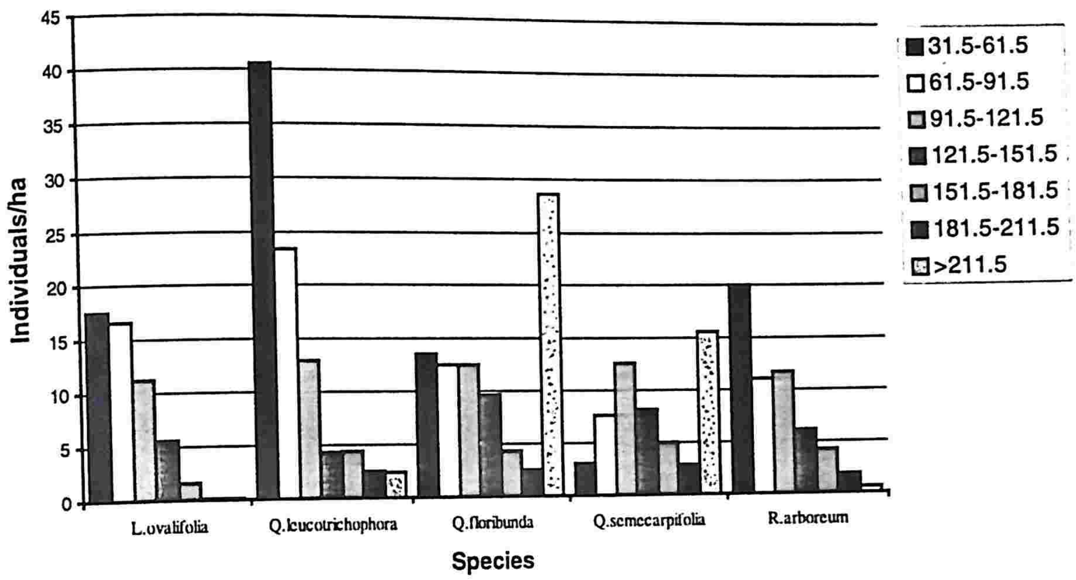
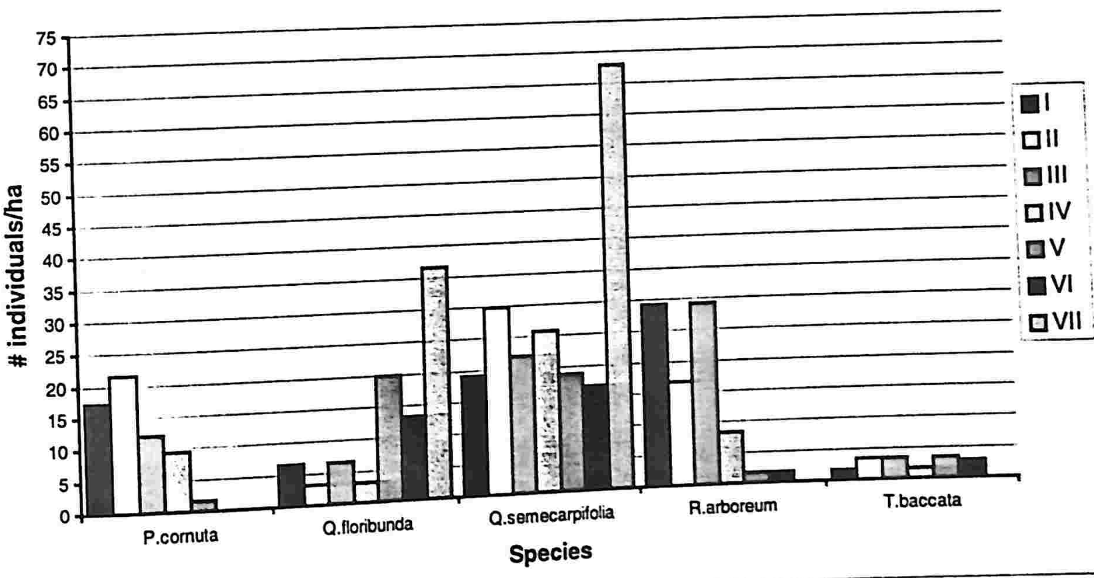


Figure-5.25 : Girth class distribution of dominanat tree species in BWS



We see that while *Q.leucotrichophora, L.ovalifolia* and *R.arboreum* have an ideal population structure *Q.floribunda* and *Q.semecarpifolia* show a negative trend. In case of *Q.floribunda* the high number of seedling and saplings indicate fresh recruitment but *Q.semecarpifolia* neither has a positive population structure nor has fresh recruitment and hence is the most affected species.

If the seedling and sapling data for different species is pooled along an altitudinal gradient between 1600-2000m, 2000-2400m, 2400-2800m and

2800-3200m (Figures-5.26 and 5.27) it is seen that maximum seedling and sapling occur in the middle elevation i.e. between 2000-2800m and is low at both the lower (1600-2000m) and higher (2800-3200m) elevation ranges. Temporary settlements and grazing might be effecting the regeneration at higher altitudes while the forests at lower altitudes, which are in the vicinity of villages human activity and grazing might be the reason for poor recruitment.

Figure-5.26: Seedling and Sapling density of tree species along an altitudinal gradient (DWS)

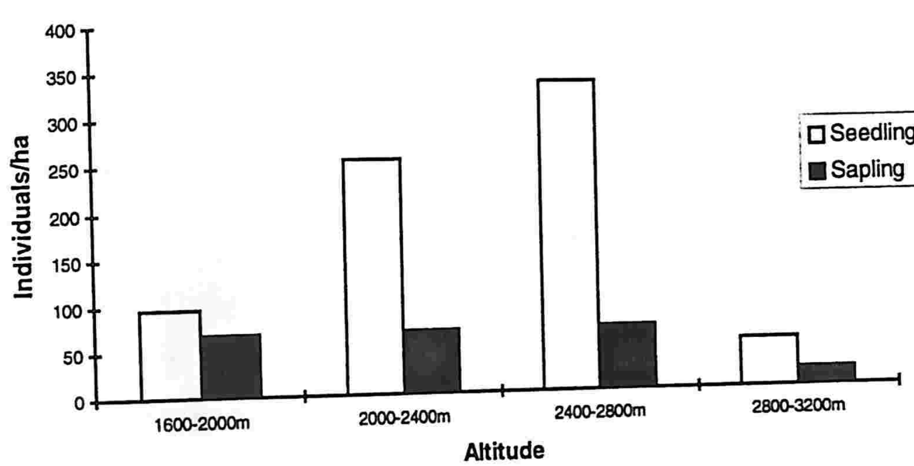
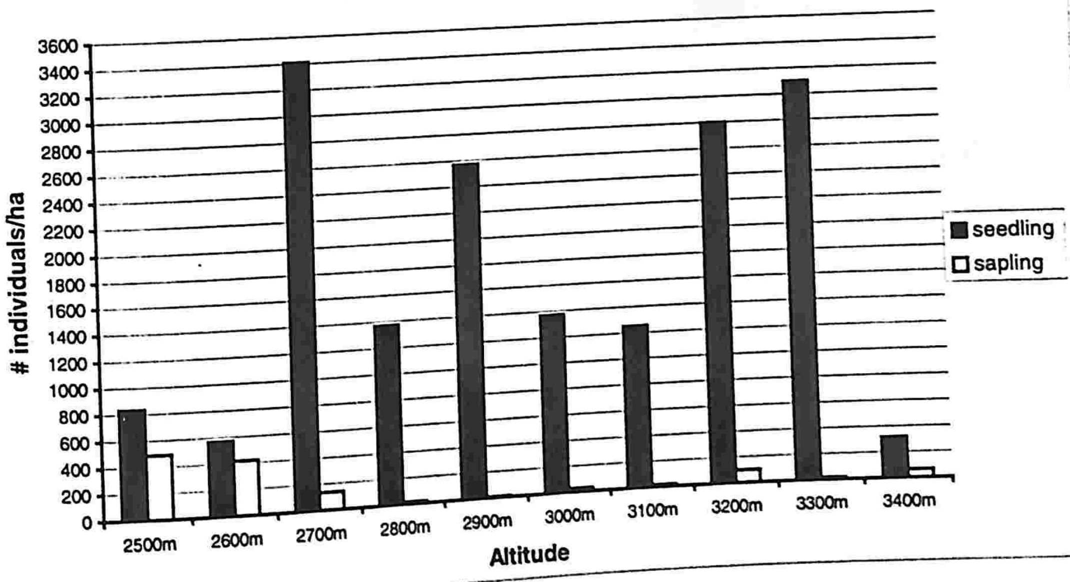


Figure-5.27 : Seedling and sapling density of tree species along an altitudinal gradient (BWS)



CHAPTER-6

Standing Biomass: Structure and Distribution

CHAPTER-6

Standing Biomass: Structure and Distribution

6.1 Introduction

Biomass may be defined as "the stored solar energy that can be converted into fuel or any other form of energy". It is expressed in terms of kg/m^2 or t/ha. Estimation of biomass (phyto/zoo) helps in understanding ecosystem functioning, setting the limits of harvest and in planning sustainable development of a region (Kaushal *et al.* 1996). Life in Indian villages is intricately associated with forests and farming. For one unit of biomass produced through farms as much as seven units of biomass are required from forest (Pandey and Singh 1984). The amount of biomass produced and the rate of forest productivity depends upon the interaction of biotic and abiotic factors. The increasing demands for energy from renewable resources have turned focus towards woody biomass and a large number of fast growing exotics are being raised to increase productivity (Negi and Tondon 1997). As elsewhere, the forests of the Himalaya are under tremendous pressure due to unsustainable harvest of forest biomass that has affected the productivity of the forests. This chapter deals with the standing forest biomass in a part of Bhagirathi catchment, Garhwal Himalaya. The objectives of the study were:

- To estimate the available above ground woody biomass in the various forest types
- To compare the status of above ground woody biomass in the two intensive study sites (ISS)

6.2 Methods

6.2.1 Field methods: For estimating the above ground biomass of tree species equations developed by Rana *et al.* (1989), Singh and Singh (1992) and Adhikari *et al.* (1995) for the areas which are geographically similar to the present study area were used (Table-6.1 and 6.2). These equations are simple, provide an alternate to the destructive sampling and give reliable estimate of the above ground biomass. The equations involve an establishment of a relationship between the biomass and some readily measured parameter such as circumference at breast height (CBH) or tree height (Clough and Scott 1989)

Table-6.1: Equations used for calculating aboveground tree biomass

Species	Equations (LnY = a+b Ln X)
Aesculus indica	Ln Y = 2.6572 + 0.9451 Ln x
Juglans regia	Ln Y = 2.193 + 0.9136 Ln x
Quercus floribunda	Ln Y = 2.8421 + 0.4997 Ln x
Litsea umbrosa	Ln Y = 0.3123 + 0.9505 Ln x
Symplocos chinensis	Ln Y = 0.2285 + 0.8750 Ln x
Ilex dipyrena	Ln Y = 0.7752 + 0.9060 Ln x
Abies pindrow	Ln Y = 2.0656 + 0.9781 Ln x
Quercus semecarpifolia	Ln Y = 1.5389 + 1.1086 Ln x
Lyonia ovalifolia	Ln Y = 0.2630 + 1.0551 Ln x
Rhododendron arboreum	Ln Y = 1.0617 + 0.9118 Ln x
Cedrus deodara	Ln Y = -5.49 + 2.51 Ln x

where LN= natural log, Y= biomass in kg, X= diameter in cm, a =intercept, b= slope

Table-6.2: Equations used (Ln Y= a + b Ln X) for calculating biomass of different components of certain preferred species

Species	Bole		Branch		Twig		Leaf	
	a	b	a	b	a	b	a	b
P.roxburghii	-6.42	2.60	-9.83	2.98	-9.34	2.63	-6.11	1.87
Q.leucotrichophora	-0.523	1.367	-0.718	1.302	-0.065	0.895	-0.976	0.854
Q.floribunda	2.0815	0.8858	1.4970	0.8350	1.6624	0.4244	1.3092	0.4997
Q.semecarpifolia	1.123	1.1217	-0.2312	1.1231	-0.8548	0.8673	-0.9425	0.8416
R.arboreum	0.2070	0.9638	-0.1113	0.8288	-0.4734	0.879	-1.5638	0.8044
Interspecies	-0.86	1.43	-0.91	1.33	-0.51	1.03	-1.11	1.04

Equations were developed for important shrub species using circumference at ground level (CGL, 10 cm above ground) and dry weight (Figures-6.1 to 6.11). These equations were later used to assess the biomass of shrubs for the second ISS (Plate-6.1).

Figure-6.2: Relationship between diameter and dry weight of *Berberis lycium*

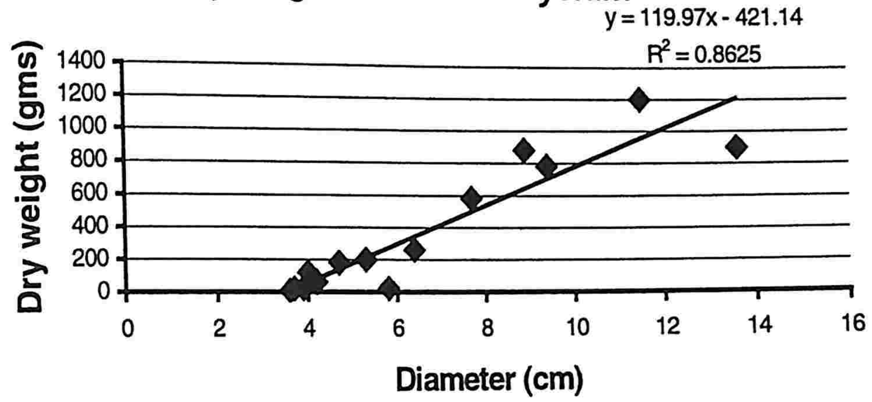


Figure-6.2: Relationship between diameter and dry weight of *Berberis lycium*

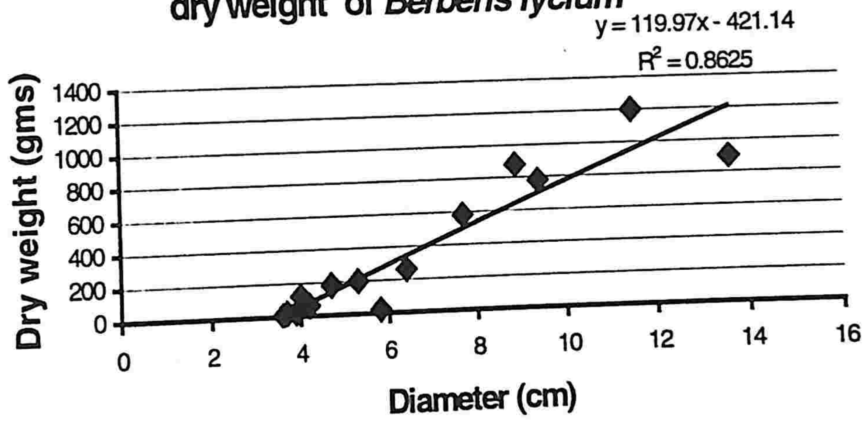


Figure-6.3: Relationship between diameter and dry weight of *Sarcococca saligna*

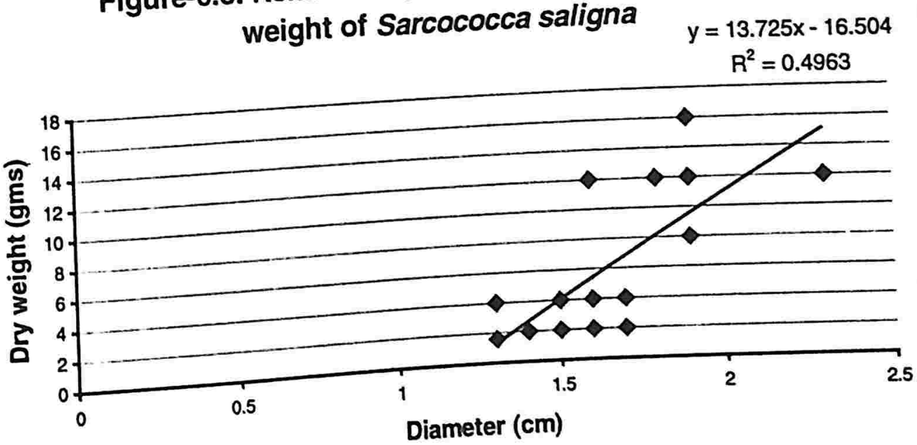


Figure-6.4: Relationship between diameter and dry weight of *Daphne papyracea*

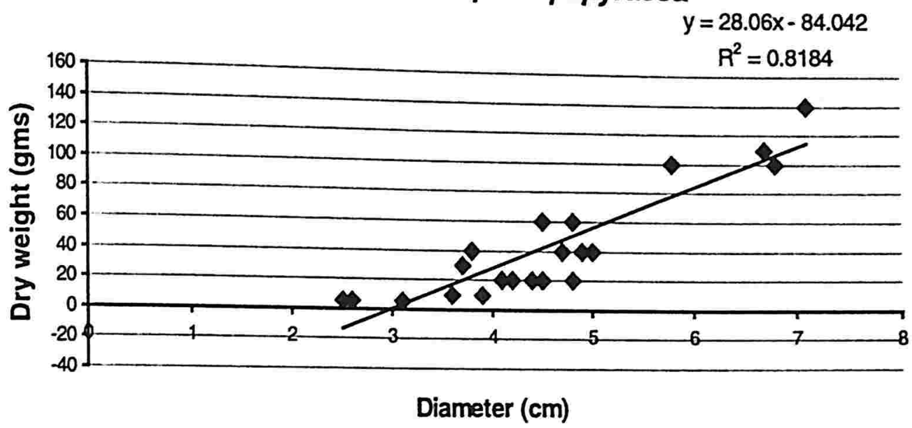


Figure-6.5: Relationship between diameter and dry weight of *Viburnum cotinifolium*

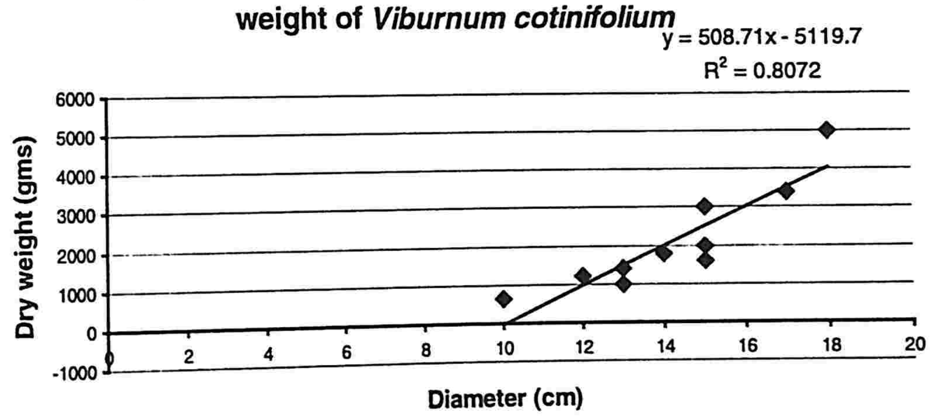


Figure-6.6: Relationship between diameter and dry weight of *Cotoneaster bacillaris*

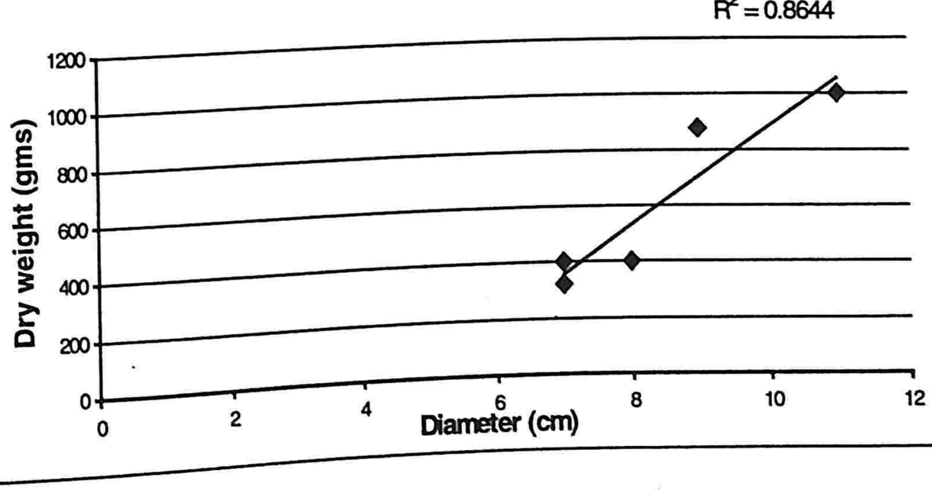


Figure-6.7: Relationship between diameter and dry weight of *Rosa brunonii*

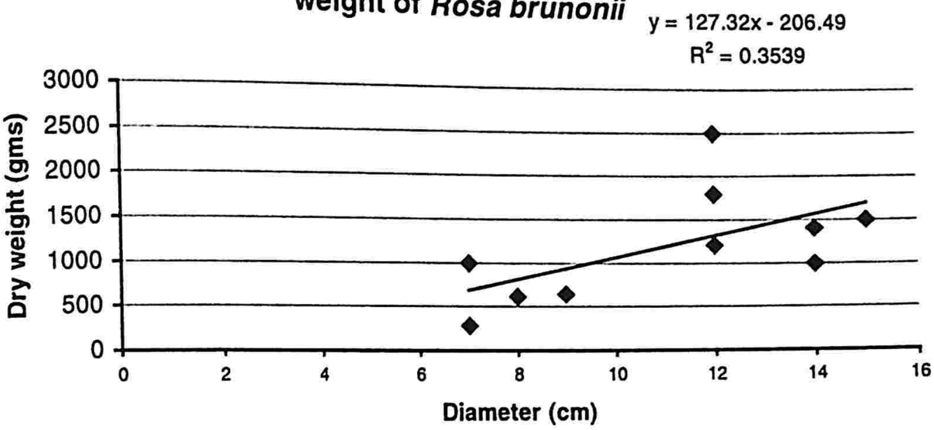


Figure-6.8: Relationship between diameter and dry weight of *Ribes glaciale*

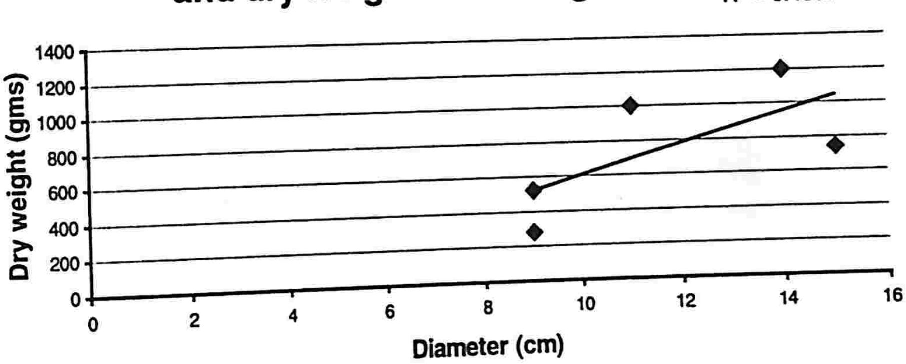


Figure-6.9: Relationship between diameter and dry weight of associate species

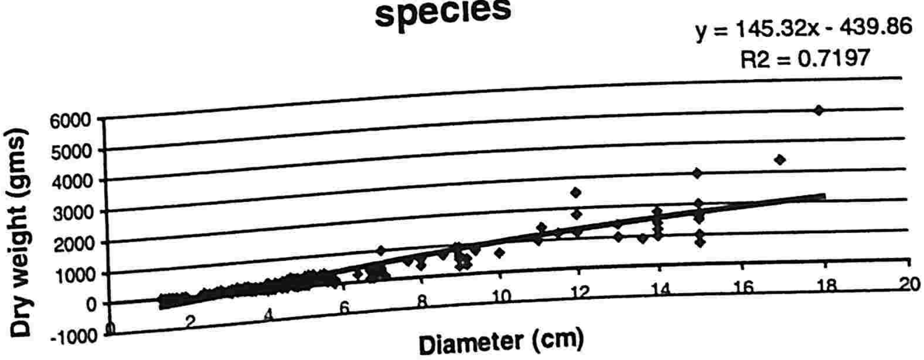


Figure-6.10: Relationship between diameter and dry weight of *Sinarundinaria falcata*

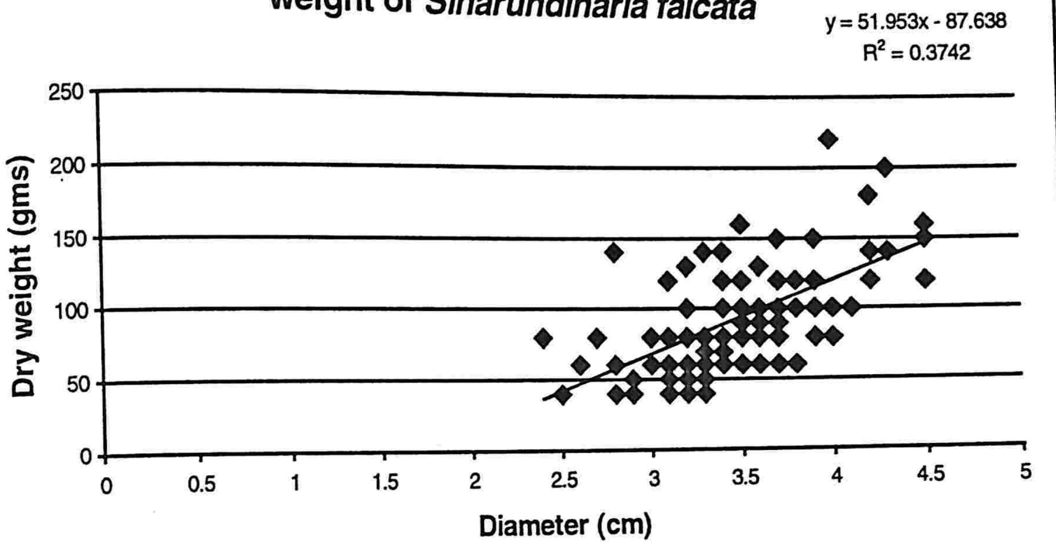
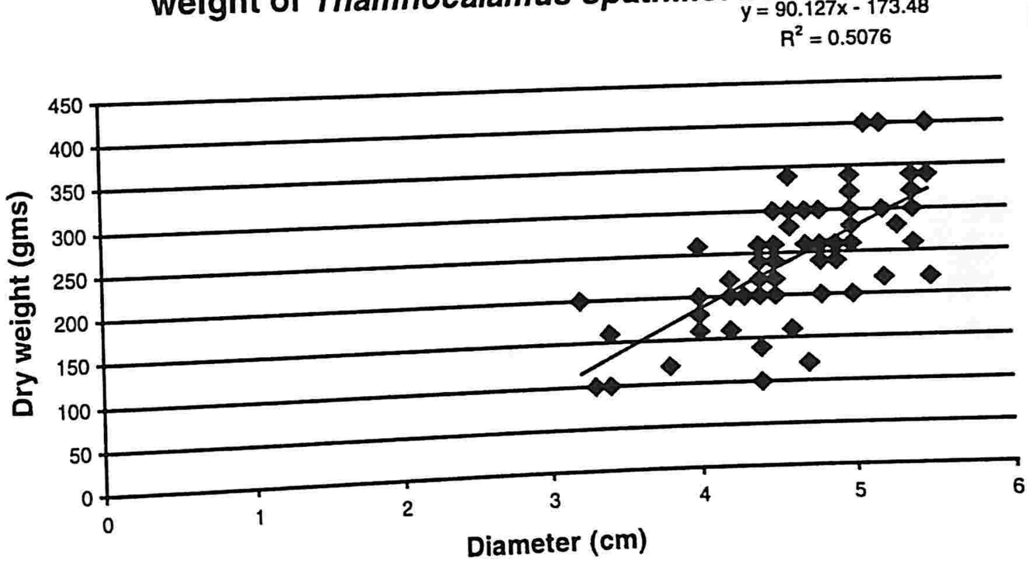


Figure- 6.11: Relationship between diameter and dry weight of *Thamnocalamus spathiflorus*



6.2.2 Analyses: Analyses were done using computer package Microsoft Excel. Total biomass was calculated by multiplying the biomass with the density of that particular species in each community. Correlation coefficient was calculated to see the relationship between tree and shrub biomass in each community. Significance test (t-test) was used to compare biomass at two ISS.

6.3 Results

6.3.1 Tree biomass distribution in Duggada Watershed (DWS): The results obtained indicate that the above ground tree biomass in DWS decreased with rise in altitude up-to 2300m. In the low elevation zone it was minimum in *Rhododendron-Lyonia* community after which there was an increase in biomass upto the timberline area where *Q.semecarpifolia-Taxus* had the maximum biomass (Table-6.3). In community, *Q.semecarpifolia-Taxus, Q.semecarpifolia* contributed the maximum (385.19 t/ha) to total biomass while *R. arboreum* contributed the least (1.89 t/ha). *R. arboreum* contributed maximum biomass in it's own community i.e. *Rhododendron-Lyonia.*

In the low altitude communities, species of *Cedrus*, *Pinus*, *Alnus*, *Pyrus*, *Carpinus*, *Q. leucotrichophora* and *Ulmus* contributed more to the total biomass. *Cedrus deodara* had maximum biomass in the low elevation community where it was planted. In other communities *Cedrus* contributed less than 8 t/ha where it grows naturally but was a co-dominant species. The contribution of *Pinus roxburghii* was maximum in the low elevation community (81.46 t/ha). The low level climax species of oak (*Q. leucotrichophora*) had the maximum biomass in *Q.leucotrichophora-Q. floribunda* community. The biomass in the mid-altitude communities was dominated by *Q.floribunda*, *Machilus*, *Aesculus* and *Acer*. The maximum biomass of mid-elevational climax species of oak (*Q. floribunda*) was in *Q. floribunda-Ilex* community while the minimum was in *Rhododendron-Lyonia* community. The biomass in the high altitude communities was dominated by *Q. semecarpifolia, Taxus, Abies* and *Aesculus. Taxus* was present in *Aesculus-Acer* and *Q.semecarpifolia-Taxus* communities where its biomass was 1.9 and 129.59 t/ha respectively.

Table-6.3: Above ground tree biomass (t/ha) in different communities of DWS

Species	*1	*2	*3	*4	*5	*6	*7	*8	*9	*10
Abies pindrow	A	A	A	A	A	A	55.48	146.24	118.78	98.43
Acer spp	A	A	A	A	A	A	5.91	44.84	85.32	16.77
Aesculus indica	A	A	A	A	A	A	31.21	53.67	210.62	9.44
Albizia julibrissin	A	2.63	A	10.04	0.19	A	A	A	A	A
Alnus nepalensis	A	97.9	119.14	13.62	12.86	5.59	A	A	A	A
Carpinus viminea	A	A	24.08	3.46	4.88	9.02	8.82	A	A	A
Cedrus deodara	288	A	A	A	5.04	8.39	A	A	A	A
Celtis australis	A	1.94	1.47	A	A	A	A	A	A	A
Euonymus tingens	A	A	A	A	A	A	5.78	A	A	A
Euonymus spp.	A	A	A	A	A	0.72	6.85	5.14	A	A
Fraxinus micrantha	2.15	A	2.01	13.31	0.29	A	A	A	A	A
Ficus palmata	A	A	A	A	0.07	A	A	A	A	A
Ilex dipyrena	A	A	A	A	A	0.62	7.73	9.89	0.12	A
Juglans regia	A	A	A	A	A	A	15.87	2.13	33.31	A
Litsea umbrosa	A	A	7.84	5.12	0.43		1.39	A	A	A
Lyonia ovalifolia	A	0.4	2.97	5.56	21.9	A	1.54	A	0.29	A
Machilus odoratissima	A	A	A	A	2.58	7.26	23.54	5.1	A	A
Pyrus pashia	A	5	7.04	26.07	8.57	A	1.23	A	A	A
Pinus roxburghii	81.46	58.8	A	A	80.79	A	A	A	A	A
Picea smithiana	A	A	A	A	A	A	0.83	A	20.1	A
Quercus floribunda	A	A	A	A	0.16	89.69	222.12	186.63	85.47	7.88

	A	A	35.26	18.76	8.38	124.18		A	A	A
Quercus leucotrichophora	A	A	A	A	A	A	A	110.39	18.67	385.2
Quercus semecarpifolia	A	A	A	A	A	A	A	1.67	0.45	1.89
Rhododendron arboreum	A	0.263	4.31	A	29.86	19.53	1.78	A	A	A
Rhus spp	A	A	A	3.16	A	A	1.3	6.84	1.16	A
Symplocos chinensis	A	A	A	1.78	0.24	0.24	0.46	A	A	A
Swida macrophylla	A	120.25	26.5	40.88	4.61	0.59	A	A	1.9	129.6
Taxus baccata	A	A	A	A	A	A	A	A	A	A
Toona sinensis	A	132.72	32.92	107.2	7.94	A	A	A	A	A
Ulmus wallichiana	A	0.5	A	7.13	1.24	A	A	A	A	A
TOTAL	371.83	312.13	263.55	256.1	190.04	265.86	391.84	572.54	576.18	649.21

* represents communities, A = absent

Table-6.4: Aboveground shrub biomass (kg/ha) in different communities of DWS

Species	*1	*2	*3	*4	*5	*6	*7	*8	*9	*10
Spipea canescens	5.37	17.34	A	1.9	59.8	120	A	A	A	A
Berberis spp.	3.2	37.7	A	17.35	24.24	A	A	A	A	A
Zanthoxylum armatum	4.6	A	A	A	A	A	A	A	A	A
Inula cappa	0.3	A	A	A	1.1	A	A	A	A	A
Cyathula tomentosa	6.9	A	A	A	A	A	A	A	A	A
Artemisia spp.	A	1.7	A	A	21.5	A	A	A	A	A
Caesalpinia decapetala	A	160.5	A	4.3	9.2	A	A	A	A	A
Debregeasia hypoleuca	A	46.9	20.86	2.26	16.21	A	A	A	A	A
Deutzia staminea	A	10.2	A	3.62	25.3	A	A	A	A	A
Prinsipea utilis	A	33.8	25.13	4.9	24.1	A	A	A	A	A
Rubus ellipticus	A	12.7	2.3	A	5.9	A	A	A	A	A
Rubus niveus	A	12.9	2.3	0.12	24.2	A	A	A	A	A
Urtica spp.	A	10.4	25.9	A	A	A	A	A	A	A
Daphne papyracea	A	A	3.14	A	12.86	6.4	4.5	5.3	1.4	0.3
Desmodium spp.	A	A	159.8	A	11.2	12.16	A	A	A	A
Elsholtzia spp.	A	A	103.7	120.4	21.25	A	149.1	54.3	278.4	45.8
Sarcococca saligna	A	A	10.1	45.79	8.7	10.5	7.1	19.6	7.9	12.4
Rosa spp.	A	A	A	A	25.9	A	45.5	A	A	A
Viburnum spp.	A	A	A	A	A	A	A	A	339.1	203.8
Rhus cotinus	A	A	A	A	3.4	A	A	A	A	A

* represents communities, A= Absent

6.3.2 Shrub biomass distribution in DWS: In case of shrub biomass, it was found that the minimum biomass was under the *Cedrus-Pinus* community. Although *Inula cappa* had the maximum IVI and density it had the least biomass (Table-6.4). The maximum shrub biomass was found in the *Aesculus-Acer* community where *Viburnum cotinifolium* had the maximum biomass and *Daphne* the minimum. A very weak positive correlation (r=0.1) was found between the tree and shrub biomass.

6.3.3 Tree biomass distribution in BWS: The results of BWS indicate that the minimum biomass was in the low altitude *Q. floribunda-B. wallichiana* community where *Q. floribunda* had the maximum biomass while *L. ovalifolia* had the minimum (Table-6.5). The maximum biomass was found in the timberline community where again *Q. semecarpifolia* contributed more than 50% to the overall biomass of the community. Unlike DWS where *Taxus* contributed the second highest biomass in the timberline area here, *A.pindrow* was the second most important contributor and *Taxus* was altogether absent. The least contributor to the biomass of the community was *Syringa emodi*. Except for the first community, *Q. semecarpifolia* was the major contributor in all the other three communities. *Acer* (46.04 t/ha) was the second most important contributor in *Q. semecarpifolia-R. arboreum* community while *P.cornuta* (27.56 t/ha) was in *Q. semecarpifolia-P. cornuta* community.

6.3.4 Shrub biomass distribution in BWS: In case of shrubs *Q. semecarpifolia-P. cornuta* community had the maximum biomass in which *Viburnum* was the major contributor. The minimum shrub biomass was found in the low altitude *Q. floribunda-B. wallichiana* community where *Berberis* was the principal contributor followed by *Prinsepia utilis* (Table-6.6). A negative correlation (r=-0.3) was found between tree and shrub biomass in BWS indicating that an increase in tree biomass led to subsequent decrease in shrub biomass.

Table-6.5: Aboveground tree biomass (t/ha) in different communities (BWS)

Species	*1	*2	*3	*4
Abies.pindrow	*A	A	13.84	41.06
Acer spp.	10.59	46.05	20.78	3.05

Aesculus indica	A	8.44	A	A
Buxus wallichiana	33.19	A	A	A
Carpinus viminea	0.92	A	A	A
Corylus jacquemontii	7.94	A	A	A
Euonymus spp.	1.2	A	1.52	A
Ilex dipyrena	5	1.28	A	A
Juglans regia	5.22	A	A	A
Lyonia ovalifolia	0.78	A	A	A
Prunus cornuta	A	10.75	27.56	7.03
Pyrus vestita	3.24	2.41	6	A
Quercus floribunda	85.76	A	A	A
Quercus semecarpifolia	12.27	202.51	118.85	289.58
Rhododendron arboreum	7.94	8.47	A	A
Rhododendron campanulatum	A	A	A	1.01
Symplocos chinensis	2.28	0.38	A	A
Syringa emodi	A	A	17.25	0.6
Taxus baccata	4.65	20.02	2.75	A
Total	180.98	300.31	208.55	342.32

*A=absent, , * represents communities

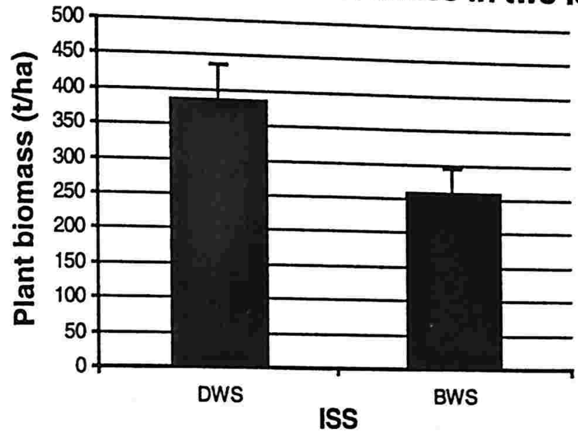
Table-6.6: Aboveground shrub biomass (kg/ha) in different communities (BWS)

Species	*1	*2	*3	*4
Berberis spp.	207	A	51.85	13
Cotoneaster bacillaris	32.7	2.6	A	9.1
Daphne papyracea	0.92	A	A	A
Prinsepia utilis	180.77	A	A	A
Rosa spp.	9.6	23.68	1.75	157
Viburnum spp.	A	1000	5400	24
Piptanthus nepalensis	A	A	A	0.05
Ribes spp.	A	A	A	23.4

* represents communities

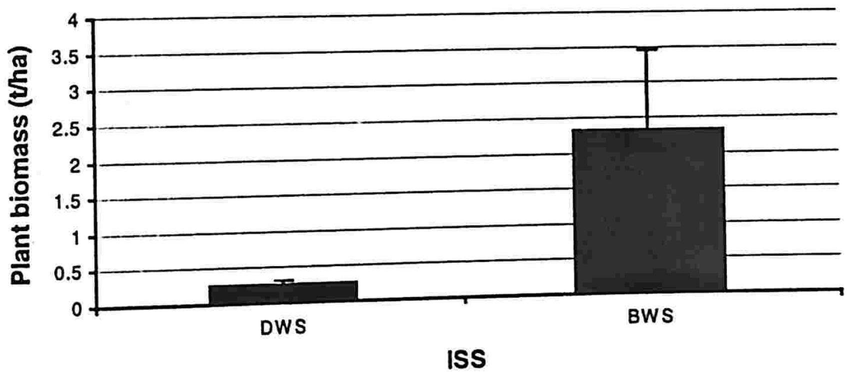
6.3.5 Comparative analyses of two ISS: A comparative account of DWS and BWS revealed that per hectare tree biomass was significantly different in two ISS ($P<0.05$, $t=0.03$). In DWS, the mean biomass was 384.93±50.62 t/ha while in BWS it was 258.04±37.94 t/ha (Figure-6.12).

Figure-6.12: Tree biomass in two ISS



However, a reverse trend was seen in the case of shrub biomass. Mean shrub biomass in BWS was 2.32±1.13 t/ha while in DWS it was 0.26±0.05 t/ha. The shrub biomass was not significantly different in the two ISS (Figure-6.13).

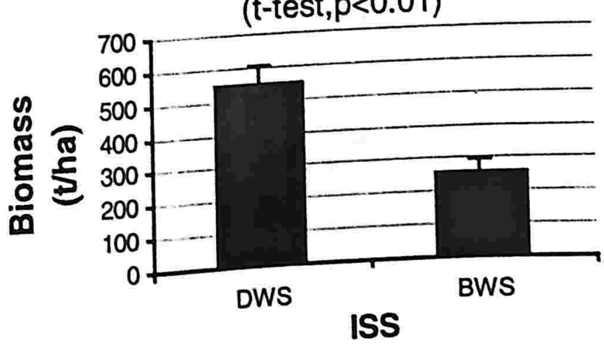
Figure-6.13: Shrub biomass in two ISS



The data for DWS was pooled to represent the altitudinal range as available in BWS. The mean biomass so obtained was also compared (Figure-6.14) and it was found that there was a significant difference in tree biomass ($P<0.01$, $t=0.001$), but for shrubs the difference was insignificant.

Figure-6.14: Tree biomass of similar altitudinal gradients in two ISS

(t-test,p<0.01)



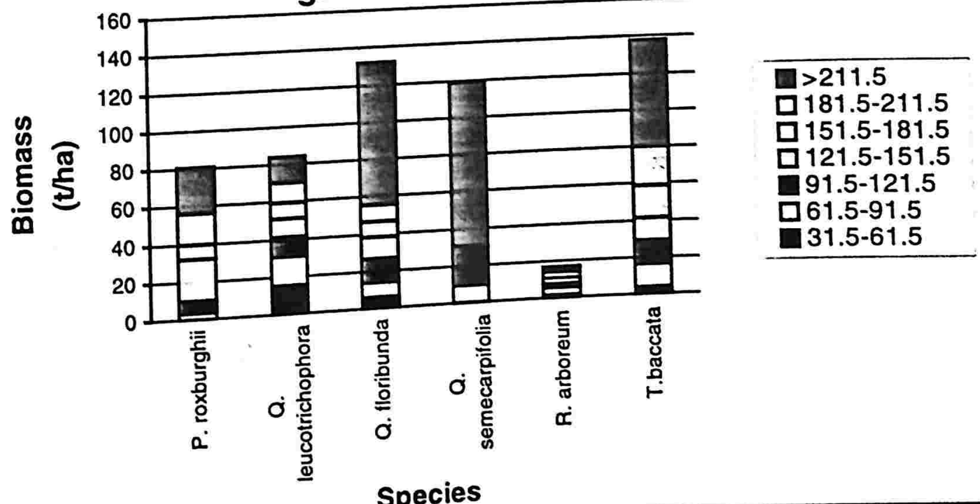
There was a significant difference in the biomass of preferred species in both the ISS (Table-6.7)

Table-6.7: Biomass (t/ha) of preferred species in DWS and BWS

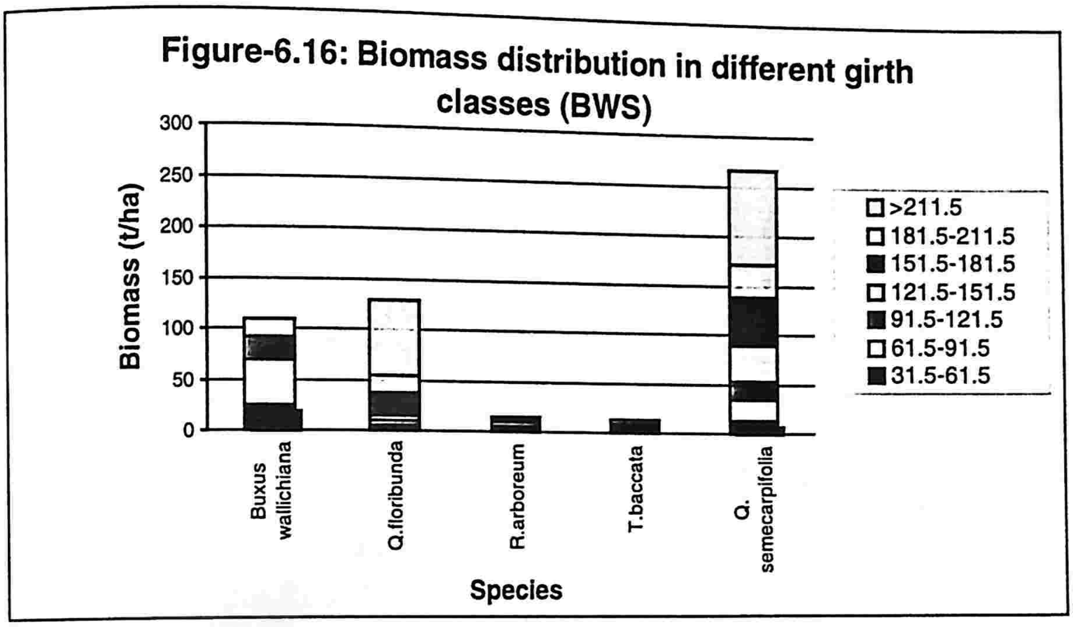
Species	DWS	BWS
Abies pindrow	104.73	27.45
Aesculus indica	76.23	8.44
Quercus floribunda	98.65	85.76
Quercus semecarpifolia	171.4	155.8
Rhododendron arboreum	7.47	8.2
Taxus baccata	65.75	9.14

6.3.6 Distribution of biomass in different girth classes: Certain highly preferred tree species were separately studied for biomass by dividing them into seven different girth classes so as to find which girth class contributed maximum towards biomass. For DWS few species such as *P.roxburghii, Q.leucotrichophora, Q. floribunda, Q. semecarpifolia, R. arboreum* and *T.baccata* were selected. In majority of species, it was found that while the higher girth classes contributed most towards the biomass the lower girth classes contributed the least. In case of *Q. leucotrichophora* a reverse trend was seen where the lower girth classes contributed the most and the higher girth classes the least (Figure-6.15).

Figure-6.15: Biomass distribution in different girth classes (DWS)



In case of BWS middle girth classes contributed the most towards the biomass for *B.wallichiana* and *R.arboreum* while for *Q.floribunda, Q.semecarpifolia* and *T.baccata* the highest and the lowest girth classes contributed the most and the least towards biomass respectively (Figure-6.16).



The contribution of bole, branch, twig and foliage was also calculated. An interesting trend was obtained in case of *Q.floribunda* where with an increase in girth the contribution of foliage to the overall biomass surpassed that of twigs (Tables- 6. 8 & 6.9).

Table-6.8: Biomass (%) of different parts of a tree in DWS

Species	Bole	Branch	Twig	Foliage
Pinus roxburghii	75.3	18.2	4.04	2.43
Quercus leucotrichophora	48.6	28.17	20.9	2.3
Quercus floribunda	64.31	28.1	3.81	3.81
Quercus semecarpifolia	74.1	20.85	2.8	2.23
Rhododendron arboreum	56.61	20.48	18.1	4.82
Taxus baccata	53.97	30.68	9.76	5.57

Table-6.9: Biomass (%) of different parts of a tree in BWS

Species	Bole	Branch	Twig	Foliage
Buxus wallichiana	51.37	30.73	11.46	6.42
Quercus floribunda	64.24	27.55	4.03	4.17
Rhododendron arboreum	54.8	21.15	19.23	4.8
Taxus baccata	53.92	30.39	9.8	5.88
Quercus semecarpifolia	87.51	9.89	1.52	1.06

6.4 Discussion

The biomass estimates in the study have revealed that this area has a mean above ground biomass of 321.25 t/ha for trees and 1.29 t/ha for shrubs which is comparatively higher than the average estimates by Tiwari *et al.* (1985) for Garhwal Himalaya.The forests on the north slopes had higher standing above ground biomass than those of the forests on the southern slopes. The warmer south facing slopes are more inhabited by the local people and hence the forests are relatively more degraded. The opening up of the forest canopy has led to the coming up of secondary scrub (Plate-6.2), which accounts for the high shrub biomass in south facing slopes when compared to north facing slopes.

In both the ISS the maximum standing biomass of trees was found in the subalpine zone probably because of large number of mature trees with higher girth class still standing and contributing much to the biomass. The lowest altitude *Cedrus-Pinus* community, which had the dominance of coniferous species, had biomass comparable to the *Cedrus* stands of Himachal Pradesh (Sharma 1988). The biomass of the community was high when compared to the chirpine forests of Kumaun Himalaya (Chaturvedi & Singh 1982) and Shiwalik hills (Gupta & Bhardwaj 1993). The highest biomass occurred in oak dominated forests which is comparable with the results of Subedi & Shakya (1988) for Nepal where the tree biomass ranged between 332-462 t/ha between an elevational range of 2600-3260 m. The forests at higher altitudes had biomass equaling 500 t/ha, that is comparable to the results of Rana *et al.* (1989). The biomass of *Q. floribunda* in the present study was however low when compared to results of Rana *et al.* (1989) for Kumaun. The forests in Kumaun chiefly comprised of oaks such as *Q.floribunda, Q. lanuginosa* and *Q. leucotrichophora* whereas in the present study area although the forests had *Q. floribunda* in dominance the understorey was formed by *Machilus, Acer* and *Aesculus* species. The above ground tree biomass was higher than Oak-Pine forests at Brookhaven (64t/ha) where the forests were comparatively young (Whittaker & Woodwell 1969). The biomass was also higher than the rain forest communities in Mount Kinabalu, Borneo that occupied an altitudinal range between 650-

3080m, where the forests at lower altitudes were dominated by *Shorea spp.* and at higher altitudes by species of *Leptospermum, Syzygium* and *Tristaniopsis* (Aiba & Kitayama 1999). The biomass values are comaparble with the results of Busing (1998) for temperate forests of Great Smoky Mountains.

The analyses of the data from DWS revealed that the mid-altitude *Rhodedendron-Lyonia* community had the lowest standing above ground biomass. It is interesting as the forests at lower altitudes in the vicinity of villages had higher biomass compared to the *Rhodedendron-Lyonia* community. The reason for this could be the difference in the composition of forests. The lower altitude forests were mainly dominated by conifer species such as *Cedrus, Pinus* and broad-leaved species of *Alnus, Toona, Litsea, Lyonia* and *R.arboreum*. These species escape the pressure from humans as they are unpalatable by cattle, the fuelwood obtained is of inferior quality and also they have higher mean diameter. The communities 3, 4 & 5 in which *Q.leucotrichophora* was present, the biomass contributed by it was low. The higher girth class individuals contributed maximum towards biomass in majority of the species but in case of *Q.leucotrichophora* low girth individuals contributed the most. This species of oak is highly preferred by locals for fuelwood and fodder. Repeated lopping of trees (Plate-6.3, Q.*leucotrichophora*) in this belt has converted the forest into sparse woodland and scrub with low diameter values.

The biomass was higher in the mid-altitude range (Plate-6.4), as these forests were relatively undisturbed and dominated by mature individuals of climax oaks species.

In case of BWS the minimum biomass was in the lowest community where *Q. floribunda* and *B. wallichiana* were the dominant species which were heavily lopped. *Q.semecarpifolia-P.cornuta* community which occurred in the vicinity of temporary sub-alpine settlements also had low tree biomass but had the highest shrub biomass because of high density of inedible *Viburnum cotinifolium* shrub which also had higher girth when compared to other shrub species.

A comparative account of the bole, branch, twig and foliage revealed that while for *P. roxburghii* bole contributed more than 75% of the overall

Plate-6.1: Quantification of shrub biomass

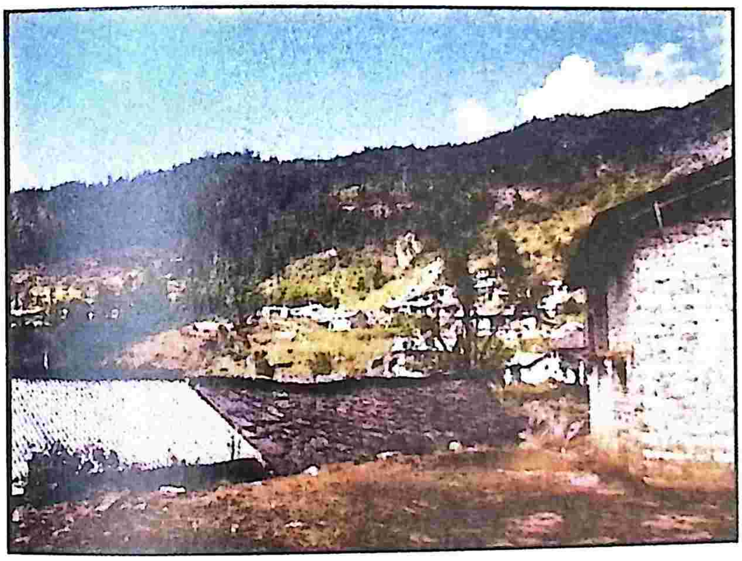


Plate-6.2: Degradation of forests near villages

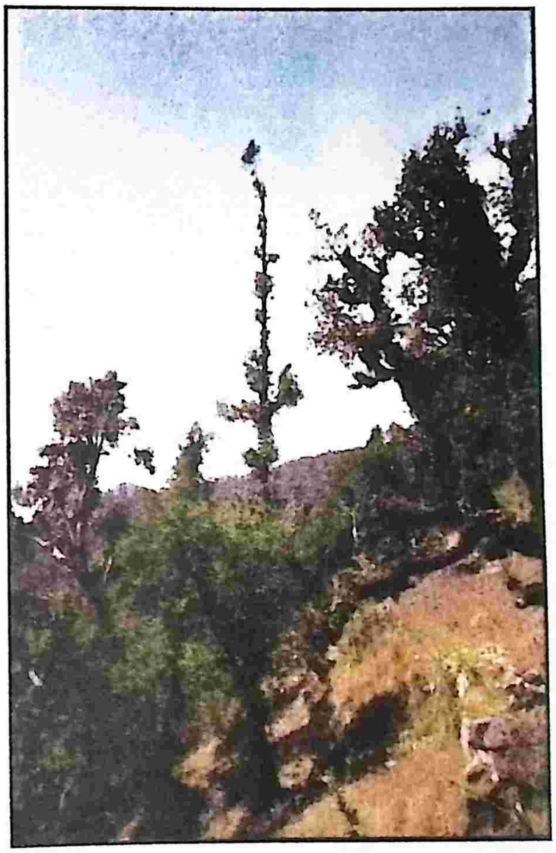
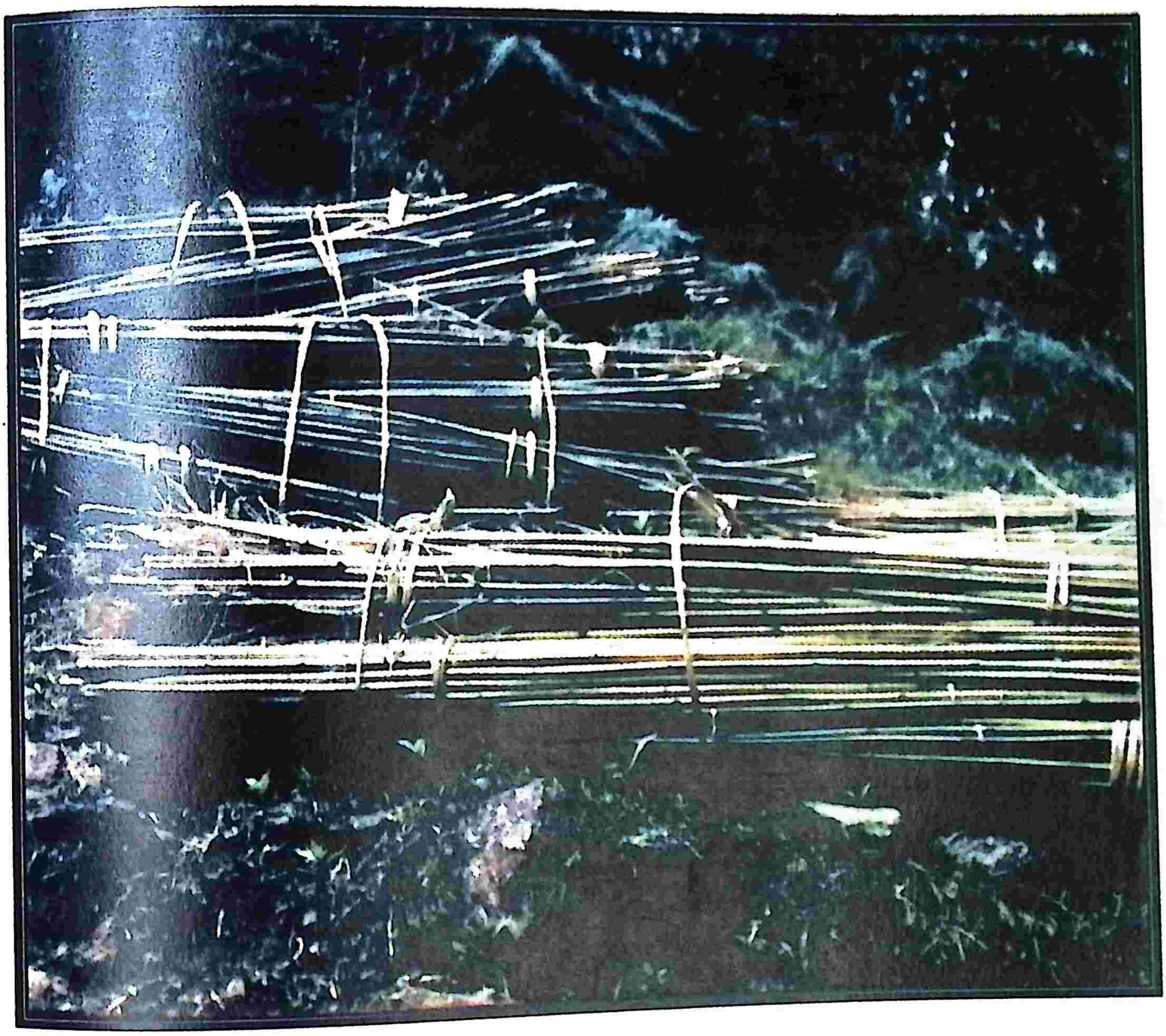


Plate-6.3: Repeated lopping influences available biomass

Plate-6.4: Relatively undisturbed forest

biomass in case of *Q. leucotrichophora* species it contributed about 50% (Table-6.8). The preference of this species for fuelwood and fodder therefore removes a considerable amount of biomass. In case of *P. roxburghii* less proportion is extracted as most of the biomass is contributed by the bole, also this species is sporadically lopped for fuelwood and is not lopped for fodder Therefore the conservation of climax oak species becomes more important for the sustainability of the mountain ecosystem.

CHAPTER-7



Ethnobotany of the Local People and the Status of Rare Plants

CHAPTER-7

Ethnobotany of the Local People and the Status of Rare and Threatened Plants

7.1 Introduction

The uses of plant species for food, medicine, fuel, timber and various other purposes by our ancestors has been well documented in our ancient literature e.g., Tulsidas 1631 (Samvat), Sensarma (1989). Of the total estimated 2,50,000 plant species in the world nearly 3,000 are exploited for food yet only 15-20 have become crops of major economic importance (Ford-Lloyd & Jackson 1986). The number of these food plants still remains more or less the same that was discovered by our forefathers through experience (Prescott-Allen & Prescott-Allen 1990). Ayurveda is another very good example of their knowledge regarding use of plants in medical science. It is this knowledge which has led to the discovery of many important drugs of modern era (e.g., Reserpine from *Rauvolfia serpentina*, Qunine from *Chincona pubescens*). Recent discovery of *Trichopus zelaynicus* by scientists of Tropical Botanic Garden and Research Institute (TBGRI) is another example of harvesting and promoting the traditional knowledge of tribals (Sharma 1996). Besides food and medicine, primitive man also depended on other natural resources for various items of the daily use. Conservation of these natural resources was a part of human culture and these formed life support system for them. However, with increasing modernization this culture and traditional knowledge has declined in many parts of the world (Bates 1985, Morardini 1996, Frankel 1970, Bellon 1996). In Himalaya also, market oriented economy and changing landuse practices have affected the symbiotic relationship of man with nature, which in turn has led to the erosion of traditional knowledge (Agrawal 1997, Maikhuri *et al.* 1997).

In order to preserve and document the traditional knowledge on the plants and other natural resources the science of ethnobotany came into existence. The term "ethnobotany" was coined by Harshberger in 1895 for the "study of plants used by primitive and aboriginal people". Schultes (1962) interpreted ethnobotany as the "study of relationships which exists between primitive people and their plant environment". Presently ethnobotany is defined as "the study of total natural relationship of man with plants" (Jain & Mudgal 1999). In India studies on ethnobotany were initiated by Dr. E.K. Janki Ammal in 1954. However, organized studies on the subject are recent (Negi & Gupta 1987, Negi *et al.* 1993, Rana *et al.* 1996, Samant & Rawal 1996). Ethnobotany not only gives an idea of the richness of traditional knowledge but also provides clue to new or lesser-known sources of medicine, food, fibre and others. It provides basic material for experimental research in pharmacognosy and nutrition (Jain & Mudgal 1999).

Traditional knowledge and sustainable harvest of wild plant resources is one aspect, overexploitation and faulty landuse practices leading to local extinction of several taxa, the other, while it is important to document the ethnobotany of the local people, assessment of rapidly declining plant taxa also becomes imperative. Although, extinction of species is a natural phenomenon and paves way for the evolution of new species (Myers 1996), today extinctions are not natural rather they are largely anthropogenic (Landey 1998, Wilson 1989).

In the Western Himalaya recent changes in landuse practices, overexploitation and natural processes (e.g., landslides, avalanches, floods) have led to decline of several species, which have become locally rare and threatened. Increasing number of such species justifies a study on their status at regional and local levels. Although several authors have surveyed the rare and threatened species in Garhwal Himalaya (e.g., Aswal & Goel 1985, Biswas 1988, Dangwal *et al.* 1993, 1994, 1995, 1997, Gaur *et al.* 1993, 1994, Goel & Bhattacharya 1983, Gaur & Rajwani 1995, Hajra 1983, Joshi *et al.* 1993, Mudaiya *et al.* 1995, Uniyal & Malhotra 1984), but very few quantitative studies have been carried out in this region (cf., Kala 1998, Maikhuri *et al.* 1998). Quantitative study of these plants is very important for their long term monitoring, conservation and management (Jain & Sastry 1980, Palmer 1987).

This chapter deals with the traditional knowledge of local people on the use of plants, the influence of modernization on their traditional knowledge and distribution of rare and threatened plants in a part of Bhagirathi catchment.

The specific objectives of the study component were:

- Documentation of traditional uses of plants by the local people

To study the population of rare and threatened plants

7.2 Materials and Methods

7.2.1. Ethnobotanical surveys: The ethnobotanical surveys were mainly based on interviews, informal discussions and observations (Martin 1995). Data were collected on the species, plant parts used and their uses. The intensity of use was ranked into three categories (1 = low use, 2 = medium use and 3 = high use) following Prance *et al.* (1987) and Chazdon and Coe (1999). The uses of plants were divided into 8 categories viz., medicinal, subsidiary food, timber, fodder, fuel, oil, fibre and others. The category "others" include uses such as agricultural implements, decorative items, narcotics, dyes, household items and palnts of religious significance. The information, thus collected has been collated and documented in descriptive form. From the field observations and surveys it was found that bamboos (*Sinarundinaria falcata* and *Thamnocalamus spathiflorus*) were the most preferred species. Therefore, its availability in the forest was quantified using 10X10 m (n=10, per one hectare) quadrats. The biomass was calculated by harvest method.

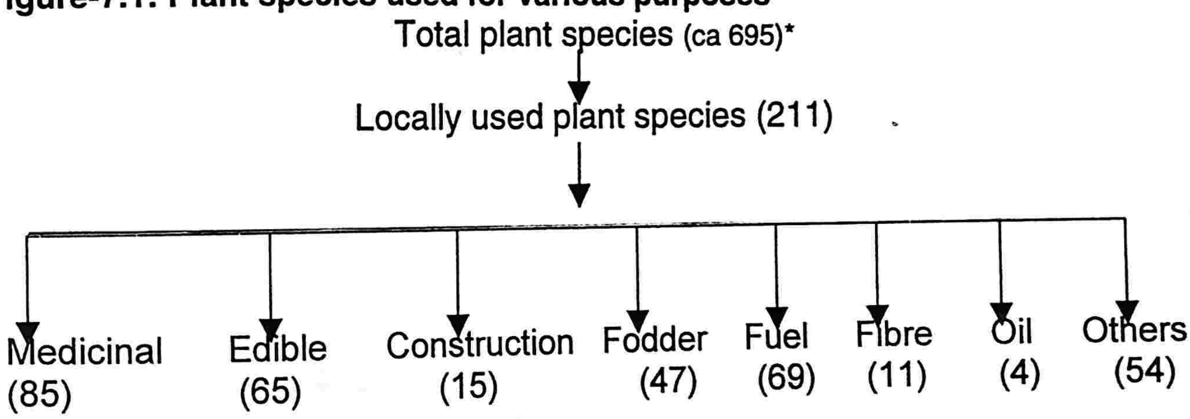
7.2.2. Quantitative analyses of rare and threatened plants: Rare and threatened plants of Bhagirathi catchment were searched from the available literature. The listing of the species was done to document the existing status of these plants. Quantitative analyses were carried out in the two ISS using quadrats 10X10 m (n=10) for trees, 5X5 m (n=10) for shrubs and 1X1m (n=10) for herbs (Chapter-4). Checklist of the plant species occurring in the area was prepared. Species under different families and genera were recorded. Density of these plants in two ISS was calculated and compared.

7.3 Results

A total of 695 plant species were recorded from the catchment area of river Bhagirathi (Appendix-7.1). Of which, locals used 211 plant species for various purposes (Appendix-7.2).

7.3.1 Local uses of wild plants: The maximum plant species were used for medicinal purposes followed by fuelwood and edible respectively (Figure-7.1). Species of oak were most preferred for fuel, fodder and miscellaneous uses while *Juglans regia, Cedrus deodara* and *Betula utilis* were preferred more for medicinal purposes even though these trees are known to have high timber value. It was also found that the bamboo species viz., *Sinarundinaria falcata* and *Thamnocalamus spathiflorus* were highly used by the locals (Plate-7.1).

Figure-7.1: Plant species used for various purposes



*Values in parentheses indicate number of species

Fuelwood: Various plant species were used as source of fuelwood. The most preferred tree species were of oaks. The reason for this could be the good heating and coal forming property of oaks (Singh 1982). Species such as *Quercus leucotrichophora, Alnus nepalensis, Rhododendron arboreum, Litsea umbrosa*, were more preferred for fuelwood in lower altitudes while at higher altitudes *Quercus semecarpifolia, Betula utilis* and *Rhododendron campanulatum* were preferred. The shrubs preferred for fuelwood at lower altitudes were species of *Berberis* and *Cotoneaster* while at higher altitudes species of *Viburnum* were more used. *Sinarundinaria falcata* and *Thamnocalamus spathiflorus* were highly used for igniting fire at lower and higher altitudes respectively. Species such as *Symplocos chinensis, Rhus punjabensis, Aesculus indica* and *Juglans regia* were also used for burning but were less preferred.

Fodder: 47 species were fed to livestock as foliage. Amongst tree species oaks were the most preferred choice because of their high nutrient content and palatability (Singh 1982) and therefore these species were exploited heavily (Plate-7.2). Other preferred fodder species were *Carpinus viminea, Debregeasia salicifolia, Ulmus wallichiana, Celtis australis. Acer* and *Desmodium* were also used as fodder especially in the temporary huts and high altitude villages. *Ilex dipyrena* and *Berberis* were mainly lopped by graziers for their sheep and goats. The bamboos (*Sinarundinaria falcata* and *Thamnocalamus spathiflorus*) were also extracted by the locals for their livestock.

Fibre: Locals used 11 different plant species for extracting fibre. *Gerardinia diversifolia, Cannabis sativa* and *Urtica parviflora* were used to make ropes. Their bark was peeled off after the plant had dried. On the other hand culms of *S.falcata* and *T.spathiflorus* provided raw material for many different articles of daily use in the households. Some of these articles such as baskets, mats, hats were prepared by the locals during their stay at temporary huts. The bamboo species and *Gerardinia diversifolia* were the most preferred while *Cannabis sativa* was least preferred. *Urtica parviflora* was moderately used.

Edible plants: Over 60 species were used for edible purposes. Some of them were preferred for vegetables while others were eaten raw as fruit. Roots and leaves of several other plants were also consumed as spices and condiments. These edible plants could be classified as follows (Table7.1)

Table-7.1: Edible plant species

Edible plants	Number of plants
Food	28
Fruit	30
Spices	4

<u>*Food:*</u> Local people used several plant species to supplement their food requirements. These wild plants also sustained them during periods of food scarcity. Some of the commonly used plant species in the villages were

Urtica parviflora, Paeonia emodi, Fagopyrum esculentum, Phytolacca acinosa and *Diplazium esculentum.* While *Allium, Capsella bursa-pastoris* and *Tetrastigma serrulatum* were consumed during their summer migration to alpine and sub-alpine meadows. The young leaves of *Paeonia emodi* and *Phytolacca* were consumed during months of April-May. *Phytolacca* was often seen growing in the kitchen gardens. On the other *Paeonia* and *Diplazium* were solely collected from the wild. Flower buds of *Bauhinia retusa* and *R.arboreum* were eaten as vegetable and raw (locally called *Athana*) respectively. Tender shoots of *S.falcata* and *T.spathiflorus* were also cooked. Tubers and roots of *Polygonatum verticillatum, Dioscorea deltoidea* and *Colocasia esculenta* were also eaten as vegetable. Fruits of *Rhus punjabensis, Viburnum mullaha, Prunus armeniaca, Ribes* and *Rosa brunonii* were used in preparing chutney and pickle. *Fagopyrum esculentum, Phytolacca acinosa* and *Allium* were the most used while *Colocasia esculenta, Capsella bursa-pastoris* were moderately used. Species of bamboo and *Polygonatum verticillatum* were rarely used.

Spices and condiments: To add flavour in various food items locally available *Allium blandum* and *Angelica glauca* were highly used by the locals. People, during their stay in their temporary huts in the alpine and sub-alpine meadows, collected these species for their own use. Besides these, leaves of *Cinnamomum tamala* and seeds of *Cannabis sativa* were also used for flavouring curries and gravy. *Angelica glauca* and *Cinnamomum tamala* were added to the tea for flavour and also to overcome effects of cold. *Cinnamomum tamala* was moderately used while *Cannabis sativa* was least preferred.

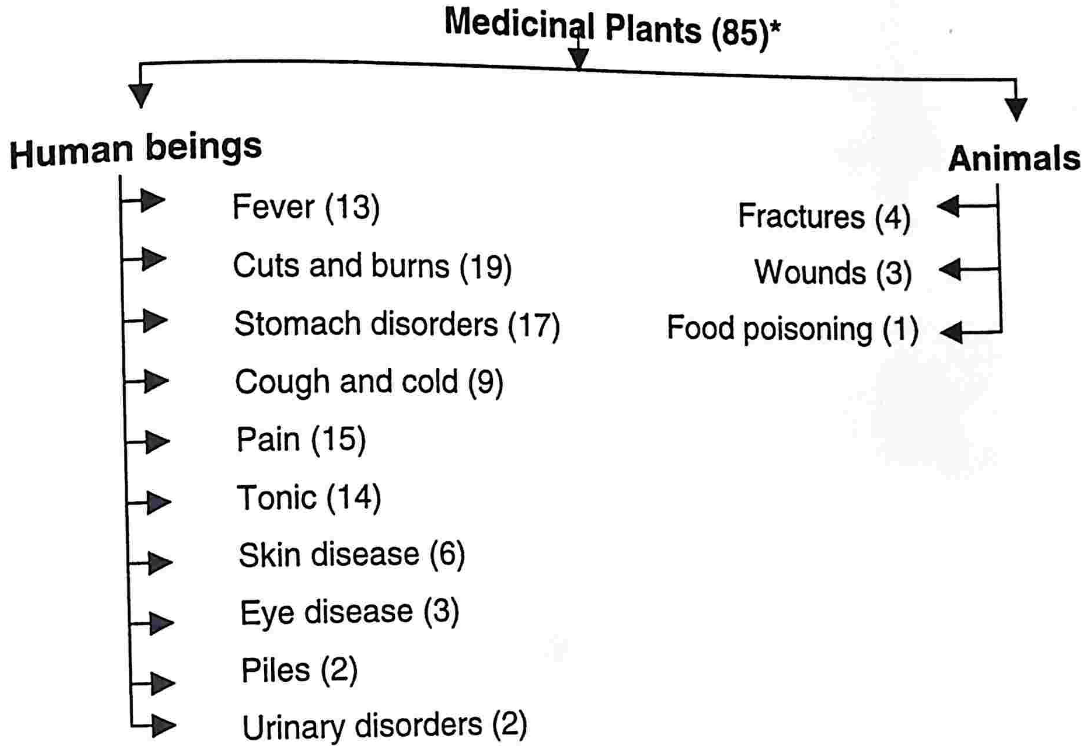
Fruits: Ripe fruits of *Berberis* spp., *Rubus* spp., *Ficus, Morus serrata, Pyracantha crenulata, Prunus armeniaca, Viburnum mullaha, Ribes, Pyrus pashia* and *Myrica esculenta* were eaten. *Pyrus pashia* is one of the favourite food plants of Himalayan Black Bear. Often Himalayan black bear raided villages for this particular fruit (Pers. Obv). *Prunus armeniaca* and *Myrica esculenta* were also sold in the local markets besides self consumption.

Timber: Wood forms an important construction material both for houses and for temporary huts. Permanent houses were chiefly made up of *P.roxburghii*, *P. wallichiana* and *C.deodara*. On the other hand temporary huts in the alpine and sub-alpine meadows were mainly constructed of *A.pindrow*, *T.baccata* and *Q.semecarpifolia* (Plate-7.4). The roofs of these huts were thatched with *Chrysopogon gryllus* and *T.spathiflorus*. Their storerooms known as "*kothars*" were totally made up of *C.deodara* as it is supposed to be highly durable and pest resistant. Amongst oak species Q.*semecarpifolia* was the most preferred followed by *Q.leucotrichophora* and *Q.floribunda*.

Oilseeds: Local people collect seeds of several wild species to extract oil. Some of the oil yielding species were *Prinsepia utilis*, *Prunus cerasoides*, *Prunus cornuta*, *Juglans regia* and *Daphne papyracea*. Of the five oil yielding species three belonged to the family Rosaceae and were used for edible purpose while seeds of *D. papyracea* yielded oil of medicinal importance. The villagers consume the ripe fruits of *P. cerasoides* and *P. comuta* and collect their seeds, which are dried in the sun to extract oil. This oil is used for cooking. Seeds of *P. utilis* are separated after washing off the juicy pulp under water. Seeds are then grinded to extract oil, which is used for cooking after mixing with other edible oils.

Medicinal plants: The Himalayan region is said to be a repository of an array of wild medicinal plants. Local people in the present study area used commonly occurring plant species to cure various ailments. Eighty five plant species were used to cure ailments of both animals and human beings (Figure-7.2).

Figure-7.2: Plants used for medicinal purposes



*Value in parentheses indicates number of species

Plants used for treatment of Animals: Eight plant species were used to treat different diseases of livestock. Of these four were used for healing bone fractures. Bark of *Boehmeria platyphylla*, *Debregeasia salicifolia*, *Ulmus wallichiana* and *Prunus cerasoides* were applied on fractured bones after making paste. Leaf and root extract of *Anaphalis triplinervis* (leaf extract) and *Rumex hastatus* (root extract) are applied to cure the laceration of foot (*Khurya*). Seeds of *Rhus punjabensis* were fed to combat poisoning caused due to intake of *R.arboreum* leaves. Roots of *Rheum australe* were applied on the cuts and wounds of animal (Table-7.2).

Plants used for treatment of human diseases: A total of 85 plant species were used in different ailments such as fever, cuts/burns, digestive disorders, Piles, cough and cold, aches and pains, skin diseases, urinary disorders, eye diseases and as tonics and blood purifiers (Table-7.3) The maximum plant species were used for cuts and burns followed by stomach disorders and fever. Amongst the various species *Angelica glauca*, *Swertia chirayita* and *Juglans regia* were frequently used by the villagers for various diseases. About 15 species such as *Rheum australe*, *Cedrus deodara* and *Adhatoda vasica* were moderately used by the villagers. The remaining species were used occasionally by the villagers.

(i) Fever: Of the 13 species used for curing fever, *Aconitum heterophyllum* and *S. chirayita* were most frequently used. Leaves of *Q.leucotrichophora* were used for curing fever locally called "Ghichak". Roots and rhizomes of majority of the species were used in the treatment while in case of *Zanthoxylum armatum* barks and seeds were used.

(ii) Cuts and Burns: Maximum plant species were used for cuts and burns. *Rheum australe* and *Eupatorium adenophorum* were the most preferred species. In most of the cases paste of leaves was applied on the affected part but in case of *R. australe* and *Dactylorhiza hatagirea* roots and tuber paste was used. Latex of *Vallaris solanacea* was also applied.

(iii) Stomach disorders: *Bergenia ciliata* and *Mentha longifolia* were the commonly used species for stomach disorders. The use of *B.utilis* was found to be a novelty. The bark of *B.utilis* was burned in a steel tumbler, which was then massaged over stomach. Roots and underground part of 10 species were used for this purpose. In addition, seeds, fruits and flowers of *Q.leucotrichophora, P.pashia* and *R.serecia* respectively were also used.

(iv) Cough and cold: Species such as *A. glauca*, *Adhatoda vasica* and *Picrorhiza kurrooa* were most frequently used for the treatment of cough and cold. Other species preferred include *P. emodi*, .*Nardostachys jatamansi* and *Barleria cristata*. In most of the cases root extract of the plant was consumed. In total 8 plant species were used to cure cough and cold.

(v) Ache and body Pain: *Swertia chirayata*, *Berginia ciliata* and *Rheum australe* were commonly used to get relief from body aches. On the hand, bark of *Z. armatum* and *J. regia* were used mainly for toothaches. In case of *Viola pilosa* and *Callicarpa macrophylla* leaves and fruits respectively were used while oil of *C.deodara* and *D.papyracea* was used mainly for rheumatic pains.

(vi) Tonic and blood purifiers: Of the total 85 species, 13 were used as tonic or blood purifier of which *P. kurrooa*, *S. chiryatia*, *N. jatamansi* and

Centella asiatica were most preferred. These species were also used as stimulant to rejuvenate the body system. In most of the cases root extract was used as a tonic while in case of *C. asiatica* and *Ichnocarpus frutescens* leaves were chewed.

(vii) Skin diseases: A total of 6 plant species were used for the treatment of skin diseases. In most of the cases whole plant was used but in case of *D.papyracea* leaf paste was applied. Fruits and seeds of *Melia azedarach* were also preferred. Although these species were common in the area, they were occasionally used by the locals.

(viii) Eye problems: Only 3 plant species were used for curing eye ailments. The root extracts of *Berberis lycium* and *Geranium wallichianum* and leaf extract of *Oxalis corniculata* were dropped into the eyes.

(ix) Piles: Two plant species were used for curing piles. The bark and root paste of *C. deodara* and *Thalictrum foliolosum* were externally applied over the affected part.

(x) Urinary diseases: Both the species of *Valeriana* i.e., *V. hardwickii* and *V. jatamansi* found in the study area were used for curing urinary disorders. Mostly decoction of roots was used.

Table-7.2: Medicinal uses of different plant species

Ailment	Species	Part(s) used
Human diseases		
Fever	*Aconitum heterophyllum*	Rts
	Acorus calamus	Rhz
	Ajuga bracteosa	Lvs
	Cynodon dactylon	Rts
	Desmodium gangeticum	Rts
	Geranium ocellatum	Plt
	Ichnocarpus frutescens	Lvs & Stm
	Picrorhiza kurrooa	Rts
	Quercus leucotrichophora	Lvs & Brk
	Swertia chirayita	Plt
	Thalictrum foliolosum	Rts
	Zanthoxylum armatum	Brk & sd
Cuts/Burns	*Anaphalis contorta*	Lvs
	Boenninghausenia albiflora	Lvs
	Colebrookea oppositifolia	Lvs
	Dactylorhiza hatagirea	Tub
	Desmodium triflorum	Lvs
	Eupatorium adenophorum	Lvs
	Pinus roxburghii	Rs
	Polygonatum verticillatum	Rts
	Rheum australe	Rhz
	Rumex hastatus	Lvs
	Tagetes minuta	Lvs
	Thlaspi arvense	Lvs
	Tridax procumbens	Plt
	Triumfetta rhomboidea	Rts
	Vallaris solanacea	Lx
Stomach disorders	*Aconitum violaceum*	Rts
	Asparagus filicinus	Rts
	Asparagus racemosus	Rts
	Aster thomsonii	Lvs
	Bergenia ciliata	Rhz
	Betula utilis	Brk
	Cissampelos pareira	Rts
	Crotalaria albida	Rts

	Cynoglossum glochidiatum	Rts
	Desmodium gangeticum	Rts
	Mentha longifolia	Lvs
	Picrorhiza kurrooa	Rts
	Polygonatum verticillatum	Rts
	Pyrus pashia	Frt
	Quercus leucotrichophora	Frt
	Rosa sericea	Flw
Cough/Cold	*Achyranthes aspera*	Lvs
	Adhatoda zeylanica	Rts & Lvs
	Angelica glauca	Rts
	Barleria cristata	Rts
	Cynoglossum lanceolatum	Plt
	Nardostachys jatamansi	Rts
	Picrorhiza kurrooa	Rts
	Paeonia emodi	Rts & Flw
	Viola biflora	Plt
Urinary disease	*Valeriana hardwickii*	Rts
	Valeriana jatamansi	Rts
Eye Disease	*Berberis lycium*	Rts
	Geranium wallichianum	Rts
	Oxalis corniculata	Lvs
Piles	*Cedrus deodara*	Brk
	Thalictrum foliolosum	Rts
Skin disease	*Daphne papyracea*	Lvs
	Galium aparine	Plt
	Geranium nepalense	Plt
	Kydia calycina	Brk
	Melia azdarach	Frt & Sd
	Vallaris solanacea	Lx
Aches/Pain	*Aconitum heterophyllum*	Rts
	Aconitum falconeri	Rts
	Artemisia vulgaris	Plt
	Bergenia ciliata	Rhz

	Cedrus deodara	Oil
	Callicarpa macrophylla	Frt
	Cuscuta reflexa	stm
	Daphne papyracea	Oil
	Delphinium denudatum	Rts
	Fagopyrum esculentum	Rts
	Juglans regia	Brk & Lvs
	Lindera pulcherrima	Sd
	Rheum australe	Rhz
	Swertia chirayita	Plt
	Viola pilosa	Lvs
	Zanthoxylum armatum	Brk
Tonic	*Astragalus candolleanus*	Rts
	Bergenia ciliata	Rhz
	Bauhinia retusa	Brk
	Boerhavia diffusa	RTs
	Centella asiatica	Lvs
	Clinopodium umbrosum	Plt
	Dactylorhiza hatagirea	Tub
	Ichnocarpus frutescens	Lvs
	Nardostachys jatamansi	Rhz
	Picrorhiza kurrooa	Rts
	Rhododendron arboreum	Flw
	Rubia manjith	Rts
	Swertia chirayita	Plt
	Woodfordia fruticosa	Lvs & Brk
Animal diseases		
Fractures	*Boehmeria platyphylla*	Brk
	Debregeasia salicifolia	Brk & Stm
	Ulmus wallichiana	Brk
	Prunus cerasoides	Brk
Foot diseases	*Anaphalis triplinervis*	Lvs
	Rumex nepalensis	Plt
Wound	*Rheum australe*	Plt
Poisoning	*Rhus punjabensis*	Sd

Rts: Root, Frt: Fruit, Brk: Bark, Plt: Plant, Lvs: Leaves, Sd: Seed, Flw: Flower, Lx: Lates,Stm: Stem, Rhz: RhizomeTub: Tuber,Rs: Resin

Other uses: Under this category plant species used for agricultural purposes, household items, decorative items, narcotics, dyes and religious beliefs were recorded. A total of 54 species had such miscellaneous uses, of which maximum number of species (19) were of sacred or religious importance (Table-7.3).

Table-7.3: Plants used for miscellaneous purposes

Other uses	Number of species
Agricultural	12
Household	13
Sacred	19
Decorative	5
Dyes	11
Narcotics	3

Agricultural uses: For making agricultural implements 12 species were used, of which all the three species of oak were used frequently. *P. pashia* was specifically made into shape of a harrow (locally called *sina*) to collect leaf litter from the forest. The handles of axes and sickle were made up of *Cotoneaster bacillaris*.

Decorative items: Cones of *C. deodara* and *P. roxburghii* were made into different artifacts and were often sold in the market and during local fairs.

Sacred and religious uses: Of the 19 plant species considered as religious in the area, *A. indica, Q. floribunda* and *T. baccata* were the most sacred trees species (Plate-7.3). These were used for making palanquins (*devta doli*) of local deity. Bark of *B. utilis* was used to make charms whereas stem of *Z.armatum* was kept in houses to ward off evil spirits. Flowers of *P.macrophylla, S. obvallata* and *R. arboreum* were offered in the temples. These flowers were specially collected for local festival known as "*Fulal*" in the month of August. *J. macrocephala, Juniperus, Tanacetum, S. laureola* and *Valeriana* were used as incense.

Narcotics: Three species were used as narcotics. Leaves of *Cannabis sativa* and *Verbascum thapsus* were consumed more frequently not only by locals but also by some *sadhus* and tourists. However in case of *Papaver somniferum* fruits were used.

Household uses: To keep curd, buttermilk and milk, pots and vases made up of *T. baccata* were used. On the other hand for making furniture wood of *T. sinensis*, *P. roxburghii*, *P. wallichiana* and *C. deodara* was preferred. Both the species of hill bamboo (*Sinarundinaria falcata* and *Thamnocalamus spathiflorus*) were used to make most of the daily need articles such as basket for collecting litter (*Swayata*) and manure (*Gheda*), basket for keeping chapatis and wool (*Kandi)*, mat (*Muraitii*), broom and winnow (*Supa*). Besides these items of daily needs bamboo culms were also collected to give support to Frenchbean seedlings. Quantification of bamboo culms needed for various items revealed that maximum number of culms were required for making mats (Table-7.4).

Table-7.4: Quantity of bamboo required for different articles

Articles	Vernacular name	Number of culms (*Ca)*
Chapati basket	Tokri	3
Manure basket	Swyata	11 large & 9 small
Basket	Gheda	11 large & 9 small (depends on size)
Basket for drying food grains	Daudka	12
Mat	Moreta	180
Rope	Daun	2-6 (depends on purpose)
Wool basket	Oonkandi	5
Broom	Jhadu	8-12 branches with leaves
Support for seedlings	Ringal	200-300 culms (field size 30X40m)

Apart from providing food, fodder, fuel, timber and various other products bamboo also plays an important role in ecology of the forest. The species are sensitive to disturbance and their gregarious undergrowth indicates areas of less disturbance (Upreti *et al.* 1985). Recently concern have been raised regarding their reducing number due to overexploitation which in turn has affected their distribution and biomass (Adkoli 1992, Johri & Prasad 1985, Rao *et al.* 1990), hence their distribution and biomass was assessed in the study area.

Two of the commonly occurring bamboos *S. falcata* and *T. spathiflorus* were found in the study area. *S. falcata* was found at lower altitudes between 1900 to 2450 m in DWS. The culm density ranged from 240 to 23030/ha. The biomass ranged from 613.3 kg/ha to 1114.11 kg/ha. The high altitude bamboo species i.e. *T. spathiflorus* was present after 2500m. The culm density of this species ranged between 780 to 14,200/ha whereas the biomass ranged between 7.98 kg/ha to 402.95 kg/ha (Table-7.5).

In case of BWS *S. falcata* was found restricted at 2400m where the culm density was 1320/ha and the aboveground biomass was 124.62 kg/ha. *T.spathiflorus* on the other hand was distributed between 2500m to 3200m. The culm density of the species varied between 80 to 8710/ha and the biomass between 14.96 kg/ha to 250.97 kg/ha (Table-7.6).

Table-7.5: Status of *S. falcata* and *T. spathiflorus* in DWS

		Sinarundinaria falcata		
Plots	**Altitude (m)**	**Slope (degrees)**	**Culms/ha**	**Biomass (kg/ha)**
1	2000	30	5760	332.78
2	2000	35	1400	96.91
3	2050	35	3040	239.53
4	2100	30	2800	193.82
5	2100	40	4700	106.1
6	2000	40	3360	209.72
7	2100	45	2660	106.19
8	2100	40	420	38.42
9	2030	30	240	16.61
10	1900	20	3100	189.65
11	2050	40	2200	175.14
12	2150	30	8200	613.33
13	1950	40	8010	466.14
14	2150	45	320	22.15
15	2230	40	2570	177.89
16	2000	20	3400	58.71
17	2100	30	520	33.92
18	2250	40	240	16.61
19	2050	30	4430	135.2
20	2200	40	23030	1114.11
21	2350	30	11410	448.48

22	2450	30	2700	186.89

		Thamnocalamus spathiflorus		
Plots	Altitude (m)	Slope (degrees)	Culms/ha	Biomass (kg/ha)
23	2500	40	4590	47.32
24	2450	20	8350	116.28
25	2500	30	3440	7.98
26	2550	30	6000	101.74
27	2600	40	14200	402.95
28	2600	20	780	15.52
29	2850	40	2640	201.99

Table-7.6: Status of *S. falcata* and *T. spathiflorus* in BWS

		Sinarundinaria falcata		
Plots	Altitude (m)	Slope (degrees)	Culms/ha	Biomass (kg/ha)
1	2400	30	1320	124.62

		Thamnocalamus spathiflorus		
Plots	Altitude (m)	Slope (degrees)	Culms/ha	Biomass (kg/ha)
2	2500	35	8710	2450.97
3	2600	40	80	14.96
4	3200	40	480	46.512

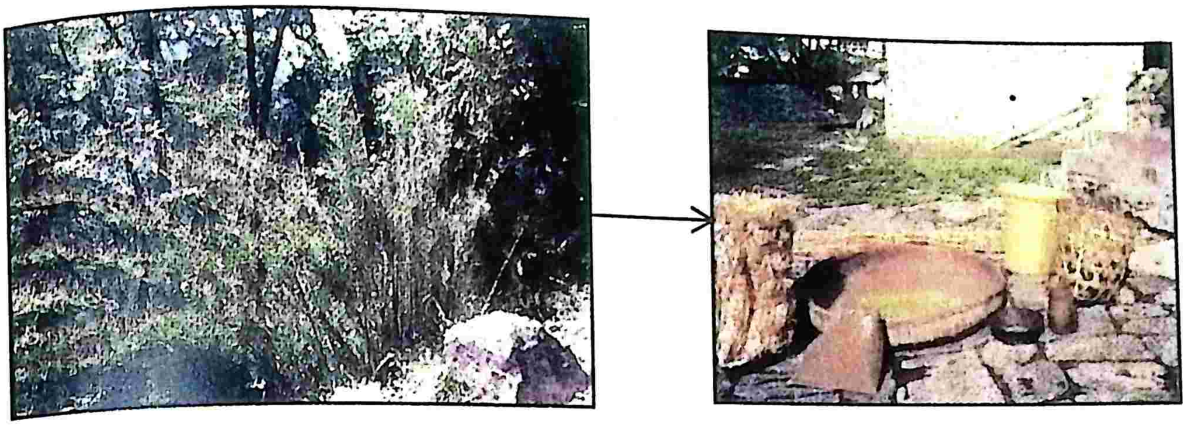


Plate-7.1: Bamboo and its products

Plate-7.2: Oak and its extraction for fodder

Plate-7.3: Horsechestnut and its use in "*Doli*"

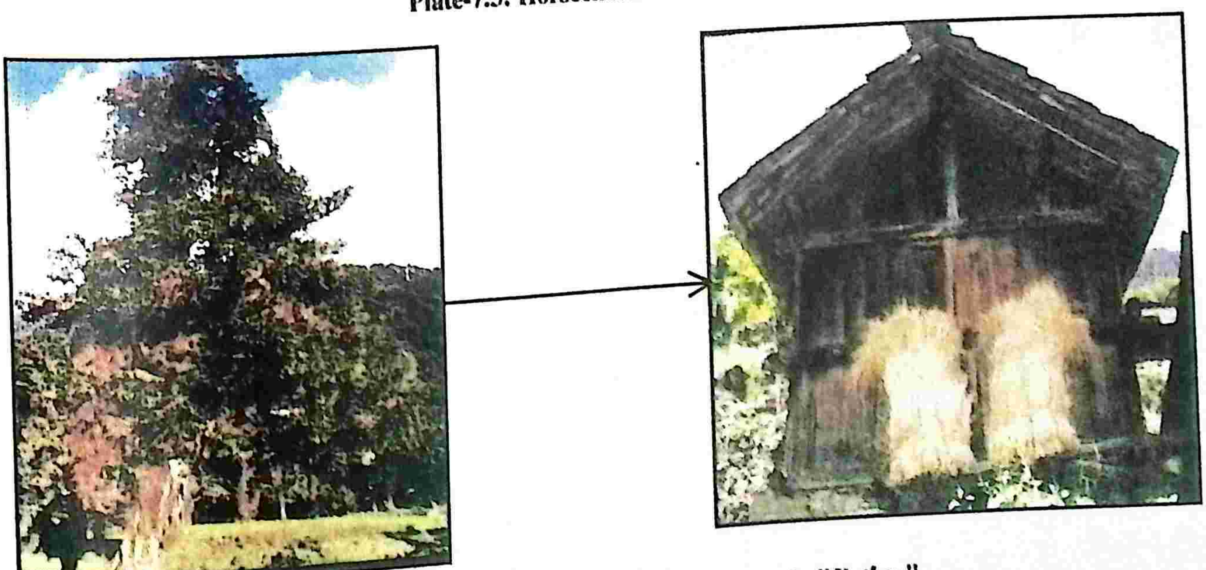


Plate-7.4: Himalayan Yew and its use in "*Kothar*"

7.3.2 Status of rare and threatened plants: Of the total recorded plant species, 66 species belonging to 20 families were listed under different legal conservation measures (Table-7.7).

Table-7.7: List of rare and threatened plants

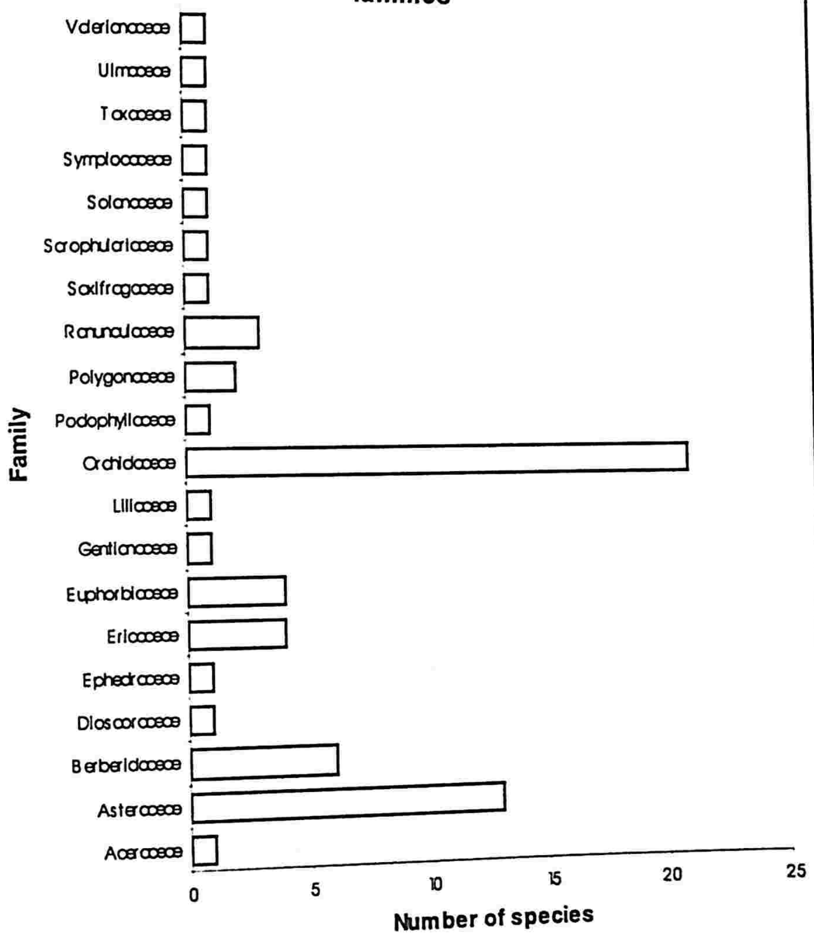
Family	Species	CITES	IUCN	P.N.	R.D.B
Aceraceae	*Acer caesium*				V
Asteraceae	*Artemisia dubia*			P	
	Artemisia falconeri			P	
	Artemisia japonica			P	
	Artemisia macrocephala			P	
	Artemisia nilagirica			P	
	Artemisia parviflora.			P	
	Artemisia roxburghiana			P	
	Artemisia scoparia			P	
	Artemisia sieversiana			P	
	Artemisia stricta			P	
	Artemisia vestita			P	
	Jurinea dolomiaea			P	
	Saussurea costus	I			E
Berberidaceae	*Berberis aristata*			P	
	Berberis asiatica			P	
	Berberis chitria			P	
	Berberis jaeschkeana			P	
	Berberis lycium			P	
	Berberis pseudoumbellata			P	
Dioscoreaceae	*Dioscorea deltoidea*	II		P	V
Ephedraceae	*Ephedra gerardiana*			P	
Ericaceae	*Rhododendron arboreum*			P	
	Rhododendron campanulatum			P	
	Rhododendron hypenanthum			P	
	Rhododendron lepidotum			P	
Euphorbiaceae	*Euphorbia emodi*	II			
	Euphorbia hirta	II			
	Euphorbia royleana	II			
	Euphorbia stracheyi	II			
Gentianaceae	*Swertia chirayita*			P	
Liliaceae	*Allium stracheyi*				V
Orchidaceae	*Aorchis spathulata*			P	
	Calanthe tricarinata	II		P	R

	Cymbidium macrorhizon	II		P	
	Cypripedium elegans	II		P	R
	Cypripedium himalaicum	II		P	R
	Dactylorhiza hatagirea	II		P	
	Dendrobium monticola	II		P	
	Epipactis gigantea	II		P	
	Epipactis helleborine	II		P	
	Epipogium aphyllum	II		P	
	Goodyera repens	II		P	
	Habenaria ensifolia	II		P	
	Habenaria intermedia	II		P	
	Habenaria marginata	II		P	
	Herminium angustifolium	II		P	
	Malaxis cylindrostachya	II		P	
	Malaxis muscifera	II		P	
	Oberonia pachyrachis	II		P	
	Pecleilis gigantea	II		P	
	Satyrium nepalense	II		P	
	Spiranthes sinensis	II		P	
Podophyllaceae	*Podophyllum hexandrum*	II			
Polygonaceae	*Rheum australe*			P	
	Rheum webbianum			P	
Ranunculaceae	*Aconitum falconeri*			P	
	Aconitum heterophyllum			P	
	Aconitum violaceum			P	
Saxifragaceae	*Bergenia stracheyi*			P	
Scrophulariaceae	*Picrorhiza kurrooa*	II		P	V
Solanaceae	*Physochlaina praealta*			P	
Symplocaceae	*Symplocos racemosa*			P	
Taxaceae	*Taxus baccata*	II		P	
Ulmaceae	*Ulmus wallichiana*		T		
Valerianaceae	*Nardostachys jatamansi*	II		P	V

P.N: Public notice list species whose export has been prohibited. It is issued by the Director General of foreign trade (30/03/1994)
R.D.B: Red data book, I & II: Appendix I & II, P: Present, R: Rare, E: Endangered, V: Vulnerable,
T: Threatened

In the catchment area family Asteraceae had the highest number of species followed by Poaceae however, the maximum number of rare and threatened plants belonged to the family Orchidaceae (21) followed by Asteraceae (Figure-7.3).

Figure-7.3: Rare and threatened plants in different families



A total of six plant species, which occurred in the sampling plots, were quantitatively analyzed The density of *T.baccata* in Duggada watershed (DWS) was higher than in Bhatwari watershed (BWS) (Table-7.8). The other tree species *Ulmus wallichiana*, which had a density of 36±8/ha in DWS, was completely absent in BWS. The endangered herb species had higher density in BWS when compared to DWS. The density of *Calanthe tricarinata* and *Podophyllum hexandrum* in BWS was 286±54/ha and 440±80/ha respectively. In DWS *Calanthe tricarinata* and *Podophyllum hexandrum* had a density value of 200±34/ha and 320±65/ha respectively. The other two threatened herb species *i.e Cypripedium himalaicum* and *Dactylorhiza hatagirea* with density/ha 880±164 and 160±23 respectively were not present in any of the samples of DWS.

Plate-7.5: *Calanthe tricarinata*

Plate-7.6: *Cypripedium himalaicum*

Plate-7.7: *Ulmus wallichiana*

Plate-7.8: *Podophyllum hexandrum*

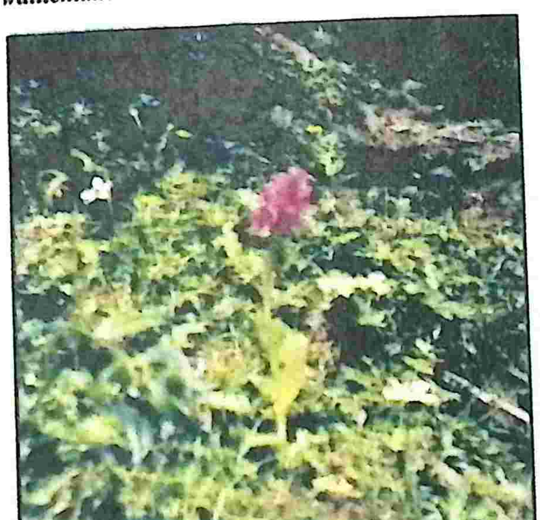


Plate-7.9: *Dactylorhiza hatagirea*

Table-7.8: Distribution of rare and threatened plant species in two ISS

Species	DWS	BWS
Calanthe tricarinata	200±34 (2800)	280±54 (3000)
Cypripedium himalaicum	A	880±164 (3200)
Dactylorhiza hatagirea	A	160±23 (3400)
Podophyllum hexandrum	320±36 (3000)	440±80 (2900–3100)
Taxus baccata	134±34 (3000)	23±13 (2600-3200)
Ulmus wallichiana	36±8 (2000)	A

A = Absent, Value in parentheses represents altitude in meters

7.4 Discussion

7.4.1 Local uses of wild plants: Ethnobotany is perhaps the oldest science, which has evolved with the evolution of man (Hawkes 1970, Vaughan & Geissler 1997). The people of Bhagirathi valley have been associated with the forests from very early times. They utilized these natural resources for various purposes. From the present study it was found that they still utilize many species for their daily needs. Though the maximum number of plant species were utilized for medicinal purposes their intensity of use was low when compared to that of fuelwood species. Earlier, people used medicinal plants mainly for physical disorders, other serious complications were believed to be the wrath of God or a curse of evil spirit. In order to please the deities cock, goat or a lamb was sacrificed. This is a common practice in most of the Himalayan villages (Shah & Joshi 1971). With increasing development and awareness, such practices are declining. The construction of hospitals and supply of allopathic medicines in the study area has limited the use of medicinal plants. Although kerosene oil and cooking gas were available, local people preferred fuelwood from the forest, as it was available free of cost. Fuelwood and fodder were mainly collected by the women probably because they were the primary users. Species such as *Symplocos chinensis* and *Aesculus indica,* although burnt, were not considered suitable because of their cracking sound and smoke they produced while burning as also reported by (Shrestha and Kaltel 1996). Lesser use of plant species for medicinal and religious purpose and cultivation of cash crops (such as potato, french bean) instead of indigenous varieties is an indicator of economic and social development of local communities (Hui-Lin 1970). This development has put more pressure on the surrounding forests due to resource scarcity at the village level. Besides this economic benefits of several wild plants have allured people for their overexploitation in many parts of the Himalaya (Singh 1999). However in the present study area though market oriented economy has replaced subsistence based agriculture but people are still unaware of the economic benefits of the medicinal plants (Awasthi 2001). This ignorance has indirectly helped in the conservation of these rare plant species. On the other hand overexploitation of certain species such as oak and bamboos has led to their degradation. Bamboo which had the highest intensity of use was sometimes overused even for simply supporting the seedlings of their cash crops (french beans). Underutilized and lesser known species should be utilized to avoid overexploitation of preferred species which are ecologically very important (Young 1994). In the present study it was found that species of oaks and bamboos which formed the climax vegetation in the area had highest intensity of use indicating their preference by local people.

In both the ISS maximum distribution of bamboos was found in 30^0-40^0 slope category where the steepness could have prevented their exploitation by locals and browsing by the animals. In DWS *S. falcata* was found between 1900 to 2450 m while it was found around 2400m in BWS. This could be because the lower altitude regions in BWS were under habitation, which also accounted for the higher average culm density (4296±1080/ha) and biomass (225.74±53.9 kg/ha) of *S. falcata* in DWS than in BWS where it's density and biomass were 1320/ha and 124.62 kg respectively. The density values are in agreement with the results of Singh and Singh (1986), Bankoti *et al.* (1992), Pathak *et al.* (1993) and Saxena and Singh (1982) for Kumaun Himalaya.

The density of *T. spathiflorus* was also higher in DWS while the biomass was higher in BWS probably because the loss of oak canopy allowed bamboo to attain considerable height and biomass. This is in affirmation with the study done by Lodhiyal *et al.* (1998). The density values are similar to the results of Rikhari *et al.* (1997) while they are higher than the estimates of Bankoti *et al.* (1992) and Singh (1999). In case of DWS the density and biomass of *T. spathiflorus* was comparatively higher than *S. falcata* again due to favourable light conditions. In case of BWS, the average density of *T.spathiflorus* was high whereas *S. falcata* contributed higher biomass. The reason for this could be that though the canopy and litter protected the bamboo from predation and hence increased culm density, it inhibited its full growth leading to reduced above ground biomass (Rao and Ramakrishnan 1987).

It was observed that in villages (e.g Barsu) where bamboo has completely vanished from the surrounding forest locals are now going for other species such as *Caesalpinia decapetala*, *Desmodium tiliaefolium*, *Debregaesia salicifolia*. In some villages (e.g Syaba) realizing the ill effects of overexploitation of bamboos villagers have started using the same bamboo culms for three-four years. This ecological awareness amongst the locals would not only help in sustaining the limited natural resources but will also help in the conservation of highly important climax vegetation. The increased ecological awareness coupled with traditional knowledge can also be effectively used for their economic upliftment (Farooquee & Saxena 1996 Kumar & Singhal 1997, Jardhari & Kothari 1997, Maikhuri *et al.* 1997). In the Bhagirathi valley people can be encouraged to cultivate medicinal plants and indigenous varieties, which will not only improve their income but will also preserve their traditional wisdom and ecological diversity.

7.4.2. Status of rare and threatened plants: The results of the study indicate that DWS had higher density of threatened tree species in comparison to BWS probably because of favourable moisture conditions and low human population. However, a reverse trend was seen in case of threatened herbaceous plants, which had higher distribution in BWS possibly because the opening of the canopy due to high anthropogenic pressures in BWS favoured their growth. The density of threatened herb species in the present study area was low when compared to the results of Maikhuri *et al.* (1998) for Nanda Devi Biosphere Reserve (NDBR), Singh (1999) for Great Himalayan National Park (GHNP), Kala (1998) for Valley of Flowers (VOF) and Kala (2000) for Indian trans-Himalaya. However, the density of *T.baccata* and *U.wallichiana* tree species was higher than the estimates of Singh (1999) (Table-7.9). The reason for this was that the present study was confined upto the timberline zone whereas the above-mentioned studies covered a large area under alpine meadows (devoid of trees but having high herbaceous flora). This explains the lower tree density in these studies and lower herb density in the present study. Another probable reason could be that NDBR, VOF and GHNP are protected areas whereas the present study was carried out in a reserved forest.

Table-7.9: Density/ha of endangered species in different parts of the Himalaya: a comparative account

Species	Present study (1700- 3400)	Kala 2000 (4270m)	Singh 1999 (1600-6400)	Kala 1998 (3200-6675)	Maikhuri 1998 (2200-3600)
C. himalaicum	880	A	A	16300	A
D. hatagirea	160	161900	8000	9000	42000
P. hexandrum	380	2000	3700	A	A
T. baccata	78.5	A	12.6	A	A
U. wallichiana	36	A	3.6	A	A

Value in parentheses represent altitude in meters, A = Absent

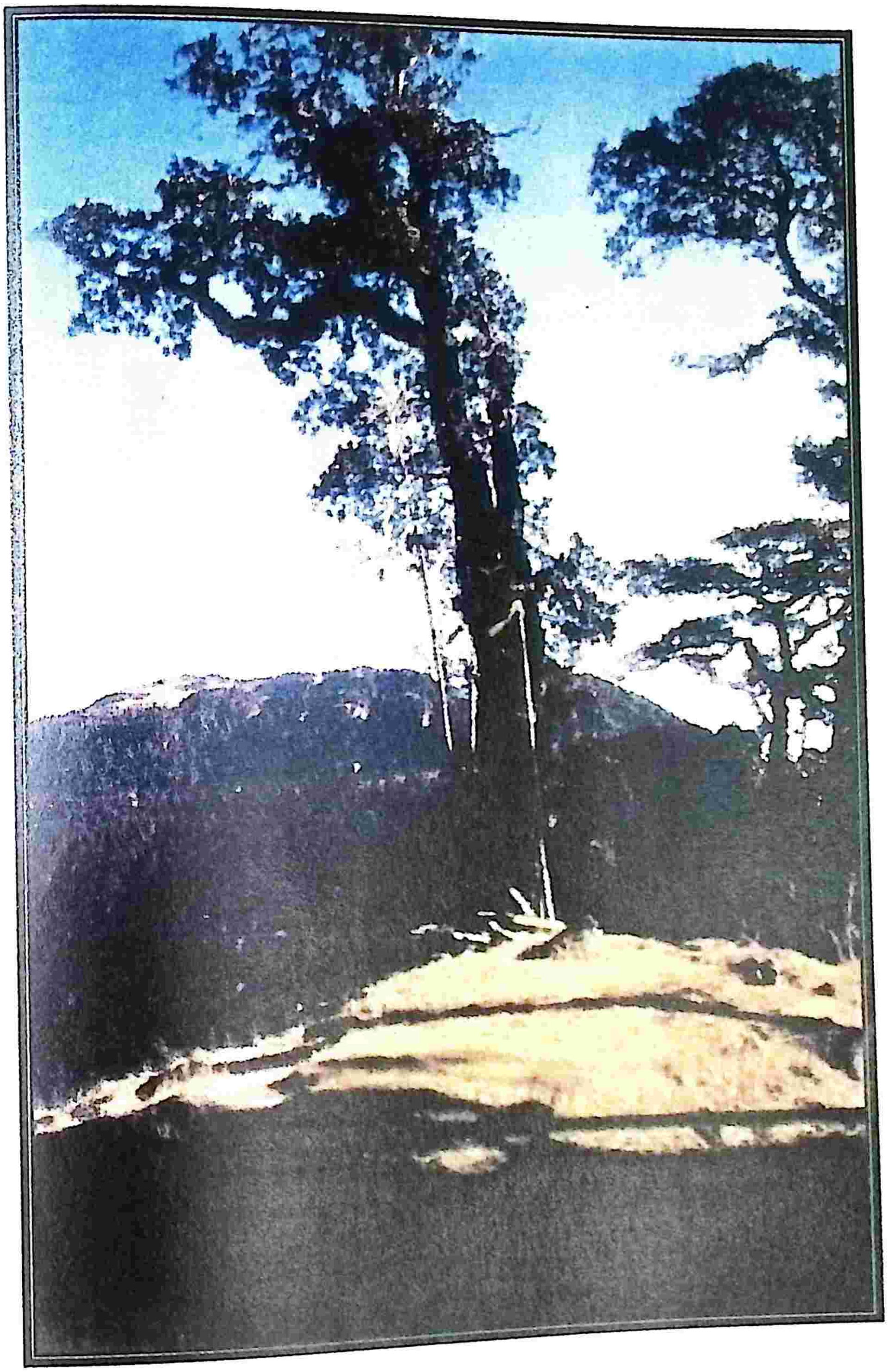
A comparative account of the families represents that out of the 16 monogeneric found in Uttarpradesh, five are found in the present study area (Table-7.10).

Table-6.10: A Comparative account of the monogeneric families

Family	Genera	Species In India	Species in U.P	Species in present study area
Coriariaceae	Coriaria	2	1	1
Cuscutaceae	Cuscuta	21	4	2
Daphniphyllaceae	Daphniphyllum	1	1	1
Moringaceae	Moringa	2	1	1
Paeoniaceae	Paeonia	1	1	1

A good status of endangered species in an area with high human pressure defines its importance for conservation. Therefore, proper conservation and scientific management of such rich and diverse forests in small watersheds should also be taken up on a priority basis. Besides, the indigenous knowledge of locals should also be promoted to sustain and strengthen the symbiotic relationship of man and nature.

CHAPTER-8



Conservation Implications and Conclusions

CHAPTER 8
Conservation Implications and Conclusions

8.1 Introduction

The concept of conservation of nature and natural resources in India has been carefully woven into various religious beliefs and customs. Worshiping of *Ficus religiosa*, *Zanthoxylum armatum*, "Nandi" (The Bull) and maintaining scared groves were all part of conservation strategy. These traditional management practices, which helped in biodiversity conservation, are now slowly breaking up mainly because of commercialization and activities geared for short term economic benefits (McNeely 1990, Srinivas 2000).

In the Bhagirathi valley construction of metalled road during the later part of 20th century has led to market oriented economy and transition in landuse practices. This has adversely affected the status of surrounding forests in the valley, which has aroused a need for their conservation. Recent notification of Gangotri National Park (GNP) is one step in this direction. Most of the area covered by GNP is inaccessible and snow covered. The remaining area outside GNP in the valley not only supports a vast diversity of vegetation types but also a large number of villages. As flat and low elevation areas in the valley are already under habitation, with growing population the demand for more land will increase pressure on the remaining forests. These forests are therefore more important for conservation.

Conservation in such areas cannot be achieved without the involvement of local communities who are directly dependent on these resources for their daily needs. The involvement of local people in decision making and management of resources can help a lot towards conservation while their isolation may lead to failure of many schemes (Pretty *et al.* 1995, Tisdell and Xiang 1996). Henwal catchment of Garhwal Himalaya is a good example to show how involvement of local people can bring about sweeping changes in conservation (Kumar *et al.* 1997, Jardhari and Kothari1997).

8.2 Present status of the forests

The inaccessibility and the rugged terrain of Himalaya pose several difficulties in status survey of its resources and periodical monitoring. In such areas modern techniques of Remote Sensing and GIS can be very useful. In the present study use of RS and GIS were found to be very useful for mapping vegetation of inaccessible areas. Fairly accurate maps (83% accuracy) produced with the help of knowledge based classification provided an insight to the status of these forests (Chapter-4).

The varied topography and climate of Himalaya support diverse vegetation types, which are influenced by various biotic and abiotic factors. The major abiotic factors are altitude, aspect and slope. In the present study effect of these factors were studied in greater details. Apart from these, anthropogenic factors also influenced the distribution of certain plant species (Chapter-5). The status of forests which are limited to gentler slopes and middle elevation is quite satisfactory compared to other parts of Garhwal. Forests near the permanent and temporary habitations were under high anthropogenic pressures due to excessive resource extraction. Overexploitation of certain species such as *Quercus semecarpifolia* for fuelwood and fodder, bamboo and girdling of *Ulmus wallichiana* for edible fungus may not only lead to their local extinction but will also cause resource scarcity for the local people in the near future.

Though the forests of Bhagirathi catchment are under tremendous pressure due to developmental activities and high tourist influx still they support a good share of biomass when compared to neighbouring areas (Chapter-6). The study revealed that available woody biomass was dependent on species composition, which in turn was affected by preference of local people for certain species. Selective removal of species has led to coming up of secondary species at the cost of climax species. This in the long run will not only affect the sustainability of mountain watersheds but also the lifestyle of villagers, as the hill agro-ecosystem is directly dependent on the surrounding forests.

Besides the threat on forests, erosion in the ethnobotanical knowledge of the villagers has also been visualized due to orientation of people towards commercialized economy (Chapter-7). The cultivation of potato as a cash crop has suddenly spurred up in the study area. Although it has improved the economy of the locals to a certain extent (and that of outsiders to a larger extent), it has increased pressure on the surrounding forests manifold.

8.3 Traditional conservation practices

In the present study area, conservation practices such as worshipping certain trees for sacred reasons is still followed by the local people. These plants therefore, have attained full growth and serve as potential seed bearers, which are important for regeneration. Traditional management practices such as "*ghasnis*" (grasslands closed for grazing during rainy season) and "*rakeeta*" (opening of grassland for fodder collection on a fixed day) not only meet the fodder requirement of local people for snow fall period but also help in the regeneration of grasslands.

In Himalaya, collection of fuelwood and fodder is mainly done by women. When these resources became degraded and scarce, women were the worst affected. To overcome resource scarcity, women in the study area have formed local conservation groups, called "*Mahila Mangal Dal*" to check the cutting of green trees and regulate the resource collection from "*ghasnis*".

8.4 Implications of the present study

In the present study area, it was observed that dependency of villagers for their basic needs is the major cause of forest degradation. In such situations programs such as ecodevelopment, Joint Forest Management (JFM) would not only help in socio-economic upliftment of the locals but will also conserve the natural resources. The creation of Van Panchayats (VP) in the present study area could be seriously looked upon for preserving the biodiversity by bringing the sense of ownership of forests amongst the villagers. Though, Forest Department (FD) and NGOs (e.g., Gangotri Conservation Project) have carried out plantation of trees in wastelands and degraded areas, they have not involved the local people and hence these projects have not received their full support. Thus to conserve the forests, immediate and concentrated efforts are required by both the local people and FD.

- People in the Bhagirathi valley should be encouraged to plant multipurpose species in the fallow lands. The seedlings and saplings of which should be made available to the villagers by the FD free of cost. This will not only help in reducing pressures on the forests but will also form a resource base for the locals during harsh winter and rainy seasons.
- Wastelands in the village surroundings could be effectively used for raising bamboos, which will not only improve the soil quality but will also, fulfill the need of locals for various household items and artifacts. Locals should be encouraged to sell these articles in the local market and tourist spots where tourists prefer to buy these as souvenirs. These activities can be well maintained by setting up cooperative societies.
- Instead of potato as a cash crop, cultivation of medicinal plants and orchards should be promoted in the valley. Cultivation of potato on steep slopes leads to increased soil erosion and extensive use of chemical fertilizers to improve production leads to soil degradation. This has also been visualized in many parts of India (Umarani and Subramaniyam 2000) and other parts of the world (Johnson and Hoffman 1998). On the other hand cultivation of medicinal plants and setting up of orchards have not only improved the socio-economic status of the villagers but have also helped in the conservation of natural resources in other parts of Uttaranchal (Farooquee and Saxena 1996). In Bhagirathi valley, places such as Harsil and Dharali are already famous for their apples and realizing the importance of medicinal plants Government has also set up medicinal farms in Bhatwari block. Due to lack of knowledge and proper guidance these farms have not earned fruitful results. Hence, proper training should be provided to the villagers for cultivation of medicinal plants, apple orchards and markets should be developed for their disposal.
- Besides, apiculture and sericulture, development of rabbit farms could also be promoted in the lower elevation villages of Bhagirathi valley.
- Since the Government has already notified GNP, a comparative study of forests within and outside GNP can reveal the difference in the status of forests and area specific conservation measures could be taken up.

The present study forms the baseline for future monitoring of these reserved forests outside GNP in Bhagirathi valley.

References:

Adhikari, B.S, Y.S. Rawat and S.P Singh (1995). Structure and function of high altitude forests of Central Himalaya 1. Dry matter dynamics. ***Annals of Botany 75:237-248.***

Adinaryana, J and N. Ramakrishna (1996). Integration of multi-seasonal remotely sensed images for improved landuse classification of a hilly watershed using Geographical information system. ***International Journal of Remote Sensing 17 (9): 1679-1688.***

Adkoli, N.S (1992). Forest based industries meeting raw material needs and generation of employment. Pages 173-230 in P.K. Khosla (ed.) ***Status of Indian Forestry-Problems and perspective.*** Solan.

Agrawal, D.P (1997). Traditional knowledge system and western science. ***Current Science 73 (9): 731-733.***

Aiba, Shin-i chiro and K. Kitamaya (1999). Structure, composition and species diversity in an altitude substrate matrix of rain forest tree communities on Mount Kinabalu, Borneo. ***Plant Ecology 140: 139-157.***

Anji Reddy, M and K.M. Reddy (1996). Performance analysis of IRS bands for landuse/landcover classification system using maximum likelihood classifier ***International Journal of Remote Sensing 17 (13): 2505-2515.***

Annon (1992). ***Action Plan for Himalaya.*** Nainital

Anonymous (1970). ***The gazetteer of district Uttarkashi.*** Allahabad.

Anonymous (1996). ***Uttarkashi forest division. Bhagirathi circle, U.P. Working Plan 1996-97 to 2006-2007. Part 1 & 2.*** Nainital

Arora, R.K and R. Nayar (1984). Wild relative of crop plants in India. NBPGR ***Sci. Monograph 7: 90***

Aswal, B.S and A.K Goel (1985). Rare or lesser known plants from Garhwal and Kumaun. ***Journal of Economic and Taxonomic Botany 6(3): 729-731.***

Aswal.B.S (1994). High altitude flora of Western Himalaya: Peculiarities and conservation. In Pangtey, Y.P.S and R.S Rawal (Eds) ***High altitudes of the Himalaya (Biogeography, Ecology and Conservation).*** Nainital.

Atkinson, E.T. (1882). ***The Himalayan districts of the North-western Province of India.*** Allahabad.

Awasthi, A (2001). ***Ecological impacts of anthropogenic pressures on high altitude forests in the upper catchment of river Bhagirathi.*** Ph.D thesis, Deemed University Forest Research Institute, D.Dun.

Awasthi, A, G.S.Rawat and A. Rajvanshi (1999). Assessment of human use and ethnobotanical values in the Tehri dam submersible area, Garhwal Himalaya. ***Journal of Non-Timber Forest Products 6 (3/4): 199-206.***

Badoni, A.K (1987). Ethnobotany of hill tribes of Uttarkashi. Plants used in rituals and psycho-medicinal practices. ***Joshard XII and XIII: 103-115.***

Baduni, N.P and C.M Sharma (1996) Effect of aspect on the structure of some natural stands of Quercus semecarpifolia in Himalayan moist temperate forest. ***Indian Journal of Forestry 19(4): 335-341.***

Bankoti, N.S, R.S Rawal, S.S Samant and Y.P.S Pangtey (1992). Forest vegetation of inner hill ranges in Kumaun, Central Himalaya. ***Tropical Ecology 32: 41-53****

Barnes, B.V, D.R Zak, S.H Denton and S.R Spurr (1997). ***Forest Ecology 4th edition.*** New York.

Bates, D.M (1985). Plant utilization: Patterns and prospects. ***Economic Botany 39 (3): 241-265.***

Bellon, M.R (1996). The dynamics of crop infraspecific diversity: A conceptual framework at farmer level. ***Economic Botany 50 (1): 26-39.***

Bhandari B.S, J.P Mehta, B.P Nautiyal & S.C Tiwari (1997). Structure of chirpine (Pinus roxburghii Sarg.) community along an altitudinal gradient in Garhwal Himalaya. ***International Journal of Ecology and Environmental Scence 23:67-74.***

Bhandari, B.S, J.P. Mehta and S.C. Tiwari (2000). Dominance and diversity relations of woody vegetation structure along an altitudinal gradient in a montane forest of Garhwal Himalaya. ***Journal of Tropical Forest Science 12 (1): 49-61.***

Biswas, Sas (1985). Studies on the forest flora of Tehri Garhwal (Uttar Pradesh): Introduction, plant exploration and phytogeography. ***Indian Journal of Forestry 8 (3): 199-204.***

Biswas, Sas (1988). Rare and threatened taxa in the forest flora of Tehri Garhwal Himalaya and the strategy for their conservation. ***Indian Journal of Forestry 11(3):233-237.***

Biswas, Sas (1994). Potential economic forest produce of Tehri Garhwal Himalaya (Uttar Pradesh) with reference to the systematic studies. ***Higher plants of Indian subcontinent. Vol III: 281-287.***

Bolstad, P.V and T.M. Lillesand (1991). Rapid maximum likelihood classifier. ***Photogrammetric Engineering and Remote Sensing 57: 67-74.***

Bray, J.R and J.T Curtis (1957). An ordination of the upland forest communities of southern Wisconsin. ***Ecological Monograph 27(4): 325-349.***

Bryant, E, A.G. Dodge and S.D. Waren (1980). Landsat for practical forest type mapping. A test case. ***Photogrammetric Engineering and Remote Sensing 46 (12): 1575-1584.***

Burkill,I.H. (1965). ***Chapters on history of botany in India.***

Busing, Richard T (1998). Composition, structure and diversity of cove forest stands in the Great Smoky Mountains: a patch dynamic perspective. ***Journal of Vegetation Science 9: 881-890.***

Champion, H.G (1939). The realtive stability of the Indian vegetational types. ***TheJournal of Indian Botanical Society 18(1): 1-12.***

Champion, H.G. and S.K. Seth (1968). ***A revised survey of the forest types of India.*** Delhi.

Chandrasekhar, M.G, K, Radhakrishanan, V. Jayaraman, D.P. Rao, B.Sahai and B, Manikiam (1992). Remote sensing activities in India-an overview Pages 7-14 In Karale (Ed.) ***Natural resource management-a new perspective***, Bangalore.

Chatterjee, D. (1939). Studies on the endemic flora of India and Burma. ***Journal of Royal Asiatic Society of Bengal 5:19-67***

Chaturvedi, O.P and J.S Singh (1982). Total biomass and biomass production of *Pinus roxburghii* trees growing in all aged natural forests. ***Canadian Journal of Forest Research 12(3): 632-640.***

Chauhan, M.S and A. Bhattacharyya (1992). A contribution to the Ethnobotany of Pokhari block, Chamoli Garhwal, U.P. Himalaya.

Journal of Economic and Taxonomic Botany additional series 10: 129-136.

Chazdon,R.L and F.G.Coe (1999). Ethnobotany of woody species in second-growth, old-growth, and selectively logged forests of Northeastern Costa Rica. ***Conservation Biology 13 (6): 1312-1322.***

Clough, B.F and K. Scott (1989). Allometric relationships for estimating above-ground biomass in six mangrove species. ***Forest Ecology and Management 27: 117-127.***

Connel, J.H and E. Orias (1964). The ecological regulation of diversity. ***American Naturalist 48:399-414.***

Cottam, G (1949). The phytosociology of an oak woods in southwestern Wisconsin. ***Ecology 30(3): 271-287.***

Curtis, J.T and G. Cottam(1956). ***Plant ecology workbook.***

Curtis,J.H and R.P McIntosh (1950). The interrelations of analytic and synthetic phytosociological characters. ***Ecology 31:434-435.***

Dangwal, L.R, R.D Gaur and D.C Nautiyal (1997). Some rare and uncommon legumes from Garhwal Himalaya. ***Journal of Economic and Taxonomic Botany 21:47-51.***

Dangwal,L.R, D.S Rawat and R.D Gaur (1993). Some interesting and rare plants of Fabaceae from Garhwal Himalaya. ***Journal of Indian Botanical Society 72: 317-318.***

Dangwal,L.R, D.S Rawat and R.D Gaur (1996). Some new records of legumes from Garhwal Himalaya. ***Journal of Bombay Natural History Society 93:113-115.***

Dangwal,L.R, D.S Rawat and R.D Gaur (1994). Some rare and less known legumes from Garhwal Himalaya. ***Journal of Indian Botanical Society 73: 311-313.***

Dangwal,L.R, D.S Rawat and R.D Gaur (1995). Some rare and interesting plants of Fabaceae from Garhwal Himalaya. ***Indian Journal of Forestry. 18(3): 255-257.***

Das, K.K, S. A. Ravan, S.K.Negi, A.Jain and P.S. Roy (1996). Forest cover monitoring using remote sensing and GIS- A case study in Dhaulkhand range of Rajaji national park, Uttarpradesh ***Journal of Indian Society of Remote Sensing 24 (1): 33-42.***

Defries, R.S and R.G. Townshend (1998). Global land cover characterization from satellite data: from research to operational implementation? ***Global Ecology and Biogeography* 8: 367-379.**

Dey, A.C, H.O Saxena and M.R Uniyal (1969). Botanical exploration in the Bhagirathi valley with particular reference to the medicinal plants. ***Indian Forester* 95 (3): 190-207.**

Dudgeon, W and L.A Kenoyer (1925). The ecology of Tehri Garhwal, a contribution to the ecology of Western Himalayas ***Journal of Indian Botanical Society*** 4:233-284.

Ehrlich, D and E.F. Lambin (1996). Broad scale landcover classification and interannual climatic variability. ***International Journal of Remote Sensing* 17 (5): 845-862.**

Elumnoh, A and R.P. Shrestha (2000). Application of DEM data to Landsat image classification: Evaluation in a tropical wet-dry landscape of Thailand. ***Photogrammetric Engineering and Remote Sensing* 66 (3): 297-304.**

Farooquee, N.A and K.G. Saxena (1996). Conservation and utilization of medicinal plants in high hills of the Central Himalayas. ***Environmental Conservation* 23 (1): 75-80.**

Fleming, M.D (1988). An integrated approach for automated cover type mapping of large inaccessible areas in Alaska. ***Photogrammetric Engineering and Remote Sensing* 54(3): 357-362.**

Ford-Lloyd, B and M. Jackson (1986). ***Plant genetic resource: An introduction to their conservation and use.*** London.

Frankel, O.H (1970). Genetic conservation of plants useful to man. ***Biological conservation* 2 (3): 162-169.**

Franklin, S.E, B.D. Titus and R.T. Gillespie (1994). Remote sensing of vegetation cover at forest regeneration site. ***Global Ecology and Biogeography letters* 4: 40-46.**

Fricke, T (1989). Introduction: Human Ecology in the Himalaya. ***Human Ecology* 17(2): 131-145.**

FSI (1997). ***State of the forest report.*** FSI. MOEF

Gaur, R.D (1999). ***Flora of the district Garhwal North West Himalaya (with ethnobotanical notes)*** Srinagar, Garhwal.

Gaur, R.D and B.P. Bhatt (1994). Folk utilization of some pteridophytes of Deoprayag area in Garhwal Himalaya: India. ***Economic Botany 48 (2): 146-151.***

Gaur, R.D. and J.K. Semwal (1983). Exploitation and threat to survival of some high altitude plants in Garhwal Himalayas.In. Jain, S. K. and R.R.Rao (eds.). ***An assessment of threatened plants of India.***

Gaur,R.D and S.Rajwani (1995). A preliminary report on the threatened arborescent taxa of Garhwal Himalaya. ***Journal of Indian Botanical Society 74: 283-292.***

Gaur,R.D, L.R Dangwal and D.S Rawat (1993). Some rare and little known plants of Fabaceae from Garhwal Himalaya. ***Journal of Indian Botanical Society 72:21-23.***

Gaur,R.D, L.R Dangwal and D.S Rawat (1994). Some rare plants of Fabaceae from Garhwal Himalaya. ***Indian Journal of Forestry 17(1): 80-83.***

Ghildiyal, B.P (1981). Soils of the Garhwal and Kumaun Himalaya. Pages 120-137 In Lal and Moddie (Ed.) ***The Himalaya aspects of change.*** New Delhi

Ghosh, S, K.K.Sen, U.Rana, K.S.Rao and K.G. Saxena (1996). Application of GIS for land-use/land-cover change analysis in a mountainous terrain. ***Journal of Indian Society of Remote Sensing 24(3): 193-202.***

Goel, A.K and U.C Bhattacharya (1983). Rare flowering plants of Garhwal Himalaya. In Jain, S.K and R.R Rao (Eds.). ***An assessment of threatened plants of India.*** Calcutta.

Goel, A.K and U.C. Bhattacharyya (1981). Contribution to the pteridophytic flora of Tehri district (Garhwal). ***Indian Journal of Forestry 4 (1): 30-37.***

Gupta, A.K, P.P. Nageswara Rao, K.Ganesh Raj, C.B.S. Dutt and M.G. Chandrasekhar (1993). An integrated approach for resource development using Remote Sensing-A case study specific to hill areas. ***Journal of Indian Society of Remote Sensing. 21(2): 99-108.***

Gupta, S.R and B.B Bhardwaj (1993). Biomass and productivity of forest ecosystems of Shiwalik hills. ***Journal of Tree Science 12 (2): 57-63.***

Gupta,R.K (1956). Botanical explorations in the Bhilangna valley of the erstwhile Tehri Garhwal state-1. ***Journal of Bombay Naural History Society 53(4): 581-594.***

Gupta,R.K (1957). Botanical explorations in the Bhilangna valley of the erstwhile Tehri Garhwal state-II. ***Journal of Bombay Naural History Society 54(4): 878-886.***

Gupta,R.K (1960). On a botanical trip to the source of river Ganga in Tehri Garhwal Himalayas. ***Indian Forester 86: 547-552.***

Gupta,R.K (1962). Botanical explorations in the Bhilangna valley of the erstwhile Tehri Garhwal state-1. ***Journal of Bombay Naural History Society 59(2): 486-512.***

Gupta,R.K and J.S Singh (1962). Succession of vegetation types in the Tons valley of Garhwal Himalayas ***Indian Forester. 88:289-296.***

Hajra, P.K (1983). ***A contribution to the botany of Nanda Devi National Park***. BSI, Calcutta.

Hajra, P.K and B.Balodi (1995). ***Plant wealth of Nanda Devi Biosphere Reserve. Flora of India. Series-4***. Botanical Survey of India.

Hajra,P.K (1983). Is Sahastradhara a threatened type locality ? In Jain, S.K and R.R Rao (Eds.). ***An assessment of threatened plants of India.*** Calcutta.

Hawkes, J.G (1970). The origin of agriculture. ***Economic Botany 24: 131-133.***

Hill, M.O. (1979). ***TWINSPAN- A fortran programme for arranging multivariate data in an ordered two way table by the classification of the individuals and attributes.*** Ithaca. New York. Cornell University.

Hobbs, R.J, J. F. Wallace and N.A. Campbell (1989). Classification of vegetation in the western Australian wheatbelt using Landsat MSS data. ***Vegetatio 80: 91-105.***

Hooker, (1906***). A sketch of flora of British India***. London.

Hooker, J.D (1872-1888). ***Flora of British India***. London.

Hui-Lin,Li (1970). The origin of cultivated plants in Southeast Asia. ***Economic Botany 24: 3-19.***

Hurlbert, S.H (1971). The non-concept of species diversity: a critique and alternative parameters. ***Ecology 52: 577-586.***

Innes,J.L and B.Koch (1998). Forest biodiversity and its assessment by remote sensing. ***Global Ecology and Biogeography Letters 7: 397-419.***

Ives, J.D and B. Messerli (1989). ***The Himalayan dilemma reconciling development and conservation.*** London.

Jackson, M.L (1973). ***Soil chemical analysis.*** New Delhi.

Jain, S.K and A.R.K. Sastry (1980). ***Threatened plants of India. A state-of-the art report.*** BSI.

Jain, S.K and R.R Rao (1983). ***An assessment of threatened plants of India.*** Calcutta.

Jain, S.K and V.Mudgal (1999). ***A handbook of ethnobotany.*** India.

Jain,S.K & A. Saklani (1991). Observations on the ethnobotany of the Tons valley in Uttarkashi district of North West Himalaya. India. ***Mountain research and Development 11(2):157-161.***

Janki Ammal, E.K (1960). The effect of Himalayan uplift on the genetic composition on the flora of Asia. ***The Journal of Indian Botanical Society 39 (3): 327-334***

Janssen, L.F, M.N. Jaarsma and ErikT.M. Van der Linden (1990). Integrating topographic data with remote sensing for land cover classification. ***Photogrammetric Engineering and Remote Sensing 56 (11): 1503-1506.***

Jardhari, V and A. Kothari (1997). Conserving agricultural biodiversity: The case of Tehri Garhwal and its implications for national policy. ***Himalayan Paryavaran 5: 101-105.***

Jensen, J.R (1996). ***Introductory digital image processing. A remote sensing perspective.*** Second edition. New Jersey.

Johnson, H and M. Hoffmann (1998). Nitrogen leaching from agricultural land in Sweden. ***Ambio 27 : 481***

Johri, S.C and B. Prasad (1985). ***Uttarkashi forest division, Bhagirathi circle, Uttar Pradesh working plan 1986-87 to 1995-96.*** Nainital.

Joshi, G.C, N.K Pandey and M.R Uniyal (1993). Inventory of disappearing angiosperms of Kumaun and Garhwal Himalaya-causes and suggestions. ***Journal of Economic and Taxonomic Botany 17:421-432.***

Joshi, N.K and S.C Tiwari (1990). Phytosociological analysis of woody vegetation along an altitudinal gradient in Garhwal Himalaya. ***Indian Forester 13(4): 322-328.***

Joshi,A (1984). Ecological note on riverine forest of Garhwal Himalayas. ***Indian Journal of Forestry 7(2): 119-123.***

Joshi,S.P and M.M Srivastava (1991) The status of grazing lands of alpine region in Garhwal Himalayas. In Rajwar,G.S (Ed.) ***Advances in Himalayan ecology.*** New Delhi.

Kala, C.P (1998). ***Ecology and conservation of alpine meadows in the Valley of Flowers national park, Garhwal Himalaya.*** Ph.D. Thesis, FRI, D.Dun.

Kala, C.P (2000). Status and conservation of rare and endangered medicinal plants in the Indian trans-Himalaya. ***Biological Conservation 93: 371-379.***

Kalakoti, B.S, Y.P.S Pangtey & A.K Saxena (1986). Quantitative analysis of high altitude vegetation of Kumaun Himalaya. ***Journal of Indian Botanical Society 65: 384-396.***

Kappelle,M, P.A.F Kennis & A.J de Vries (1995). Changes in diversity aong a successional gradient in a Costa Rican upper montane Quercus forest. ***Biodiversity and Conservation 4:10-34.***

Kasturirangan, K, M.G Chandrasekhar and S.K Shivkumar (1992). Indian remote sensing satellite system-evolution, performance and future. Pages15-24. In Karale (ed) ***Natural resource management-A new perspective.*** Bangalore.

Kaushal, R, A.R. Bhandari, J.C. Sharma and D. Tripathi (1996). Tree productivity in North-West Himalayas: Deodar tree productivity in dry temperate zone of North-West Himalayas. ***Indian Journal of Forestry 19 (3): 258-263.***

Kawosa, M.A (1988). ***Remote sensing of the Himalaya.*** Dehra Dun.

Kimothi,M.M & R,N Jadhav (1998). Forest fire in the central Himalaya: an extent, direction and spread using IRS LISS-1 data. ***International Journal of Remote Sensing 19(12): 2261-2274.***

Knight, D.H (1975). A phytosociological analysis of species-rich tropical forest on Barro Colarado island, Panama. ***Ecological monographs 45: 259-284.***

Kumar, A, C.M Sharma and N.P Baduni (1997). Community structure and physical environment: A case study of the temperate mixed coniferous lata forest in The Malari valley of Garhwal Himalaya. ***Journal of Tropical Forest Science 9(4):449-457.***

Kumar, K (1983). Population structure of U.P Himalaya. In Singh (ed). ***The Himalayan nature, man and culture.*** New Delhi.

Kumar, P, V. Kumar & R. M. Singhal (1997). People's participation in the Eco-Restoration of Henwal Watershed, Garhwal Himalaya. ***Himalayan Paryavaran 5: 52-55.***

Kumar, S and N Rohtagi (1996). A note on some important medicinal plants of Garhwal Himalayas. ***Annals of Forestry 4(2):175-185.***

Lakhanpal, R.N (1991). Early stages in ther development of the Himalayan flora. ***The Journal of Indian Botanical Society70: 13-20.***

Lal, C, B.S Negi, M Kukreti, E.M Singh and J.C Ghildiyal (1997). The aquatic vegetation of Uttarkashi-Garhwal Himalayan region, U.P. ***Journal of Economic and Taxonomic Botany 21:79-82.***

Lande, R (1998). Anthropogenic, ecological and genetic factors in extinction. Pages 29 - 51 in Mace et al. (ed) ***Conservation in a changing world. Conservation Biology series 1. Cambridge. U.K.***

LeDuc, M.G and D.C Havill (1998). Competition between Quercus petraea and Carpinus betulus in an ancient wood in England: seedling survivorship. ***Journal of Vegetation Science 9:873-880.***

Lillesand,T.M and R.W. Kiefer (1994). ***Remote sensing and image interpretation, 3rd edition.*** New York.

Lindenmayer, D.B and J.F. Franklin (1997). Managing stand structure as a part of ecologically sustainable forest management in Australian mountain ash forests. ***Conservation Biology 11(5):1053-1068.***

Lodhiyal, L. S, S.P. Singh and N. Lodhiyal (1998). Phenology, population structure and dynamics of ringal bamboo (*Arundinaria falcata*) in Nainital hill of Central Himalaya. ***Tropical Ecology 39 (1): 109-115.***

Ludwig, J.A. and J.F. Reynolds (1988). ***Statistical ecology: A primer on methods and computing.*** New York.

Magurran, A.E (1988). ***Ecological measurement and its diversity.*** London

Maikhuri, R.K., S. Nautiyal, K.S. Rao and K.G Saxena (1998). Medicinal plant cultivation and biosphere reserve management: A case study from the Nanda Devi biosphere reserve, Himalaya. ***Current Science 74(2): 157-163.***

Maikhuri,R.K, R.L. Semwal, K.S.Rao, S.Nautiyal and K.G.Saxena (1997). Eroding traditional crop diversity imperils the sustainability of agricultural systems in central Himalaya. ***Current Science 73 (9): 777-782.***

Malhotra, C.L, B.Balodi and S.Singh (1988). Two little known plants from Western Himalaya. ***Journal of Economic and Taxonomic Botany 12:237-240.***

Mani, M.S (1978). ***Ecology and phytogeography of high altitude plants of the North West Himalaya.*** New Delhi.

Mani, M.S (ed.)(1974). ***Ecology and biogeography in India.*** Dr. W.Junk, The Hague.

Martin, G.J (1995). ***Ethnobotany A methods manual.*** London.

McIntosh, R.P (1967). An index of diversity and the relation of certain concepts to diversity. ***Ecology 48 (3): 392-404.***

McNeely, J.A (1990). How conservation strategies contribute to sustainable development. ***Environmental Conservation 17: 9-13.***

Mehta, J.P, S.C Tiwari & B.S Bhandari (1997). Phytosociology of woody vegetation under different management regimes in Garhwal Himalaya. ***Journal of Tropical Forest Science 10(1): 24-34.***

Meusel, H. (1971). Mediterranean elements in the flora and vegetation of the west Himalaya. Pages 53-72 in P .H. Davis, P. C. Harper and I.C. Hedge (eds.). ***Plant life of South west Asia.***.Edinburgh.

Misra, R (1968).***Ecology workbook.*** New Delhi.

Mohan, N.P & G.S Puri (1955). The Himalayan conifers III-The succession of forest communities in oak-conifer forests of the Bashahr Himalayas. ***Indian Forester :465-487, 549-562, 646-652, 705-711.***

Morandini, R (1996). A modern forest dependent community: the *Magnifica Comunita di Fienume* in Italy. ***Unasylva 47 (186): 47-52.***

Mudaiya, R.K, G.C Joshi and N.K Pandey (1995). Status of some vulnerable plant species from Ranikhet (Kumaon Himalaya). ***Journal of Economic and Taxonomic Botany 19:663-666.***

Mueller-Dombois, D (1984). Classification and mapping plant communities: a review with emphasis on tropical vegetation. In Woodwell (Ed.) ***The role of terrestrial vegetation in the global carbon cycle: measurement by remote sensing.*** SCOPE 23, U.K.

Muller-dombois, D and H. Ellenberg (1974). ***Aims and methods of vegetation ecology.*** New York.

Myers, N (1996). The biodiversity crisis and the future of evolution. ***The Environmentalist 16: 37-47.***

Naithani, B.D (1984-1985). ***Flora of Chamoli Vol. 1 & 2.*** Botanical survey of India. Howrah

Naithani, B.D (1995). Botanising the Jadh Ganga Valley in Uttarkashi, Garhwal, U.P. ***Journal of Economic and Taxonomic Botany 19(1): 63-74.***

Naithani,H.B and S.C Tiwari (1982). Flowering plants of Pauri and its vicinity. . ***Indian Journal of Forestry 5:142-148.***

Naithani,H.B and S.C Tiwari (1983). Flowering plants of Pauri and its vicinity. . ***Indian Journal of Forestry 6: 70-74.***

Nanda, N. (1990). Who is destroying the Himalayan forests. In. Rustomji, N.K. and C. Ramble (eds.). ***Himalayan environment and culture.*** Shimla.

Nayak,A.K, R.P Purohit and R.K Thapliyal (1991). Phytosociological analysis of some temperate forests of Chamoli (Garhwal). In Rajwar,G.S (Ed.) ***Advances in Himalayan ecology.*** New Delhi.

Negi, G.S (1980). Visual interpretation of Landast imagery of Alaknanda catchment. ***Indian Journal of Forestry 3 (1): 43-46.***

Negi, K.S, J.K Tiwari & R.d Gaur (1985). Economic importance of some trees in Garhwal Himalaya, An ethnobotanical study. ***Indian Journal of Forestry 8(4):276-289.***

Negi, K.S, J.K Tiwari, R.D Gaur & K.C Pant (1993). Notes on the ethnobotany of five hill districts of Garhwal Himalaya. Uttar Pradesh. India. ***Ethnobotany 5:73-81.***

Negi, K.S, R.D. Gaur and J.K Tiwari (1999). Ethnobotanical notes on the flora of Har-Ki-Doon (District Uttarkashi), Garhwal Himalaya, Uttar Pradesh, India. ***Ethnobotany 11: 9-17.***

Negi, M.S and V.N. Tondon (1997). Biomass and nutrient distribution in an age sequence of Populus deltoides ecosystems in Haryana. ***Indian Forester 111-117.***

Negi, P.S & B.K Gupta (1987). Forest resources of Surkanda Devi, Garhwal himalaya, India. ***Indian Journal of Forestry 10(4):283-289.***

Negi,K.S, J.K Tiwari and R.D Gaur (1985). A contribution to the flora of Dodital-A high altitude lake in Garhwal Himalaya (Uttarkashi), U.P. ***Journal of Bombay natural History Society 82: 258-272.***

Osmaston, A.E (1922). Notes on the forest communities of Garhwal Himalayas. ***Journal of Ecology 10:129-167.***

Osmaston,A.E (1927). ***A forest flora for Kumaon.***Allahabad.

Paliwal, G.S. (eds.) (1984). ***The vegetational wealth of Himalayas.*** New Delhi.

Palmer, M.E (1987). A critical look at rare plant monitoring in the United states. ***Biological Conservation 39: 113-127.***

Pandey, U and J.S. Singh (1984). Energy flow relationships between agro- and forest ecosystems in Central Himalaya. ***Environmental Conservation 10: 343-345.***

Pangtey, L, V.R.S Rawat, R.K Suri & S.P Banerjee (1987). Quantitative ecology of woody species in the forests of Machhlad sub-watershed of Pauri Garhwal (Uttar Pradesh). ***Indian Journal of Forestry 10(3):207-213.***

Pant, D.N and P.S Roy (1990).Vegetation and landuse analysis of Aglar watershed using satellite remote sensing technique. ***Journal of Indian Society of Remote Sensing 18(4): 1-14.***

Pant, D.N and P.S Roy (1994). Analysing forest cover and landuse dynamics in central Himalaya using Remote sensing and GIS. ***Proceedings of ISRS silver jubilee symposium 1994-95. Pages 44-58.***

Pant, D.N and S.C. Kharkwal (1995). Monitoring landuse change and its impact on environment of Central Himalaya using remote sensing and GIS techniques. ***Journal of Hill Research 8 (1): 1-8.***

Pant, D.N, K.K Das and P.S Roy (1996) Digital mapping of forest fire in Garhwal Himalaya using Indian remote sensing satellite. ***Indian Forester 122(5): 390-395.***

Pascal, J.P & R. Pelissier (1996). Structure and floristic composition of a tropical evergreen forest in south-West India. ***Journal of Tropical Ecology 12:190-214.***

Pathak, M.C, S.S Bargali & Y.S Rawat (1993). Analysis of woody vegetation in a high elevation ok forest of central Himalaya. ***Indian Forester (119):722-731.***

Philip, G and K.V. Ravindran (1998). Glacial mapping using Landsat thematic mapper data: a case study in parts of Gangotri glacier, NW Himalaya. ***Journal of Indian Society of Remote Sensing 26 (1&2): 29-34.***

Pielou, E.C (1969). ***An introduction to mathematical ecology***. New York.

Polunin, O and A. Stantion (1984). ***Flowers of the Himalaya***. New Delhi.

Porwal, N.C and D.N. Pant (1989). Forest cover type and landuse mapping using Landsat Thematic mapper false colour composite. A case study for Chakrata in Western Himalaya. ***Journal of Indian Society of Remote Sensing 17 (1): 33-40.***

Prance, G.T, W.Balee, B.M. Boom and R.L Cameiro (1987). Quantitative ethnobotany and the case for conservation in Amazonia. ***Conservation Biology 1: 296-310.***

Prescott-Allen, R and C. Prescott-Allen (1990). How many plants feed the world. ***Conservation Biology 4 (4): 365-374.***

Pretty, J.N, J. Thompson and J.K. Kalra (1995). Agricultural regeneration in Kenya: the catchment approach to soil and water conservation. ***Ambio 24 (1): 7-15.***

Price, M.F (1998). Mountains: globally important ecosystems. ***Unasylva 195 Vol. 49:3-12.***

Puri, G.S, V. M Meher-Homji, R.K Gupta and S.Puri (1989). ***Forest ecology. Phytogeography and forest conservation. Vol.1 & 2.*** New Delhi.

Puri, G.S. (1960). ***Indian Forest ecology. Vol. I.*** New Delhi.

Raghubanshi, A.S, J.S. Singh and B.S. Venkatachala (1991). Environmental change and biological diversity: present, past and future. ***Palaeobotanist 39 (1): 86-109.***

Rajwar, G.S (1987). Vegetation types and floristic patterns in the alpine zone of Garhwal Himalaya. In Pangtey,Y.P.S and S.C Joshi (Ed.). ***Western Himalaya. Environment, problems and development.*** Nainital.

Rajwar, G.S and L.P Dobhal (1991). Ecological studies in some oak forests of Western Garhwal Himalaya. In Rajwar,G.S (Ed.) ***Advances in Himalayan ecology***. New Delhi.

Rajwar,G.S (1988). The forest vegetation the east and west facing slopes of the Bhagirathi valley near Uttarkashi. Garhwal Himalaya. In Prakash,R, S.S Negi and M.P Shiva (Eds.) ***Advances in forestry research in India. Vol 1:199-206.***

Rajwar,G.S (1989). Human impact on the forests of Garhwal Himalaya. In Prakash,R (Ed.) ***Advances in forestry research in India. Vol 3:229-241.***

Ramakrishna,P.S, U.M. Chandrashekara, C. Elouard, C.Z. Guilmoto, R.K. Maikhuri, K.S. Rao, S.Sankar and K.G. Saxena (2000). ***Mountain biodiversity, landuse dynamics, and traditional ecological knowledge.*** New Delhi.

Rana, B.S, S.P. Singh and R.P. Singh (1989). Biomass and net primary productivity in Central Himalayan forests along an altitudinal gradient. ***Forest Ecology and Management 27: 199-218.***

Rana,T.S, D Bhaskar & R.R Rao (1996). Strategies for sustainable utilization of plant resources by tribals of the Tons valley. Western Himalaya. ***Ethnobotany 8:96-104.***

Rao, D.P (2000). Geographic data needed in the interpretation of Indian satellite based remote sensing data: Opportunities and realities. ***Current Science 79(4): 468-473.***

Rao, K.S. and P.S. Ramakrishnan (1987). Comparative analysis of the population dynamics of two bamboo species, *Dendrocalamus hamiltonii* and *Neohouzeua dulloa*, in a successional environment. ***Forest Ecology and Management 21: 177-189.***

Rao, R.R (1994). ***Biodiversity in India: Floristic aspects***, Dehra Dun.

Rao. R, I.V, G.Gnanaharan and C.B. sastry (1990 Ed.) ***Bamboos current research.*** Proocedings of the International Bamboo workshop held in Cochin, India from 14-18th Nov. 1988. Published Jointly by Kerala Forest Research Institute, India and International Development Research Centre, Canada.

Rathore,S.K.S, S.P Singh, J.S Singh and A.K Tiwari (1997). Changes in forest cover in a central Himalayan catchment:Inadequacy of assessment based on forest area alone. ***Journal of Environmental Mangement 49: 265-276.***

Raturi, P.D (1938). ***Working plan for the Uttarkashi forest division. Tehri Garhwal state 1939-40 to 1959-60.*** Calcutta.

Rau, M.A (1963). The vegetation around Jumnotri in Tehri Garhwal, U.P. ***Bulletin of Botanical Survey of India 5:277-280.***

Rau, M.A (1975). ***High altitude flowering plants of Himalaya.*** Calcutta.

Rau, M.A.(1974). Vegetation and Phytogeography of Himalaya. In. Mani, M.S (ed.). ***Ecology and biogeography in India.*** Hague.

Rawat, A.S. (1985). Forest movement in Uttar Pradesh Himalaya 1906-1947. In. Singh, J.S. (ed.) ***Environmental regeneration in Himalaya.Concept and strategies.*** Nainital.

Rawat,G.S (1994). Protected areas and conservation of rare endemic plants in the Himalaya. In Pangtey,Y.P.S and R.S rawal (Ed.). ***High altitudes of the Himalaya. (Biogeography, Ecology and conservation).*** Nainital

Rawat,G.S, S Sathyakumar and S.N Prasad (1999). Plant species diversity and community structure in the outer fringes of Kedarnath widlife sanctuary, Western Himalaya: Conservation implications. ***Indian Forester 125 (9):873-882.***

Razi, B.A. (1955). Some observations on plants of South Indian hilltops and their distribution. ***Proc.Natl.Inst.Sci.India 21B: 79-89***

Rikhari, H.C, B.S Adhikari and Y.S Rawat (1997). Woody species composition of temperate forests along an elevational gradient in Indian central Himalaya. ***Journal of Tropical Forest Science 10 (2): 197-211.***

Risser,P.G & E.L Rice (1971). Diversity in tree species in Oklahama forests. ***Ecology 52(5): 876-880.***

Risser,P.G & E.L Rice (1971). Phytosociological analysis of Oklahoma upland forest species. ***Ecology 52(5):940-945.***

Ritchie, M.E and H. Olff (1999). Spatial scaling laws yield a synthetic theory of biodiversity. ***Nature 400: 557-560.***

Rodgers, W.A & H.S Panwar (1988). ***Planning a wildlife protected area network in India. Vol I & II.*** Wildlife Institute of India. Dehradun.

Rowe, J.S (1956) Use of undergrowth species in forestry. ***Ecology 37:461-473.***

Roy, P.S and G.S. Pujar (1998). Scope of remote sensing and geographic information systems in ecosystem management and monitoring. Pages 431-452 in Pathak and Saxena (Ed.) ***Ecology today: An anthology of contemporary ecological research.*** New Delhi.

Roy, P.S, C.B.S. Dutt, R.N. Jadhav, B.K. Rangnath, M.S.R. Murthy, B. Gharai, V.Udaya lakshmi, A.K. Kandya and P.S. Thakkar (1996). IRS-1C data utilization for forestry applications. ***Current Science 70 (7): 606-613.***

Sader, S , A.D. Ahl and Wen-shu Lion (1995). Accuracy of Landsat TM and GIS Rule-based methods for forest wetland classification in Maine ***Remote Sensing of the Environment 53: 133-144.***

Sahai, B and M.M. Kimothi (1994-95). Resource survey of Nanda Devi Biosphere eserve. ***Proc. of ISRS Silver jubilee symposium 1994-95: 26-33.***

Saklani, P.S (1993). ***Geology of the lower Himalaya (Garhwal).*** Delhi.

Samant,S.S, U Dhar and R.S Rawat (1996). Natural resource use by some natives within Nanda Devi Biosphere Reserve in west Himalaya. ***Ethnobotany 8:40-50.***

Saraf, A.K, J.L.Foster, P.Singh and S.Tarafdar (1999). Passive microwave data for snow-depth and snow-extent estimation in the Himalayan mountains. ***International journal of remote sensing 20 (1): 83-95.***

Saxena , M.M (1987). ***Environmental analyses water, soil and air.*** India.

Saxena, A.K & J.S Singh (1982). Quantitative profile structure of certain forests in the Kumaun Himalaya. ***Proeedings of Indian Academy of Sciences (Plant Sci.) 91(6): 529-549.***

Saxena, A.K, T. Pandey & J.S Singh (1985). Altitudinal variation in the vegetation of Kumaun Himalaya pages 43-66. In Rao, D.N et al (Eds). ***Perspectives in Environmental Botany***. Lucknow.

Saxena, H.O and P.B.L Srivastava (1973). Forest communities of Mussoorie. ***Tropical Ecology 14 (2): 197-218.***

Saxena,A.K & J.S Singh (1982). A phytosociological analysis of woody species in forest communities of a part of Kumaun Himalaya. ***Vegetatio 50: 3-22.***

Schweinfurth, U (1957). ***Die Horizontale and vertikale Verbreitung der vegetation in Himalaya.*** Bonn.

Sensarma,P (1989). ***Plants in India Purans-An ethnobotanical investigation.*** Calcutta.

Shah, N.C (1975). Prospects of botanical drugs from hill districts of Uttar Pradesh. ***Indian Drugs 12: 17-23.***

Shah, N.C and M.C. Joshi (1971). An ethnobotanical study of the Kumaun region of India. ***Economic Botany 25: 414-422.***

Shah,N.C (1983). Endangered medicinal and aromatic taxa of U.P. Himalayas. In Jain, S.K and R.R Rao (Eds.). ***An assessment of threatened plants of India.*** Calcutta.

Sharma, B.D (2000). Affinities-Palaeobotanical and geological evidences, relationship with adjacent, past and recent plant migration. Pages 1-200 in Singh et al. (ed.). ***Flora of India. Introductory volume part II***, BSI.

Sharma, B.M (1988). ***Biomass and net primary productivity of Cedrus deodara plantations of the Kullu Himalayas.*** Presented in CHEA and INTACH workshop on "Biomass production and utilization strategies". September 1988. Nainital. India.

Sharma,K (1996). Green gold hunter. ***Science Reporter 33 (6): 16-17.***

Shasby, M and D. Carneggie (1986). Vegetation and terrain mapping in Alaska using Landsat MSS and digital terrain data. ***Photogrammetric Engineering and Remote Sensing 52(6):779-785.***

Shiva, V. and J. Bandhyopadhyay (1986). The evolution, structure and impact of chipko movement. ***Mountain Research and Development 6(2): 133-142.***

Shrestha, R and G.R.Kaltel (1996). Women's indigenous knowledge and attitudes in wildlife conservation: A case study in Padampur village development community (VDC), Royal Chitwan National park, Nepal. ***Tiger Paper 23(3): 20-22.***

Simpson, E.H (1949). Measurement of diversity. ***Nature 163: 688.***

Singh, A, V.S Reddy & J.S Singh (1995). Analysis of woody vegetation of Corbett national park, India. ***Vegetatio 120: 69-79.***

Singh, J.S and S.P Singh (1992). ***Forests of Himalaya. Structure, functioning and impact of man.*** Nainital. India.

Singh, R.V (1982) ***Fodder trees of India.*** New Delhi.

Singh, S.K (1999). ***A study on the plant community composition and species diversity in Great Himalayan National Park, Western Himalaya.*** Ph.D. Thesis. Kumaun University, Nainital.

Singh, S.P & J.S Singh (1986). Structure and function of the central Himalayan oak forests. ***Proceedings of Indian Academy Sciences (Plant Sci.) 96(3): 159-189.***

Singh, S.P, Y.S Rawat & S.C Garkoti (1997). Failure of brown oak (Quercus semecarpifolia) to regenerate in Central Himalaya: A case of environmental surprise. ***Current Science 73(4): 371-374.***

Singh, V.B (1963). ***Working plan for the Uttarkashi forest division. Tehri Garhwal circle. U.P. Parts I & II 1961-62 to 1975-76.*** Nainital.

Singh,H, A Saklani and B Lal (1990). Ethnobotanical observations on some gymnosperms of Garhwal Himalaya. Uttar Pradesh, India. ***Economic Botany 44:349-354.***

Singh,J.S & S.P Singh (1987).Forest vegetation of the Himalaya. ***Botanical Review 53: 80-192.***

Singh,J.S, Y.S Rawat & O.P Chaturvedi (1984). Replacement of oak forest with pine in the Himalaya affects the nitrogen cycle. ***Nature 311:54-56.***

Skole, D and C. Tucker (1993). Tropical deforestation and habitat fragmentation in the Amazon: satellite data from 1978 to 1988. ***Science 26: 1905-1910.***

Srinivas, M.N (2000). Let the villages survive. Pages 58-59 in Anon (ed.) ***A future past the present. Special issue. Hindustan Times.***

Subedi, M.N and P.R Shakya (1988). ***Aboveground biomass and productivity studies of Quercus semecarpifolia Smith forest at Phulchoki hill.*** Presented in CHEA and INTACH workshop on "Biomass production and utilization strategies". September 1988. Nainital. India.

Ter Braak, C.J.F (1986). Canonical Correspondence Analysis: A new eigenvector technique for multivariate direct gradient analysis. ***Ecology 67 (5): 1167-1179.***

Ter Braak, C.J.F (1987). The analysis of vegetation-environment relationships by canonical correspondence analysis. ***Vegatatio 69: 69-77.***

Tisdell,C and Z.Xiang (1996). Reconciling economic development, nature conservation and local communities: Strategies for biodiversity conservation in Xishuangbanna, China. ***The Environmentalist 16: 203-211.***

Tiwari, A.K, A.K. Saxena and J.S Singh (1985). Inventory of forest biomass for Central Himalaya. Pages 236-247 in J.S Singh (ed.) ***Environmental regeneration in the Himalaya: concept and strategies.*** Nainital.

Tiwari, A.K, M. Kudrat and S.K Bhan (1992). Application of IRS-1A data for forest cover and wildlife habitat evaluation. Pages 335-341. In Karale, R.L (ed) ***Natural resource management-A new perspective.*** Bangalore.

Tiwari, A.K, M.Kudrat and M.L. Manchanda (1996). Remote sensing and GIS: Indispensable tools for regional ecological studies. ***Tropical Ecology 37 (1): 79-92.***

Tiwari, K.P (1978). A comparative evaluation of landuse and forest type classification and mapping with aerial photograph vis-à-vis conventional ground stock mapping-A case study in Tehri Garhwal Himalaya. ***Indian Forester :757-767.***

Tiwari, S.C and S.K Gupta (1984). Grassland ecology of Garhwal Himalayas with reference to microclimate and phytosociology. In Paliwal, G.S (Ed.). ***The vegetational wealth of the Himalayas.*** New Delhi.

Tiwari,A.K, J.S Mehta,O.P Goel and J.S Singh (1986). Geo-forestry of landslide affected areas in a part of Central Himalya. Conserv.13: 299

Tiwari,S.C & R.R Mishra (1995). Nodulation status of Alnus nepalensis seedlings in pure stands. ***Jopurnal of Tree Science 14(2): 49-54.***

Treitz, P and P, Howash (2000). Integrating spectral, spatial and terrain variables for forest ecosystem classification. ***Photogrammetric engineering and remote sensing 66 (3): 305-317.***

Tulsidas (1631,samvat). ***Ramcharitmanas.***

Umarani, R and K. Subramaniyam (2000). Modernization of agriculture- A boon or bane?. ***Current Science 79 (11): 1515***

Uniyal,B.P and C.L Malhotra (1984). Economic exploitation of rare North Western Himalayan plants. In Paliwal,G.S (Ed.). ***The vegetational wealth of Himalayas.*** New Delhi.

Uniyal,B.P, S Singh and D.K Singh (1995). ***Plant diversity in the Tehri dam submersible area.*** Calcutta.

Uniyal,M.R (1968). Medicinal plants of Bhagirathi valley lying in Uttarkashi forest division. ***Indian Forester 94:407-420.***

Upreti,D.K & H.R Negi (1996).Folk use of Thamnolia vermicularis (Swartz) Ach. in lata village of Nanda Devi biosphere reserve. ***Ethnobotany 8(1&2):92-95.***

Upreti,N, J.C Tewari & S.P Singh (1985). The oak forests of Kumaun Himalaya (India): Composition, Diversity and regeneration. ***Mountain Research & Development 5(2): 163-174.***

Valdiya K.S (1985). Accelerated erosion and landslide prone zones in the central Himalayan region. In Singh and Singh (Ed.). ***Environmental regeneration in Himalaya. Concept and strategies.*** Nainital.

Valdiya, K.S (1999). Rising Himalaya: Advent and intensification of monsoon. ***Current Science 76(4): 514-524.***

Van Es, E (1972). A reconnaissance survey of the forest vegetation in the Doon valley with the aid of aerial photographs. ***Indian Forester 98: 503-506.***

Van Es, E (1974). Interpretation of the forest vegetation of the Doon valley on ERTS-1 Imagery. ***ITC journal 5: 550-554.***

Vaughan, J.G and C.A. Geissler (1997). ***The new oxford book of food plants.*** New York.

Vishnu-Mittre (1965). Floristic and ecological reconsiderations of the Pleistocene plant impressions from Kashmir. ***Palaeobotanist 13. 308-327.***

Vishnu-Mittre (1984). Floristic change in the Himalaya (Southern slopes) and Siwaliks from the mid-tertiary to the recent times. Pages 483-503 in Whyte (Ed.) ***The evolution of the east Asian environment. Volme II Palaeobotany, Palaeozoology and palaeoanthropology.*** Hong Kong.

Wadia,D.N (1975). ***Geology of India.*** New Delhi.

Whitford, P.B (1949). Distribution of woodland plants in relation to succession and clonal growth. ***Ecology 30: 199-208.***

Whittaker, R.H (1972). Evolution and measurement of species diversity. ***Taxon 21: 213-251.***

Whittaker, R.H and G.M. Woodwell (1969). Structure, production and diversity of the oak-pine forest at Brookhaven, New York. ***Journal of Ecology 57: 155-174.***

Wilson, E.O (1989). Threats to biodiversity. ***Scientific American, September issue : 60-66.***

Wood B (1993). Managing nature. Pages 25-34 in Goldsmith and Warren (ed.) ***Conservation in progress***, New York.

Woodcock, C.E, J.B.Collins, S. Gopal, V.D. Jakabhazy, X.Li. S. Comber, S. Ryherd, V.J. Harward, J. Levitan, Y.Wu and R. Warbington (1994). Mapping forest regeneration using Landsat TM imagery and a canopy reflectance model. ***Remote sensing of the environment 50:240-254.***

Young, R.L (1994). Forest product utilization research: providing technology for wise use. ***Unasylva 45 (177): 38-45.***

Zar, J.H (1984). ***Biostastical analysis*** 2nd edition, USA.

Appendix-7.1: List of plant species

Family	Plant name	Habit
Acanthaceae	Adhatoda zeylanica Medik.	Shrub
	Aechmanthera gossypina Nees	Shrub
	Barleria cristata L.	Herb
	Goldfussia dalhousiana Nees	Herb
	Rungia pectinata (L.) Nees	Herb
	Strobilanthes atropurpureus Nees	Herb
Aceraceae	Acer acuminatum Wall. ex D.Don	Tree
	Acer caesium Wall. ex Brandis	Tree
	Acer laevigatum Wall.	Tree
	Acer oblongum Wall. ex DC.	Tree
Agavaceae	Agave cantula Roxb.	Herb
Amaranthaceae	Achyranthes aspera L.	Herb
	Amaranthus viridis L.	Herb
	Cyathula capitata Moq.	Herb
	Gomphrena celosioides Mart.	Herb
Anacardiaceae	Cotinus coggygria Scop.	Shrub
	Pistacia khinjuk Stocks	Tree
	Rhus chinensis Mill.	Tree
	Rhus parviflora Roxb.	Shrub
	Rhus wallichii Hook.f.	Shrub
Apiaceae	Angelica glauca Edgew.	Herb
	Bupleurum candollii Wall. ex DC.	Herb
	Bupleurum longicaule Wall. ex DC	Herb
	Bupleurum hamiltonii Balak.	Herb
	Centella asiatica (L.) Urb.	Herb
	Cortia depressa (D.Don) Norman	Herb
	Ferula jaeschkeana Vatke	Herb
	Foeniculum vulgare Mill.	Herb
	Heracleum lanatum Michx.	Herb
	Heracleum pinnatum Michx.	Herb
	Heracleum thomsonii Clarke	Herb
	Pimpinella diversifolia DC.	Herb
	Pleurospermum candollii (DC.) Clarke	Herb
	Pleurospermum stellatum (Don) Clarke	Herb
	Selinum vaginatum (Edgew.) Clarke	Herb
	Selinum wallichianum Raizada & Saxena	Herb
	Seseli sibiricum Benth.	Herb
	Vicatia coniifolia DC.	Herb
Apocynaceae	Ichnocarpus frutescens (L.) R.Br.	Climber
	Vallaris solanacea (Roth) Kuntze.	Climber
Aquifoliaceae	Ilex dipyrena Wall.	Tree
Araceae	Acorus calamus L.	Herb
	Arisaema flavum (Forsk.) Schott	Herb
	Arisaema intermedium Bl.	Herb
	Arisaema tortuosum (Wall.) Schott	Herb
	Colocasia esculenta (L.) Schott	Herb
	Typhonium diversifolium Scholtz. ex Lind.	Herb
Araliaceae	Hedera nepalensis Koch	Climber
Asclepiadceae	Cynanchum glaucum Wall.	Herb
	Cynanchum vincetoxicum (L.) Pers.	Herb
Aspleniaceae	Asplenium falcatum Lam.	Herb
Asteraceae	Ainsliaea aptera DC.	Herb
	Ainsliaea latifolia Sch.-Bip.	Herb
	Anaphalis busua (Buch.-Ham.ex D.Don) DC.	Herb
	Anaphalis contorta (D.Don) Hook.f.	Herb
	Anaphalis royleana DC.	Herb
	Anaphalis triplinervis (Sims.) Clarke	Herb
	Artemisia dubia Wall. ex Bess. var. dubia	Herb
	Artemisia dubia Wall. ex Bess. var. Intermedia (DC.) Airy-Shaw	Herb
	Artemisia japonica Thunb.	Herb

	Artemisia macrocephala Jacq. ex Bess.	Herb
	Artemisia nilagirica (Clarke) Pamp.	Herb
	Artemisia roxburghiana Wall.ex Bess.	Herb
	Artemisia capillaris Thunb.	Herb
	Artemisia sieversiana Ehrh. ex Willd.	Herb
	Artemisia stricta Edgew.	Herb
	Artemisia gmelinii Web. ex Stech. var. vestita (Wall. ex DC.) Naithani	Herb
	Aster albescens (DC.) Hand.-Mazz.	Herb
	Aster peduncularis Wall. ex Nees	Herb
	Aster thomsonii Clarke	Herb
	Bidens pilosa L.	Herb
	Bidens tripartita L.	Herb
	Blainvillea acmella (L.) Philipson	Herb
	Brachyactis pubescens (DC.) Aitch. & Clarke	Herb
	Brachyactis roylei (DC.) Wendelbo.	Herb
	Carduus edelbergii Reich.f.	Herb
	Cicerbita macrorhiza (Royle) Beauv.	Herb
	Cirsium falconeri (Hook.f.) Petrak	Herb
	Cirsium verutum (D.Don) Spreng.	Herb
	Conyza canadensis (L.) Cronq.	Herb
	Cousinia thomsonii Clarke	Herb
	Cremanthodium arnicoides (Wall.) R.Good.	Herb
	Dichrocephala integrifolia Kuntze.	Herb
	Eclipta prostata (L.) L.	Herb
	Erigeron alpinus L.	Herb
	Eupatorium adenophorum Spreng.	Herb
	Galinsonga parviflora Cav.	Herb
	Gnaphalium luteo-album L. ssp. affine (D.Don) Koster	Herb
	Inula cappa (Buch.-Ham. ex D.Don) DC.	Shrub
	Inula cuspidata (DC.) Clarke	Shrub
	Jurinea dolomiaea Boiss.	Herb
	Lactuca dissecta D.Don	Herb
	Lactuca dolichophylla Kitam.	Herb
	Parthenium hysterophorus L.	Herb
	Saussurea albescens (DC.) Sch.-Bip.	Herb
	Saussurea ceratocarpa Decne.	Herb
	Saussurea gnaphalodes (Royle ex DC.) Sch.-Bip.	Herb
	Saussurea gossypiphora D.Don	Herb
	Saussurea obvallata (DC.) Edgew.	Herb
	Saussurea roylei (DC.) Sch.-Bip.	Herb
	Seigesbeckia orientalis L.	Herb
	Senecio laetus Edgew.	Herb
	Senecio graciliforus DC.	Herb
	Senecio krascheninnikovil Schischk.	Herb
	Senecio nudicaulis Buch.-Ham.	Herb
	Solidago virga-aurea L.	Herb
	Sonchus asper Vill.	Herb
	Synotis alata (Wall.ex DC.) Jeffrey & Chen	Herb
	Synotis kunthiana (Wall.ex DC.) Jeffery & Chen	Herb
	Synotis rufinervis (DC.) Jeffery & Chen	Herb
	Tagetes minuta L.	Herb
	Taraxacum officinale Weber	Herb
	Tridax procumbens L.	Herb
	Waldheimia tomentosa (Decne.) Regel	Herb
	Youngia japonica (L.) DC.	Herb
Balsaminaceae	Impatiens bicornuta Wall.	Herb
	Impatiens brachycentra Kar. & Kir.	Herb
	Impatiens cristata Wall.	Herb
	Impatiens scabrida DC.	Herb
	Impatiens sulcata Wall.	Herb
Begoniaceae	Begonia amoena Wall. ex DC.	Herb
Berberidaceae	Berberis aristata DC.	Shrub
	Berberis asiatica Roxb. ex DC.	Shrub

	Berberis chitria Lindl.	Shrub
	Berberis jaeschkeana Schneid.	Shrub
	Berberis lycium Royle	Shrub
	Berberis pseudoumbellata Parker	Shrub
Betulaceae	Alnus nepalensis D.Don	Tree
	Betula alnoides Buch.-Ham.	Tree
	Betula utilis D.Don	Tree
	Carpinus viminea Lindl.	Tree
Bombacaceae	Bombax ceiba L.	Tree
Boraginaceae	Arnebia benthamii Johnston	Herb
	Arnebia euchroma (Roxb.) John.	Herb
	Cynoglossum glochidiatum Wall. ex Benth.	Herb
	Cynoglossum lanceolatum Forssk.	Herb
	Cynoglossum zeylanicum (Vahl) Thunb. ex Lehm.	Herb
	Eritrichum canum (Benth.) Kitam.	Herb
	Lindelofia stylosa (Kar. & Kir.) Brand.	Herb
	Lappula barbata (M.Bieb.) Gurke	Herb
	Onosma echioides Gaertn.	Herb
Brassicaceae	Arabidopsis himalaica (Edgew.) Schult.	Herb
	Arabidopsis thaliana (L.) Heynh.	Herb
	Arabis pterosperma Edgew.	Herb
	Arabis tibetica Hook.f. & Thoms.	Herb
	Capsella bursa-pastoris (L.) Medik.	Herb
	Cardamine scutata Thunb.	Herb
	Descurainia sophia (L.) Webb. ex Prantl.	Herb
	Erysimum hieracifolium L.	Herb
	Lepidium sativum L.	Herb
	Lepidium virginicum L.	Herb
	Thlaspi arvense L.	Herb
	Turritis glabra L.	Herb
Buddlejaceae	Buddleja asiatica Lour.	Shrub
Buxaceae	Buxus wallichiana Baill.	Tree
	Sarcococca saligna (D.Don) Muell.-Arg.	Shrub
Caesalpiniaceae	Bauhinia semla Wunderlin	Tree
	Bauhinia vahlii Wt.& Arn.	Tree
	Bauhinia variegata L.	Tree
	Cassia occidentalis L.	Herb
	Cassia tora L.	Herb
	Ceasealpinia decapetala (Roth) Alston	Shrub
Campanulaceae	Campanula alsinoides Hook.f. & Thoms.	Herb
	Campanula argyrotricha Wall. ex DC.	Herb
	Campanula aristata Wall. ex Roxb.	Herb
	Campanula colorata (D.Don) Hook.f.	Herb
Cannabaceae	Cannabis sativa L.	Herb
Caprifoliaceae	Abelia triflora R.Br. ex Wall.	Shrub
	Leycesteria formosa Wall.	Shrub
	Lonicera angustifolia Wall. ex DC.	Shrub
	Lonicera asperifolia Hook.f & Thoms.	Shrub
	Lonicera hypoleuca Decne.	Shrub
	Lonicera myrtillus Willd.ex Roem.& Schult.	Shrub
	Lonicera obovata Roxb. ex Hook.f. & Thoms.	Shrub
	Lonicera quinquelocularis Hardw.	Shrub
	Lonicera rupicola Hook.f.& Thoms.	Shrub
	Lonicera spinosa (Jacq. ex Decne.) Walp.	Shrub
	Viburnum cotinifolium D.Don	Shrub
	Viburnum cylindricum Buch.-Ham.ex D.Don	Shrub
	Viburnum mullaha Buch.-Ham. ex D.Don	Shrub
	Viburnum nervosum D.Don	Herb
Caryophyllaceae	Arenaria festucoides Royle	Herb
	Arenaria neelgherrensis Wt.& Arn.	Herb
	Arenaria serpyllifolia L.	Herb
	Cucubalus bacciferus L.	Herb
	Dianthus angulatus Royle	

	Lychnis brachypetala Hornem	Herb
	Minuartia kashmirica (Edgew.) Mattf	Herb
	Silene edgeworthii Bocquet	Herb
	Silene gonosperma (Rupr.) Bocquet ssp. himalayensis (Rohrb.) Bocquet	Herb
	Silene griffithii Boiss.	Herb
	Silene tenuis Willd.	Herb
	Silene vulgaris (Moench) Garcke	Herb
	Stellaria himalayensis Majumdar	Herb
	Stellaria media (L.) Vill.	Herb
	Stellaria monosperma Buch.-Ham. ex D.Don	Herb
	Stellaria monosperma var. paniculata (Edgew.) Majumdar	Herb
	Thylacospermum caespitosum (Camb.) Schischkin	Herb
Celastraceae	Cassine glauca (Rottb.) Kuntze	Tree
	Euonymus echinatus Wall.	Tree
	Euonymus fimbriatus Wall.	Tree
	Euonymus tingens Wall.	Tree
	Euonymus hamiltonianus	Tree
Chenopodiaceae	Axyris amaranthoides L.	Herb
	Chenopodium album L.	Herb
	Chenopodium botrys L.	Herb
	Chenopodium foliolosum (Moench) Asch.	Herb
	Chenopodium hybridum L.	Herb
	Chenopodium murale L.	Herb
Commelinaceae	Commelina paludosa Bl.	Herb
Convolvulaceae	Convolvulus arvensis L.	Herb
	Ipomoea eriocarpa R.Br.	Herb
	Ipomoea quamoclit L.	Herb
Coriariaceae	Coriaria nepalensis Wall.	Shrub
Cornaceae	Benthamidia capitata (Wall.) Hara	Tree
	Cornus macrophylla Wall.	Tree
Corylaceae	Corylus jacquemontii Dcne.	Tree
Crassulaceae	Rosularia alpestris (Kar. & Kir.) Boiss.	Herb
	Sedum ewersii Ledeb.	Herb
	Sedum linearifolium Royle	Herb
	Sedum tibeticum Hook. f. & Thoms.	Herb
	Sedum trifidum Wall.	Herb
Cucurbitaceae	Trichosanthes anguina L	Herb
Cupressaceae	Cupressus torulosa D.Don	Tree
	Juniperus communis L.	Shrub
	Juniperus polycarpos Koch$	Tree
	Juniperus squamata Buch.-Ham	Shrub
	Juniperus wallichiana Brandis	Shrub
Cuscutaceae	Cuscuta europea L.	Parasitic herbs
	Cuscuta reflexa Roxb.	Parasitic herbs
Cyperaceae	Carex breviculmis R.Br.	Herb
	Carex cruciata Wahlenb.	Herb
	Carex infuscata Nees	Herb
	Carex neiogyna Strachey	Herb
	Carex nivalis Boott	Herb
	Carex nubigena D.Don	Herb
	Carex obscura Nees	Herb
	Carex setigera D.Don	Herb
	Cyperus niveus Retz.	Herb
	Cyperus paniceus (Rottb.) Boeck.	Herb
	Eriophorum comosum Wall.ex Nees	Herb
	Fimbristylis complanata (Retz.) Link	Herb
	Fimbristylis dichotoma (L.) Vahl	Herb
	Kobresia royleana (Nees) Boeck.	Herb
Daphniphyllaceae	Daphniphyllum himalayense (Benth.) Muell.-Arg.	Tree
Datiscaceae	Datisca cannabina L.	Shrub
Dioscoreaceae	Dioscorea belophylla (Prain) Haines	Twiner
	Dioscorea bulbifera L.	Twiner
	Dioscorea deltoidea Wall. ex Griseb.	Twiner

Dipsacaceae	Dipsacus mitis D.Don	Herb
	Morina coulteriana Royle	Herb
	Morina longifolia Wall. ex DC.	Herb
Elaeagnaceae	Elaeagnus parvifolia Wall.ex Royle	Shrub
	Hippophae salicifolia D.Don	Shrub
Ephedraceae	Ephedra gerardiana Wall. ex Stapf	Shrub
Ericaceae	Cassiope fastigiata D.Don	Shrub
	Gaultheria nummularioides D.Don	Shrub
	Gaultheria trichophylla Royle	Shrub
	Lyonia ovalifolia (Wall.) Drude	Tree
	Rhododendron arboreum Smith	Tree
	Rhododendron campanulatum D.Don	Shrub
	Rhododendron hypenanthum Balf.f	Shrub
	Rhododendron lepidotum Wall. ex D.Don	Shrub
Euphorbiaceae	Euphorbia emodi Hook.f.	Herb
	Euphorbia hirta L.	Herb
	Euphorbia royleana Boiss.	Shrub
	Euphorbia strachyei Boiss.	Herb
	Euphorbia tibetica Boiss.	Herb
	Mallotus philippinensis (Lam.) Muell.-Arg.	Tree
	Sapium insigne (Royle) Benth. ex Hook.f.	Tree
Fagaceae	Quercus floribunda Rehder	Tree
	Quercus lanata Sm.	Tree
	Quercus semecarpifolia Sm.	Tree
	Quercus leucotrichophora A. camus	Tree
Flacourtiaceae	Casearia tomentosa Roxb.	Tree
	Xylosma longifolium Clos.	Tree
Fumariaceae	Corydalis cashmeriana Royle	Herb
	Corydalis stracheyi Wall. ex DC.	Herb
	Corydalis vaginans Royle	Herb
	Fumaria indica Pugsley	Herb
Gentianaceae	Gentiana argentea DC.	Herb
	Gentiana capitata Buch.-Ham. ex D.Don	Herb
	Gentiana coronata Royle	Herb
	Gentiana tianschanica Rupr.	Herb
	Gentianella tenella (Rottb.) Bornm.	Herb
	Gentianella paludosa (Hook.f.) Ma	Herb
	Swertia angustifolia Buch.-Ham.	Herb
	Swertia chirayita (Roxb. ex Flem.) Karsten	Herb
	Swertia ciliata (G.Don) Burtt	Herb
	Swertia cordata Clarke	Herb
	Swertia petiolata D.Don	Herb
	Swertia speciosa D.Don	Herb
Geraniaceae	Geranium collinum Steph. ex Willd.	Herb
	Geranium nepalense Sw.	Herb
	Geranium ocellatum Camb.	Herb
	Geranium pratense L.	Herb
	Geranium wallichianum D.Don ex Sw.	Herb
Grossulariaceae	Ribes alpestre Wall. ex Dcne.	Shrub
	Ribes glaciale Wall.	Shrub
	Ribes grossularia L.	Shrub
	Ribes orientale Desf.	Shrub
Hippocastanaceae	Aesculus indica (Colebr.ex Camb.) Hook.	Tree
Hydrangeaceae	Deutzia corymbosa R.Br.	Shrub
	Deutzia staminea R.Br. ex Wall.	Shrub
Hyperiaceae	Hypericum elodeoides Choisy	Shrub
	Hypericum oblongifolium Choisy	Shrub
	Hypericum perforatum L.	Herb
Iridaceae	Iris duthiei Foster	Herb
	Iris kumaonensis Wall. ex D.Don	Herb
Juglandaceae	Juglans regia L.	Tree
Juncaceae	Juncus concinnus D.Don	Herb
	Juncus himalensis Klotz.& Garcke.	Herb

	Juncus membranaceus Royle	Herb
	Luzula multiflora Lej.	Herb
	Luzula spicata DC.	Herb
Lamiaceae	Ajuga bracteosa Wall. ex Benth.	Herb
	Anisomeles indica (L.) Kuntz.	Herb
	Clinopodium umbrosum (M.Bieb.) Koch	Herb
	Clinopodium vulgare L.	Herb
	Colebrookea oppositifolia Sm.	Shrub
	Elscholtzia ciliata (Thunb.) Hayland.	Herb
	Elscholtzia eriostachya (Benth.) Benth.	Herb
	Elsholtzia fruticosa (D.Don) Rehder	Shrub
	Elsholtzia strobilifera Benth.	Herb
	Hyssopus officinalis L.	Herb
	Isodon plectranthoides Schrad ex Kudo	Herb
	Lamium rhomboideum Benth.	Herb
	Mentha longifolia (L.) Huds.	Herb
	Micromeria biflora (Buch.-Ham ex D.Don) Benth.	Herb
	Nepeta discolor Benth.	Herb
	Nepeta erecta (Royle ex Benth.) Benth.	Herb
	Nepeta eriostachya Benth.	Herb
	Nepeta govaniana Benth.	Herb
	Nepeta hindostana (Heyne ex Roth) Haines.	Herb
	Origanum vulgare L.	Herb
	Phlomis bracteosa Royle	Herb
	Plectranthus japonicus (Burm.f.) Koidzuma	Shrub
	Plectranthus rugosus Wall. ex Benth.	Shrub
	Pogostemon benghalense (Burm.f.) O.Kuntz.	Herb
	Salvia hians Royle ex Benth.	Herb
	Salvia lanata Roxb.	Herb
	Salvia moorcroftiana Wall. ex Benth.	Herb
	Salvia nubicola Wall.ex Sw.	Herb
	Scutellaria prostrata Jacq. ex Benth.	Herb
	Scutellaria scandens D.Don	Herb
	Thymus linearis Benth.	Herb
Lauraceae	Cinnamomum tamala Nees	Tree
	Lindera pulcherrima (Nees) Benth. ex Hook.f.	Small tree
	Litsea monopetala Roxb.	Small tree
	Litsea umbrosa	tree
	Neolitsea cuipala (Buch.-Ham.ex D.Don) Kosterm.	tree
	Persea duthiei King ex Hook.f.	tree
Liliaceae	Allium carolinianum DC.	Herb
	Allium humile Kunth	Herb
	Allium stracheyi Baker	Herb
	Allium prattii Wright	Herb
	Asparagus adscendens Buch.-Ham. ex Roxb.	Herb
	Asparagus filicinus Buch.-Ham.ex D.Don.	Herb
	Asparagus racemosus Willd.	Herb
	Cardiocrinum giganteum (Wall.) Makino	Herb
	Daiswa polyphylla (Sm.) Rafin.	Herb
	Fritillaria roylei Hook.	Herb
	Gagea lutea (L.) Ker.-Gwal	Herb
	Lilium polyphyllum D.Don.	Herb
	Polygonatum cirrhifolium (Wall.) Royle	Herb
	Polygonatum verticillatum (L.) All.	Herb
Linaceae	Reinwardtia indica Dumort	Herb
Lythraceae	Woodfordia fruticosa (L.) Kurz	Shrub
Malvaceae	Kydia calycina Roxb.	Tree
	Malva rotundifolia L.	Herb
	Malvastrum coromandelianum (L.) Garcke.	Herb
	Sida cordata (Burm.f.) Borss.	Shrub
	Sida cordifolia L.	Shrub
	Sida rhombifolia L.	Shrub
	Urena lobata L.	Shrub

Magnoliaceae	Michelia kisopa Buch.-Ham.ex DC.	Tree
Meliaceae	Melia azederach L.	Tree
	Toona sinensis (A.Juss.) Roem	Tree
Menispermaceae	Cissampelos pareira L.	climber
Mimosaceae	Albizia chinensis (Osbeck.) Merr.	Tree
	Albizia julibrissin Durazz.	Tree
	Mimosa himalayana Gamble	Shrub
Moraceae	Ficus sarmentosa Buch.-Ham. ex J.E.Sm.	climber
	Ficus palmata Forssk.	Tree
	Ficus semicordata Buch.-Ham.ex Sm.	Tree
	Morus serrata Roxb.	Tree
Myricaceae	Myrica esculenta Buch.-Ham. ex D.Don	Tree
Myrsinaceae	Myrsine africana L.	Tree
Nyctaginaceae	Boerhavia diffusa L.	Herb
	Oxybaphus himalaicus Edgew.	Herb
Oleaceae	Fraxinus micrantha Linge.	Tree
	Jasminum humile L.	Shrub
	Jasminum officinale L.	Shrub
	Syringa emodi Wall. ex G.Don	Tree
Onagraceae	Circaea alpina L.	Herb
	Epilobium brevifolium D.Don	Herb
	Epilobium cylindricum D.Don	Herb
	Epilobium latifolium L.	Herb
	Epilobium minutiflorum Haussk.	Herb
	Epilobium palustre L.	Herb
	Epilobium royleanum Haussk.	Herb
	Oenothera rosea Ait.	Herb
Orchidaceae	Aorchis spathulata (Lindl.) Vermeul.	Herb
	Calanthe tricarinata Lindl.	Herb
	Cymbidium macrorhizon Lindl.	Herb
	Dactylorhiza hatagirea (D.Don) Soo	Herb
	Dendrobium monticola Hunt et Summerh.	Herb
	Epipactis gigantea Dougl. ex Hook.	Herb
	Epipactis helleborine (L.) Crantz.	Herb
	Epipogium aphyllum (Schmidt.) Swartz.	Herb
	Goodyera repens (L.) R.Br.	Herb
	Habenaria ensifolia L.	Herb
	Habenaria intermedia D.Don	Herb
	Habenaria marginata Colebr.	Herb
	Herminium lanceum (Thunb. ex Sw.) Vuijk.	Herb
	Malaxis cylindrostachya (Lindl.) Ktze.	Herb
	Malaxis muscifera (Lindl.) O.Ktze.	Herb
	Oberonia pachyrachis Rchb.f.	Herb
	Pecteilis gigantea (Smith) Rafin.	Herb
	Satyrium nepalense D.Don	Herb
	Spiranthes sinensis (Pers.) Ames	Herb
Orobanchaceae	Orobanche epithymum DC.	Parasitic herb
Oxalidaceae	Oxalis corniculata L.	Herb
Paeoniaceae	Paeonia emodi Wall.ex Royle	Herb
Parnassiaceae	Parnassia nubicola Wall. ex Wight.	Herb
Papaveraceae	Meconopsis aculeata Royle	Herb
	Papaver somniferum L.	Herb
Papilionaceae	Astragalus amherstianus Royle ex Benth.	Herb
	Astragalus candolleanus Royle ex Benth.	Herb
	Astragalus coluteocarpus Boiss.	Herb
	Astragalus himalayanus Klotz.	Herb
	Astragalus multiceps Wall. ex Baker	Herb
	Astragalus peduncularis Royle ex Baker	Herb
	Cicer microphyllum Benth.	Herb
	Crotalaria albida Heyne ex Roxb.	Herb
	Desmodium elegans DC.	Shrub
	Desmodium gangeticum (L.) DC.	Shrub
	Desmodium laxiflorum DC.	Shrub

	Desmodium triflorum (L.) DC.	herb
	Erythrina suberosa Roxb.	Herb
	Indigofera cassioides Rottl. ex DC.	Shrub
	Indigofera dosua Buch.-Ham. ex D.Don	Shrub
	Indigofera heterantha Wall. ex Brandis	Shrub
	Lespedeza juncea (L.f.) Pers. var. sericea (Thunb.) Lace & Hemsley	Shrub
	Mucuna pruriens (L.) DC.	climber
	Oxytropis duthieana Ali	Herb
	Oxytropis tatarica Jacq.ex Royle	Herb
	Parochetus communis Buch.-Ham. ex D.Don	Herb
	Piptanthus nepalensis (Hook.f) D.Don	Shrub
	Thermopsis barbata Royle	Herb
	Trigonella emodi Benth.	Herb
	Vicia sativa L.	Herb
Phytolaccaceae	Phytolacca acinosa Roxb.	Herb
Pinaceae	Abies pindrow Royle	Tree
	Cedrus deodara (Royle ex D.Don) G. Don	Tree
	Picea smithiana (Wall.) Boiss.	Tree
	Pinus roxburghii Sarg.	Tree
	Pinus wallichiana Jacks.	Tree
Plantaginaceae	Plantago depressa Willd.	Herb
	Plantago himalaica Pilger	Herb
	Plantago major L.	Herb
Poaceae	Agrostis canina L.	Herb
	Agrostis pilosula Trin.	Herb
	Agrostis stolonifera L.	Herb
	Andropogon munroi Clarke	Herb
	Apluda mutica L.	Herb
	Arthraxon lancifolius (Trin.) Hochst.	Herb
	Arundinella nepalensis Trin.	Herb
	Brachiaria ramosa (L.) Stapf	Herb
	Bromus ramosus Huds.	Herb
	Calamagrostis emodensis Griseb.	Herb
	Calamagrostis lahulensis Singh	Herb
	Calamagrostis pseudophragmites (Hall.f.) Koeler	Herb
	Capillipedium assimile (Steud.) A.camus	Herb
	Chrysopogon gryllus (L.) Trin.	Herb
	Cymbopogon distans (Nees ex Steud.) W.Wats.	Herb
	Cymbopogon martinii (Roxb.) Wats.	Herb
	Cynodon dactylon (L.) Pers.	Herb
	Dactylis glomerata L.	Herb
	Danthonia cachemyriana Jaub.& Spach.	Herb
	Elymus nutans Griseb.	Herb
	Elymus semicostatus (Nees ex Steud.) Meld.	Herb
	Eragrostis nigra Nees ex Steud.	Herb
	Eulalia mollis (Griseb.) Kuntz.	Herb
	Eulaliopsis binata (Retz.) C.E.Hubb.	Herb
	Festuca gigantea Vill.	Herb
	Festuca rubra L.	Herb
	Festuca valesiaca Schleich. ex Gaud.	Herb
	Helictotrichon pratense (L.) Pilger	Herb
	Helictotrichon virescens (Ness ex Steud.) Henr.	Herb
	Hordeum vulgare L.	Herb
	Imperata cylindrica (L.) Raeusch.	Herb
	Melica canescens (Regl.) Lavernko.	Herb
	Oplismenus compositus (L.) P.Beauv.	Herb
	Oryzopsis lateralis (Regel.) Stapf	Herb
	Pennisetum flaccidum Griseb.	Herb
	Pennisetum lanatum Klotz.	Herb
	Pennisetum orientale Rich.	Herb
	Phacelurus speciosus (Steud.) C.E. Hubb.	Herb
	Poa annua L.	Herb
	Poa nepalensis Wall.ex Duthie	Herb

	Poa pagophila Bor	Herb
	Polypogon monspeliensis Desf.	Herb
	Setaria glauca (L.) P.Beauv.	Herb
	Sinarundinaria falcata (Nees) Chao & Renvoize	Shrub
	Stipa jacquemontii Jaub. et Spach.	Herb
	Stipa roylei (Nees) Mez.	Herb
	Thamnocalamus spathiflorus (Trin.) Munro	Shrub
	Themeda anathera (Nees ex Steud.) Hack.	Herb
Podophyllaceae	Podophyllum hexandrum Royle	Herb
Polygonaceae	Bistorta affinis (D.Don) Green	Herb
	Bistorta vivipara (L.) S.F. Grey	Herb
	Fagopyrum dibotrys (D.Don) Hara	Herb
	Fagopyrum esculentum Moench	Herb
	Oxyria digyna Hill.	Herb
	Polygonum nepalense Meisn.	Herb
	Polygonum amplexicaule D.Don	Herb
	Polygonum capitatum Buch.-Ham. ex D.Don	Herb
	Polygonum chinense L.	Herb
	Polygonum islandicum (L.) Hook.f.	Herb
	Polygonum plebejum R.Br.	Herb
	Polygonum polystachyum Wall.ex Meisn.	Shrub
	Polygonum recumbens Royle ex Bab.	Herb
	Polygonum sinuatum Royle	Herb
	Polygonum tortuosum D.Don	Herb
	Rheum australe D.Don	Herb
	Rheum webbianum Royle	Herb
	Rumex hastatus D.Don	Herb
	Rumex nepalensis Spreng.	Herb
	Rumex orientalis Bernh. ex Schultz.	Herb
Primulaceae	Androsace lanuginosa Wall.	Herb
	Androsace primuloides (Hook.f.) Duby	Herb
	Androsace rotundifolia Hardw.	Herb
	Lysimachia pyramidalis Wall.	Herb
	Primula denticulata Smith	Herb
	Primula petiolaris Wall.	Herb
	Androsace umbellata (Lour.) Merr.	Herb
Ranunculaceae	Aconitum falconeri Stapf	Herb
	Aconitum heterophyllum Wall.	Herb
	Aconitum violaceum Jacq. ex Stapf	Herb
	Actaea spicata Wall. ex Royle	Herb
	Anemone obtusifolia D.Don	Herb
	Anemone rupicola Camb.	Herb
	Anemone tetrasepala Royle	Herb
	Aquilegia pubiflora Wall. ex Royle	Herb
	Clematis buchananiana DC.	climber
	Clematis gouriana Roxb. ex DC.	climber
	Clematis montana Buch.-Ham. ex DC.	climber
	Delphinium denundatum Wall.	Herb
	Ranunculus diffusus DC.	Herb
	Ranunculus hirtellus Royle ex D.Don	Herb
	Ranunculus laetus Wall. ex Royle	Herb
	Thalictrum alpinum L.	Herb
	Thalictrum cultratum Wall.	Herb
	Thalictrum foetidum L.	Herb
	Thalictrum foliolosum DC.	Herb
	Thalictrum javanicum Blume	Herb
	Thalictrum minus L.	Herb
	Thalictrum reniforme Wall.	Herb
Rhamnaceae	Rhamnus prostrata Jacq. ex Parker	Shrub
	Rhamnus triqueter (Wall.) Lawson	Shrub
	Rhamnus virgatus Roxb.	Shrub
	Ziziphus mauritiana Lamk.	Shrub
Rosaceae	Acomastylis elata (Wall.ex Royle) Bolle	Herb

	Agrimonia eupatorium L.	Herb
	Agrimonia pilosa Ledeb.	Herb
	Cotoneaster acuminatus Lindl.	Shrub
	Cotoneaster bacillaris Wall.ex Lindl.	Shrub
	Cotoneaster microphyllus Wall. ex Lindl.	Shrub
	Cotoneaster rosea Edgew.	Shrub
	Fragaria nubicola Lindl.ex Lacaita	Herb
	Potentilla argyrophylla Wall.ex Lehm.	Herb
	Potentilla astrisanguinea Lodd.	Herb
	Potentilla biflora Willd.ex Schlecht.	Herb
	Potentilla cuneifolia Bertol	Herb
	Potentilla eriocarpa Wall. ex Lehm.	Herb
	Potentilla fruticosa L.	Herb
	Potentilla fulgens Wall.	Herb
	Potentilla microphylla D.Don	Herb
	Potentilla nepalensis Hook.	Herb
	Potentilla peduncularis D.Don	Herb
	Prinsepia utilis Royle.	Shrub
	Prunus cerasoides D.Don	Tree
	Prunus cornuta (Wall.ex Royle)Steud.	Tree
	Pyracantha crenulata (Don) Roem.	Shrub
	Pyrus lanata D.Don	Tree
	Pyrus pashia Buch.-Ham.ex D.Don	Tree
	Rosa brunonii Lindl.	Shrub
	Rosa macrophylla Lindl.	Shrub
	Rosa moschata Herrm.	Shrub
	Rosa sericea Lindl.	Shrub
	Rosa webbiana Wall.ex Royle	Shrub
	Rubus ellipticus Smith	Shrub
	Rubus niveus Thunb.	Shrub
	Rubus paniculatus Smith	Shrub
	Sibbaldia cuneata Hornem.ex Ktze.	Shrub
	Sorbaria tomentosa (Lindl.) Vill.	Shrub
	Sorbus foliolosa (Wallich) Spach.	Tree
	Spiraea bella Sims.	Shrub
	Spiraea canescens D.Don	Shrub
Rubiaceae	Asperula cynanchica L.	Herb
	Galium aparine L.	Herb
	Galium mollugo L. subsp. asperifolium (Wall.) Kitam	Herb
	Galium kumaonense Bhattacharya	Herb
	Galium pauciflorum Bunge.	Herb
	Galium rotundifolium L.	Herb
	Galium serpylloides Royle ex Hook.f.	Herb
	Galium verum L.	Herb
	Leptodermis lanceolata Wall.	Shrub
	Rubia manjith Roxb.ex Fleming	climber
	Rubia tibetica Hook.f.	Herb
	Wendlandia puberula DC.	Tree
Rutaceae	Boeninghausenia albiflora (Hook.) Meissn.	Herb
	Dictamnus albus L.	Shrub
	Skimmia anquitilia N.P.Taylor & Airy-Shaw	Shrub
	Zanthoxylum armatum DC.	Shrub
Salicaceae	Populus ciliata Wall. ex Royle	Tree
	Salix denticulata Anders.	Shrub
	Salix Karelinii Turcz. ex Stschel.	Shrub
	Salix lindleyana Wall. ex Anders.	Shrub
	Salix sericarpa Anders.	Shrub
	Salix wallichiana Anders.	Tree
Santalaceae	Thesium himalense Royle ex Edgew.	Herb
Sapindaceae	Dodonaea viscosa Jacq.	Shrub
Saxifragaceae	Astilbe rivularis Buch.-Ham. ex D.Don	Herb
	Bergenia ciliata (Haw.) Sternb.	Herb
	Bergenia stracheyi (Hook.f. et Thoms.) Engl.	Herb

	Saxifraga brunoni Wall.ex Ser.	Herb
	Saxifraga filicaulis Wall.	Herb
	Saxifraga pallida Wall. ex DC.	Herb
Scrophulariaceae	Bacopa monnieri (L.) Pennell	Herb
	Digitalis lanata Ehrh.	Herb
	Euphrasia officinalis L.	Herb
	Euphrasia platyphylla Pennell	Herb
	Hemiphragma heterophyllum Wall.	Herb
	Leptorhabdos parviflora (Benth.) Benth.	Herb
	Mazus surculosus D.Don	Herb
	Pedicularis bicornuta Klotz.	Herb
	Pedicularis carnosa Wall.	Herb
	Pedicularis hoffmeisteri Klotz.	Herb
	Pedicularis pectinata Wall. ex Benth.	Herb
	Picrorhiza kurrooa Royle ex Benth.	Herb
	Scrophularia dentata Royle ex Benth.	Herb
	Scrophularia himalensis Royle	Herb
	Verbascum thapsus L.	Herb
	Veronica agrestis L.	Herb
	Veronica cana Wall.	Herb
	Veronica lanosa Royle ex Benth.	Herb
Smilacaceae	Smilax aspera L.	Shrub
	Smilax glaucophylla Klotz.	Herb
	Smilax pallida Royle	Herb
	Smilax zeylanica L.	Herb
Solanaceae	Datura stramonium L.	Herb
	Physalis minima L.	Herb
	Physochlaina praealta (Decne.) Miers.	Herb
	Solanum indicum L.	Herb
	Solanum nigrum L.	Herb
Symplocaceae	Symplocos chinensis Druce	Tree
	Symplocos paniculata (Thunb.) Miq.	Tree
	Symplocos racemosa Roxb.	Tree
Tamaricaceae	Myrtama elegans (Royle) Ovch. & Kinz.	Shrub
Taxaceae	Taxus Wallichiana Zucc.	Tree
Thymelaeaceae	Daphne papyracea Wall. ex Steud.	Shrub
	Wikstroemia canescens Meissn.	Shrub
Tiliaceae	Triumfetta rhomboidea Jacq.	Shrub
Ulmaceae	Celtis australis L.	Tree
	Ulmus wallichiana Planch.	Tree
Urticaceae	Boehmeria platyphylla D.Don	Shrub
	Boehmeria rugulosa Wedd.	Shrub
	Debregeasia salicifolia (D.Don) Rendle	Shrub
	Girardinia diversifolia (Link) Friis.	Herb
	Lecanthus peduncularis (Royle) Wedd.	Herb
	Pilea scripta (Buch.-Ham. ex D.Don) Wedd.	Herb
	Pilea umbrosa Wedd.	Herb
	Pouzolzia hirta (Bl.) Hassk.	Herb
	Urtica ardens Link	Herb
	Urtica dioica L.	Herb
	Urtica hyperborea Jacq. ex Willd.	Herb
Valerianaceae	Nardostachys grandiflora DC.	Herb
	Valeriana hardwickii Wall.	Herb
	Valeriana jatamansi Jones	Herb
Verbenaceae	Callicarpa macrophylla Vahl	Shrub
	Caryopteris odorata (D.Don) B.L. Robinson	Shrub
	Premna barbata Wall. ex. Sch.	Shrub
Violaceae	Viola biflora L.	Herb
	Viola canescens Wall. ex Roxb.	Herb
	Viola pilosa Blume	Herb
Vitaceae	Ampelocissus divaricata Planch.	Climber
	Tetrastigma serrulatum (Roxb.) Planch.	Climber
	Vitis lanata Roxb.	Climber

Zingiberaceae	Cautleya gracilis (Sm.) Dandy	Herb
	Curcuma angustifolia Roxb.	Herb
	Hedychium spicatum Buch.-Ham. ex Smith	Herb
	Roscoea alpina Royle	Herb
	Roscoea procera Wall.	Herb

Appendix-7.2: Ethnobotanical uses of different plant species along with their use values

Family	Species	Med	Edb	Con	Fdr	Ful	Oil	Fib	Oth	UV
Acanthaceae	*Adhatoda zeylanica*	2	1							3
	Barleria cristata	1								1
Aceraceae	*Acer acuminatum*					1				1
	Acer caesium				2	1				3
	Acer lavigatum					1				1
	Acer oblongum					1				1
Amaranthaceae	*Achyranthes aspera*	1								1
Amaranthaceae	*Amaranthus viridis*		2							2
Anacardiaceae	*Rhus parviflora*	2	1			2				5
	Rhus punjabensis					1				1
	Rhus wallichii					1				1
Apiaceae	*Angelica glauca*	3	3							6
	Centella asiatica	1								1
Apocynaceae	*Ichnocarpus frutescens*	1						1		2
	Vallaris solanacea		1							1
Aquifoliaceae	*Ilex dipyrena*				2	1				3
Araceae	*Colocasia esculenta*		2							2
Asteraceae	*Anaphalis contorta*	1								1
	Anaphalis triplinervis	1								1
	Artemisia vulgaris	1							1	2
	Aster thomsonii	1								1
	Bidens pilosa L.				1					1
	Eupatorium adenophorum	2								2
	Jurinea dolomiaea								3	3
	Lactuca dissecta		1							1
	Saussurea obvallata								3	3
	Tagetes minuta	1								1
	Tanacetum								1	1
	Taraxacum officinale								1	1
	Tridax procumbens	1								1
Berberidaceae	*Berberis aristata*	2	1			2			1	6
	Berberis asiatica					2				2
	Berberis chitria					2				2
	Berberis jaeschkiana					1				1
	Berberis lycium	2	1			2			1	6
	Berberis pseudumbellata					1				1
Betulaceae	*Alnus nepalensis*					3			2	5
	Betula alnoides					1				1
	Betula utilis	2		1	2	3			2	10
	Carpinus viminea				3	2			2	7
Bombacaceae	*Bombax ceiba*		1					1		2
Boraginaceae	*Cynoglossum glochidiatum*	1								1
	Cynoglossum lanceolatum	1								1
Brassicaceae	*Capsella bursa-pastoris*		2							2
	Thlaspi arvense		1							1
Buxaceae	*Buxus wallichiana*					2			2	4
Caesalpiniaceae	*Bauhinia retusa*	2							2	4
	Bauhinia variegata		1		1					2
	Ceaselpinia decapetala	1			1	2				4
Cannabinaceae	*Cannabis sativa*		1					1	1	3
Caprifoliaceae	*Viburnum cotinofolium*		2			3				5
	Viburnum cylindricum				1	3				4
	Viburnum foetens					3				3
	Viburnum nervosum		2			3				5
	Viburnum stellulatum		2			2				4

Chenopodiaceae	*Chhenopodium album*		2						2
Commelinaceae	*Commelina paludosa*		2						2
Corariaceae	*Coriaria nepalensis*					2			2
Cornaceae	*Benthamidia capitata*		1						1
	Cornus macrophylla				1			1	2
Corylaceae	*Corylus jacquemontii*		1						1
Cupressaceae	*Cupressus torulosa*			2				1	3
	Juniperus communis					2		1	3
Cuscutaceae	*Cuscuta reflexa*	1							1
Cyperaceae	*Carex breviculmis*				2				2
	Carex condensata				2				2
	Carex infuscata				2				2
	Carex neiogyna				2				2
	Carex nivalis				2				2
	Carex nubigena				2				2
	Carex obscura				2				2
	Carex setigera				2				2
	Cyperus niveus				2				2
Daphniphyllaceae	*Daphniphyllum himalayense*							1	1
Dioscoreaceae	*Dioscorea deltoidea*	2	2						4
Elaeagnaceae	*Hippophae salicifolia*		1						1
Ephedraceae	*Ephedra gerardiana*		1			1			2
Ericaceae	*Gaultheria trichophylla*		2						2
	Lyonia ovalifolia	1							1
	Rhododendron arboreum	2	2			3		2	9
Euphorbiaceae	*Mallotus philippensis*				1	1		1	3
Fabaceae	*Crotolania albida*	1							1
Fagaceae	*Quercus floribunda*			1	3	3		3	10
	Quercus semecarpifolia			3	3	3		3	12
	Quercus leucotrichophora	1		2	3	3		3	12
Flacourtiaceae	*Xylosoma longifolium*					1			1
Gentianaceae	*Nardostachys jatamansi*	1							1
	Picrorhiza kurroa	1							1
	Swertia chirytia	3							3
Geraniaceae	*Geranium nepalense*	1							1
	Geranium ocellatum	1							1
	Geranium pratense	1							1
	Geranium wallichianum	1							1
Grossulariaceae	*Ribes alpestre*		2						2
Hippocastanaceae	*Aesculus indica*		1			1		2	4
Hydrangeaceae	*Deutezia corymbosa*					1			1
	Deutezia staminea					1			1
Juglandaceae	*Juglans regia*	3	2	2		1	1	2	11
Lamiaceae	*Ajuga bracteosa*	1							1
	Clinopodium umbrosum	1							1
	Colebrookea oppositifolia	1							1
	Mentha longifolia	1							1
Lauraceae	*Cinnamomum tamala*		2						2
	Lindera pulcherrima	1							1
	Litsea monopetala					3		1	4
	Skimmia laureola							3	3
Liliaceae	*Allium belandum*		3						3
	Allium govanianum		3						3
	Allium victoralis		3						3
	Asparagus filicinus	1							1
	Polygonatum cirrhifolium		1						1
	Polygonatum verticillatum	1							1

Lythraceae	*Woodfordia fruticosa*	2						2	4
Malvaceae	*Kydia calycina*	1		1		1	1		4
Meliaceae	*Melia azaderach*	1				2			3
	Toona sinensis			2		1		2	5
Menispermaceae	*Cissampelos pariera*	1							1
Mimosaceae	*Albizia chinensis*				1				1
	Albizia julibrissin				1				1
Moraceae	*Ficus semicordata*		1		1		1		3
	Morus serrata		1		1			1	3
Myricaceae	*Myrica esculenta*		2						2
Nyctaginaceae	*Boerhavia diffusa*	1							1
Oleaceae	*Fraxinus micrantha*					2		2	4
Orchidaceae	*Dactylorhiza hatagirea*	1							1
Oxalidaceae	*Oxalis corniculata*	1	1						2
Paeoniaceae	*Paeonia emodi*	1	2					1	4
Papaveraceae	*Papaver somniferum*							1	1
Papilionaceae	*Astragalus candolleanus*	1							1
	Desmodium elegans				2	2			4
	Desmodium gangeticum	1			2	2			5
	Desmodium laxiflorum				2	2			4
	Desmodium triflorum	1			2	2			5
	Indigofera heterantha		1					1	2
Phytolaccaceae	*Phytolacca acinosa*		3						3
Pinaceae	*Abies pindrow*			3		1			4
	Cedrus deodara	2		3		3		2	10
	Pinus roxburghii	1	2	3		2		3	11
	Pinus wallichiana		2			3		1	6
Poaceae	*Agrostis pilosula*				1				1
	Andropogon munroii				1				1
	Apluda mutica				1			1	2
	Arundinaria falcata		1	3	3	3	3	3	16
	Arundinella nepalensis							1	1
	Capillipedium assimile				1				1
	Chrysopogon gryllus			2					2
	Cynodon dactylon	1			1				2
	Thamnocalamus spathiflorus		2	3	3	3	3	3	17
Podophyllaceae	*Podophyllum hexandrum*		1						1
Polygonaceae	*Fagopyrum esculentum*	1	3						4
	Rheum australe	2							2
	Rumex hastatus	1	1						2
	Rumex nepalensis	2	1						3
Primulaceae	*Primula macrophylla*							3	3
Ranunculaceae	*Aconitum falconeri*	1							1
	Aconitum heterophyllum	3							3
	Aconitum violaceum	1							1
	Acorus calamus L.	1							1
	Clematis gauriana						1		1
	Delphinium denundatum	1							1
	Thalictrum foliolosum	1							1
Rhamnaceae	*Ziziphus mauritiana*		1						1
Rosaceae	*Cotoneaster acuminata*					2			2
	Cotoneaster bacillaris					2		2	4
	Cotoneaster microphyllus		1			2			3
	Cotoneaster rosea					2			2
	Fragaria nubicola		1						1
	Prinsepia utilis				2	2	1	1	6
	Prunus cerasoides	1	3						4

	Prunus cornuta		2		2	2	2			**8**
	Pyracantha crenulata		1			1				**2**
	Pyrus pashia	1	2			2			3	**8**
	Rosa sericea	1	2			2			2	**7**
	Rosa webbiana		1							**1**
	Spirea canescens					2				**2**
Rubiaceae	*Gallium aparaine*	1								**1**
	Rubia manjith	1							1	**2**
	Rubus ellipticus		2							**2**
	Rubus niveus		2							**2**
	Rubus paniculatus		2							**2**
	Wendlandia puberula					1				**1**
Rutaceae	*Boeninghausenia albiflora*	1								**1**
	Zanthoxylum armatum	3							3	**6**
Salicaceae	*Populus ciliata*					2				**2**
Saxifragaceae	*Astilbe rivularis*				1					**1**
	Bergenia ciliata	1								**1**
Scrophulariaceae	*Verbascum thapsus*								2	**2**
Solanaceae	*Solanum indicum*				1					**1**
Symplocaceae	*Symplocos chinensis*					1			1	**2**
Taxaceae	*Taxus baccata*			3		2			2	**7**
Thymelaceae	*Daphne papyracea*	1					1			**2**
	Wickstroemia canescens							1		**1**
Tiliaceae	*Triumfetta rhomboidea*	1								**1**
Ulmaceae	*Celtis australis*				1					**1**
	Ulmus wallichiana	2			2	1			1	**6**
Urticaceae	*Boehmeria platyphylla*	1			1					**2**
	Boehmeria rugulosa				1					**1**
	Debregeasia salicifolia	1			3	2				**6**
	Gerardiana diversifolia							3		**3**
	Urtica dioca		2					1		**3**
	Urtica ardens		3							**3**
Valerianaceae	*Valeriana hardwickii*	2							2	**4**
	Valeriana jatamansi	2							2	**4**
Verbenaceae	*Callicarpa macrophylla*	1	1							**2**
	Caryopteris odorata				1					**1**
Violaceae	*Viola biflora L.*	1								**1**
	Viola canescens	1								**1**
	Viola pilosa	1								**1**
Vitaceae	*Tetrastigma pentaphylla*		2							**2**
Zingiberaceae	*Hedychium spicatum*								1	**1**
Pteridophyte	*Diplazium*		3							**3**
Total		**111**	**111**	**34**	**80**	**129**	**5**	**17**	**96**	**583**

Med:Medicinal,Edb:Edible, Con:Construction, Fdr:Fodder, Ful:Fuelwood, Fib:Fibre, Oth:Others & UV: Use value