To determine habitat characterization of Western Tragopan (Tragopan melanocephalus) and Musk Deer (Moschus chrysogaster) and Geo-botanical trend analysis in Great Himalayan National Park Conservation Area (GHNPCA), Vegetation and Geo-morphological maps were visually interpreted with FCC of IRS 1B LISS II 1993. Vegetation profile diagrams were also studied. It was observed that nearly 10% area of Eco Development Area is under Habitation/Agriculture/Orchard category (HAO). The change detection analysis (Year 1961–1993) reflects that an increase in area under HAO with a corresponding decline in area under cultivation. The fuel wood/fodder consumption has also increased in that period. Area covered by the vegetation types was different under each terrain parameter. The effect of altitude was dominant along with soil and climate. Measuring interspersion and juxtaposition values with restrictive factors, habitat suitability modeling was done. About 10% and 23% of GHNPCA provides good habitat for Western Tragopan and for the Musk Deer respectively. The generated database in GIS can be used by the PA management in monitoring and for preparing landscape management plan.

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Habitat Evaluations and Geo-botany

Naithani

Suneet Naithani

Wildlife Habitat Evaluations and Geo-botanical Characterization

Wildlife Habitat Evaluations and Geo-botanical Characterization (A Case Study in Great Himalayan National Park,India)

LAP LAMBERT Academic Publishing

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Dedicated to all those people, who have trusted, wished and wanted me to reach new horizons in life.

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The study on habitat characterization in Great Himalayan National Park using Remote Sensing and Geographical Information System (GIS) with special emphasis on geobotanical aspects which has been carried out between May, 1996 and June, 2000 has involved innumerable hours of work in the GIS laboratory in creating a comprehensive spatial database and trekking in field for the ground truthing of satellite imageries for habitat characterization. In these activities help, encouragement, guidance and advice were received from a large number of people, to whom I am highly indebted.

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1. GENERAL INTRODUCTION

The Himalaya is geologically young and one of the biologically richest mountain systems in the world. It is not only well known for its wide array of flora and fauna and hydrological regime but it also offers life support system for millions of people in the northern region of the Indian subcontinent (Rodgers and Panwar, 1988). It is one of the most fragile ecosystems on the earth, which extends over 2400 km ranging from NorthWest to SouthEast and covering 150 to 250 km in width.

But increasing human pressure has led to the loss of rich biological resources in the fragile Himalayan ecosystem. The existing network of protected areas (PAs) in the Indian Himalayan region covers only 9.2% of the total Himalayan region (Rodgers and Panwar, 1988). Most of the PAs in Himalayas suffer from human pressure from within and outside, resulting in human - animal interface conflicts. The dwindling forests have had a serious impact on wildlife resources because of loss of habitat. Most of the species that were abundant in our country are now in need of intense protection. Therefore, PA managers need precise knowledge of floral and faunal communities and the influence of biotic pressures on them in order to effectively manage them. Creation of a wildlife reserve is an effective means of conservation of nature as a part of overall environmental preservation. Great Himalayan National Park (GHNP) is one of the important PAs for the conservation of the biological diversity in Himalayan region but scanty scientific data are available (Gaston *et al* 1981; Gaston and Garson, 1992). A multidisciplinary survey of the area was conducted in 1979-80 with particular emphasis on wildlife and the impact of human disturbance and livestock on the structure and composition of the vegetation (Gaston *et al* 1981). Cavallini (1992) assessed the status of goral in GHNP in late 1989. The GHNP has rich biodiversity as compared to the other areas in similar altitude in Western Himalaya (Gaston *et al* 1981). It supports several endangered mammals and pheasants and is one of the two National Parks in the world which support a population of the endangered Western Tragopan (*Tragopan melanocephalus)* (Collar and Andrew, 1988). The GHNP has been recognized as one of the globally important "Endemic bird areas" by ICBP (International Council for Bird Preservation) Biodiversity project (ICBP, 1992). Himalayan Musk Deer (*Moschus chrysogaster)* has been recorded in the Tirthan valley in GHNP (Gaston *et al* 1981).

Habitat characterization is an integral component of wildlife management. Habitat includes a wide variety of factors *viz.* soils, topography, water availability, vegetation and cover characteristics including human influences on all of these. Basically, habitat is the place occupied by a specific population within a community (Smith, 1974). Several ground methods have been used to evaluate and parameterize the habitat. Most of these methods have limitations because whole area cannot be traversed. Vegetation and geomorphological mapping using remote sensing data for use in habitat characterization, is already in practice in India (Roy *et al* 1986; Unni *et al* 1986). Understorey information can be picked up using large-scale aerial photographs and integrated with ground sample and terrain details (Porwal and Roy, 1991b).

Porwal and Roy (1991a) used habitat suitability rating technique in various management sectors of Kanha National Park, M.P. Each section was evaluated for three parameters *viz.* cover types (food and shelter values), water and terrain such as valley plains, plateau, moderate and steep slopes.

The Great Himalayan National Park (GHNP) supports a population of endangered species, especially Western Tragopan and Himalayan Musk Deer. Western Tragopan are distributed in temperate coniferous forest having sufficient understorey (Islam, 1982). These pheasants are generally observed to select specific habitat conditions. Musk Deer is a territorial ungulate, which usually lives singly, and occurs in relatively low densities. It is a nocturnal animal of the sub alpine and alpine scrub. Keeping above points in view, emphasis has been given to both species for their habitat characterization. It is essential to analyze baseline data on the physical set up, vegetation and socio-economic environment to ensure the effectiveness of the conservation effort.

There is a need for developing an integrated approach to management and conservation of wildlife. This is possible only if scientifically documented baseline data can be generated on biological resources and on all associated physical aspects. Management of wildlife depends on basic understanding of biotic and biotic elements of habitat such as animal, vegetation, water, soil, geomorphology, geology, etc.

A 5-year major Forestry Research, Education and Extension Project (FREEP) funded by the International Development Association and executed by the Director, Project Tiger, Government of India was launched in the GHNPCA in April, 1995. The project aimed to assess biodiversity, socio-economic conditions and forest dependency of local communities, identify critical habitats, ecologically sensitive species and their habitat needs and biotic pressures on the resources. The WII worked on the research and monitoring component of this project under which a multi-disciplinary team of 8 researchers, 9 faculty members, 7 national consultants and 5 international consultants were engaged. The present study formed a part of the WII's FREEP-GHNPCA project.

1.1 OBJECTIVES

The specific objectives for this study were:

(i) Mapping of major vegetation communities using remotely sensed data.

(ii) Geomorphological mapping of study area using remotely sensed data, along with its relationship with vegetation.

(iii) Development of a wildlife information base, including inventory data on habitats and species, for analyzing habitat values with speciesecial reference to Musk Deer and Western Tragopan.

1.2 JUSTIFICATION

The present study provides valuable and significant inputs for management of wildlife habitats and monitoring changes. For better wildlife management, information on food, water, shelter and site condition suited to a particular animal species should be known accurately. The spatial relationship between cover types, their respective areas, nearness to water, suitable corridors for daily movement and seasonal migration are also important in determining the habitat suitability for wildlife. However, habitats are generally inadequately surveyed and monitored and require adequate and elaborate surveys using scientific methodology. To fill this gap, this study on habitat characterization with integration of spatial & non-spatial data has been carried out. Derived indicators were utilized for grading and selecting various sites in the study area, which would facilitate the development of appropriate management practices. The study provides the conservation status and distribution map of two endangered species along with habitat suitability map of the study area. Habitat zonation mapping of inaccessible areas along with Digital Elevation Model (DEM) developed in the study will also be helpful for planning appropriate wildlife management practices. The interrelationship between vegetation and geomorphology will help wildlife managers to understand the distribution of animals in relation to slope and other parameters.

The potential of Geographical Information System (GIS) used in combination with Remote Sensing enhances capabilities to analyze spatial and non-spatial data with reliable accuracy and efficiency, and this has been successfully demonstrated in this study.

1.3 ORGANIZATION OF THE THESIS

The thesis is organized in 5 chapters; Chapter 1 deals with the general introduction and objectives of the study. Chapter 2 deals with the study area. Chapter 3 gives a brief review of literature with detailed mapping of vegetation, its analysis, results and discussion. The vegetation characterization has been done through profile diagrams. Chapter 4 deals with the Geomorphological/Geological mapping of the study area along with review of literature, methodology and detailed analysis of units as well as geobotanical trend analysis with results and discussion. Chapter 5 provides information about the habitat requirements of two endangered species and discusses the habitat suitability models.

2. THE STUDY AREA

2.1 INTRODUCTION

The study was conducted in Great Himalayan National Park Conservation Area (GHNPCA) in Himachal Pradesh Fig. 2.1. The GHNP encompasses nearly 1171 km^2 area and lies between 31^0 33' 00" N to 31^0 56' 56" N lat. and 77^0 17" 15" E to 77^0 52' 05" E long. and altitude varies from 1344 to 6248 m. The area is located at the junction of two great faunal realms i.e., Palaearctic to the North and Oriental to the South (Mackinon *et al* 1986). According to Biogeographic Classification; GHNP falls under north-western Himalayan biotic province i.e., 2A (Rodgers *et al* 2000). The park is well known for its rich diversity compared to other areas at similar altitudes in the north western Himalaya (Gaston *et al* 1981). It is one of the two National Parks in the world that support a population of endangered Western Tragogan (*Tragopan melanocephalus*) (Collar & Andrew 1988) and a large number of rare and threatened plant species, many of which have medicinal values (Gaston & Garson 1992). The park is bounded by Rupi Baba Wildlife Sanctuary (WLS) in the east, Pinvalley National Park in the north-east and Kunawar WLS in the north-west. However, in the south-west the park is bounded by human habitations, which are involved in cultivation activities and growing of orchards. This area has been designated as the Ecodevelopment Area (EDA) (Fig. 2.2). GHNP, along with adjoining protected areas forms a large, relatively undisturbed and contiguous area having great potential for long term conservation of natural resources. GHNP covers the catchment areas of Jiwanal, Sainj, Parvati and Tirthan rivers which are tributaries of Beas River. Tirthan and Sainj rivers flow in East-west direction, while they criss-cross through the steep gorges. The park boundary is approachable by road from Aut near Kullu; however there are no motorable roads insides the park.

Fig. 2.1

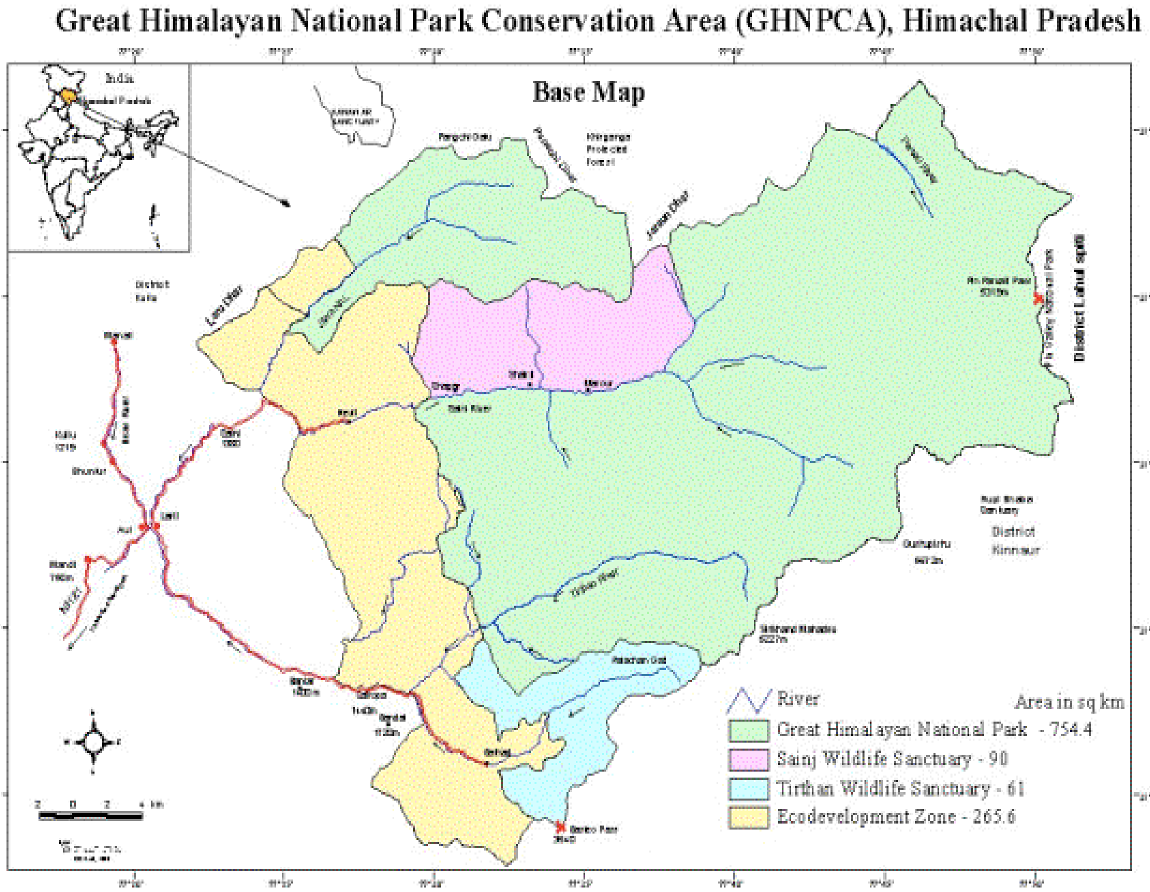
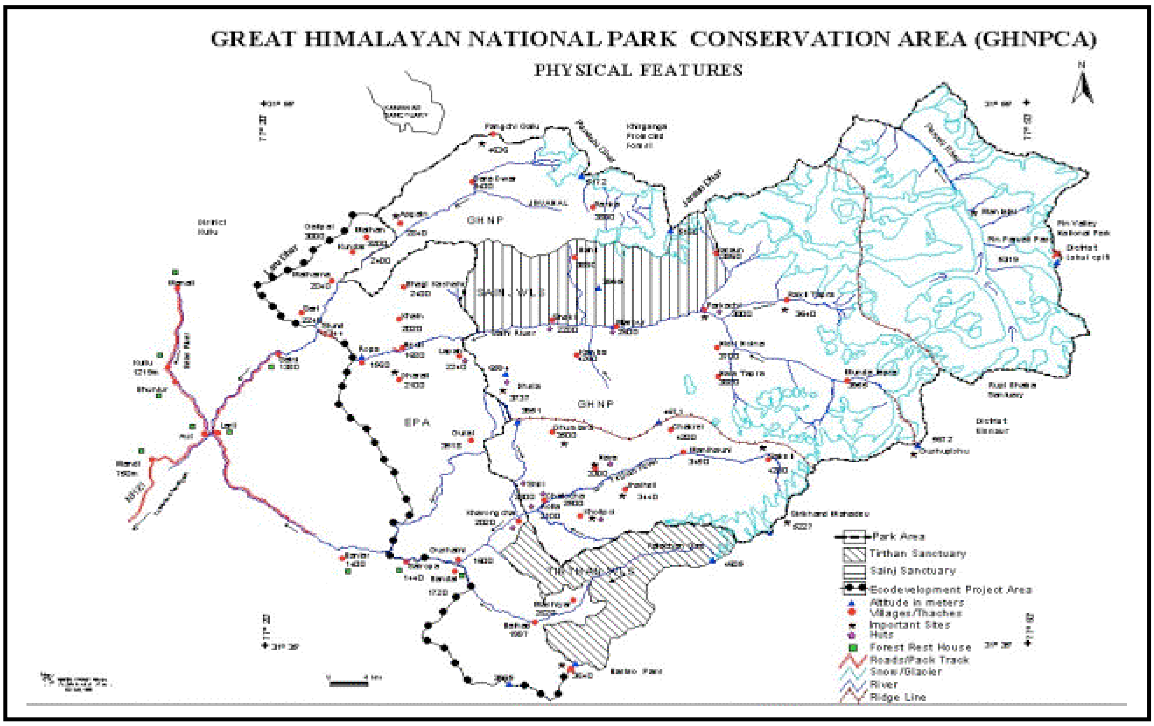

Great Himalayan National Park Conservation Area (GHNPCA), Himachal Pradesh
Base Map
India
District Lahul spiti
District Kinnaur
River
Area in sq km
Great Himalayan National Park - 754.4
Sainj Wildlife Sanctuary - 90
Tirthan Wildlife Sanctuary - 61
Ecodevelopment Zone - 265.6

Fig 2.2


GREAT HIMALAYAN NATIONAL PARK CONSERVATION AREA (GHNPCA)
PHYSICAL FEATURES
GHNP
EPA
Park Area
Tirthan Sanctuary
Sainj Sanctuary
Ecodevelopment Project Area
Altitude in meters
Villages/Thaches
Important Sites
Huts
Forest Rest House
Roads/Pack Track
Snow/Glacier
River
Ridge Line

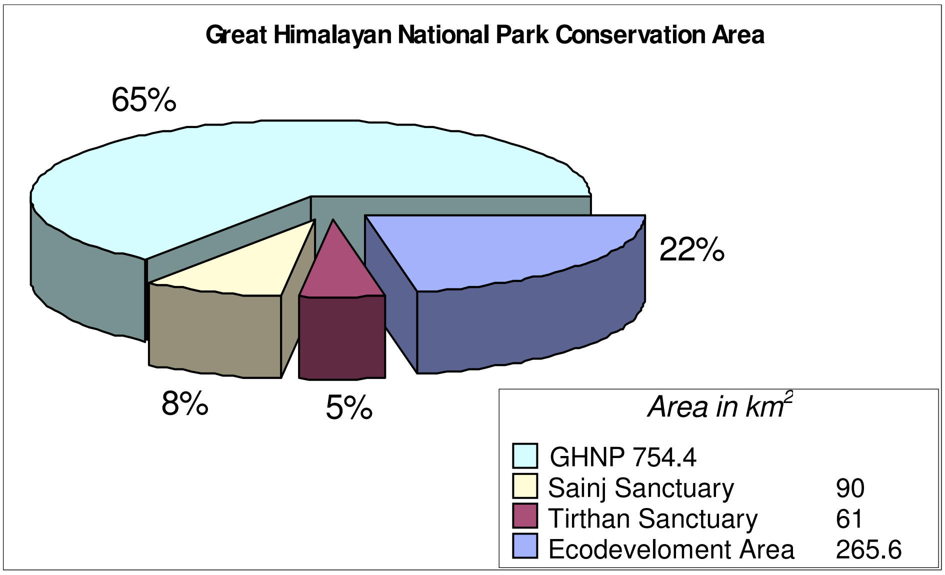
2.2 TOPOGRAPHY

Topographically, the area has highly undulating features. Minimum altitude is recorded near Seund at the confluence of Jiwanal and Sainj khad and is about 1344m . The maximum altitude is 6248 m at peak in Kheerganga Protected forest. The study area is subdivided into four Subwatersheds (Negi, 1996), which are:

SWS1 - Jiwanala
SWS2 - Sainj khad
SWS3 - Tirthan khad
SWS4 - Parvati nadi SWS- (subwatershed)

The Government of Himachal Pradesh vide Notification Number FFE-B-F (3)-2/29 dated 21.05.1999 has re-constituted the boundaries of the Great Himalayan National Park. An area of 10.6 km^2 has been denotified from the GHNP and added to the EDA. The distribution of study sites in Great Himalayan National Park Conservation Area (GHNPCA) (1171 km^2) shows that nearly 65% of the total area is under GHNP. Tirthan and Sainj sanctuaries constitute nearly 13% and rest includes habitation and cultivation area and is also known as Ecodevelopment Area, as shown in Fig. 2.3.

Fig. 2.3 PA MANAGEMENT ENTITIES OF GHNPCA



The altitude of the area varies from 1344 m near Seund at the confluence of Jiwanal and Sainj river to 6248 m at an unnamed peak in Khirganga P.F. in the east of Mathaun Dhar. Nearly 50% of the area lies between the altitudinal range of 4000-5600 m.

The topography of the area has also been influenced by avalanches and land slides. Avalanches occur frequently after heavy snow, often originating from steep southern aspect, especially from April to June. Landslides are common features during rainy season

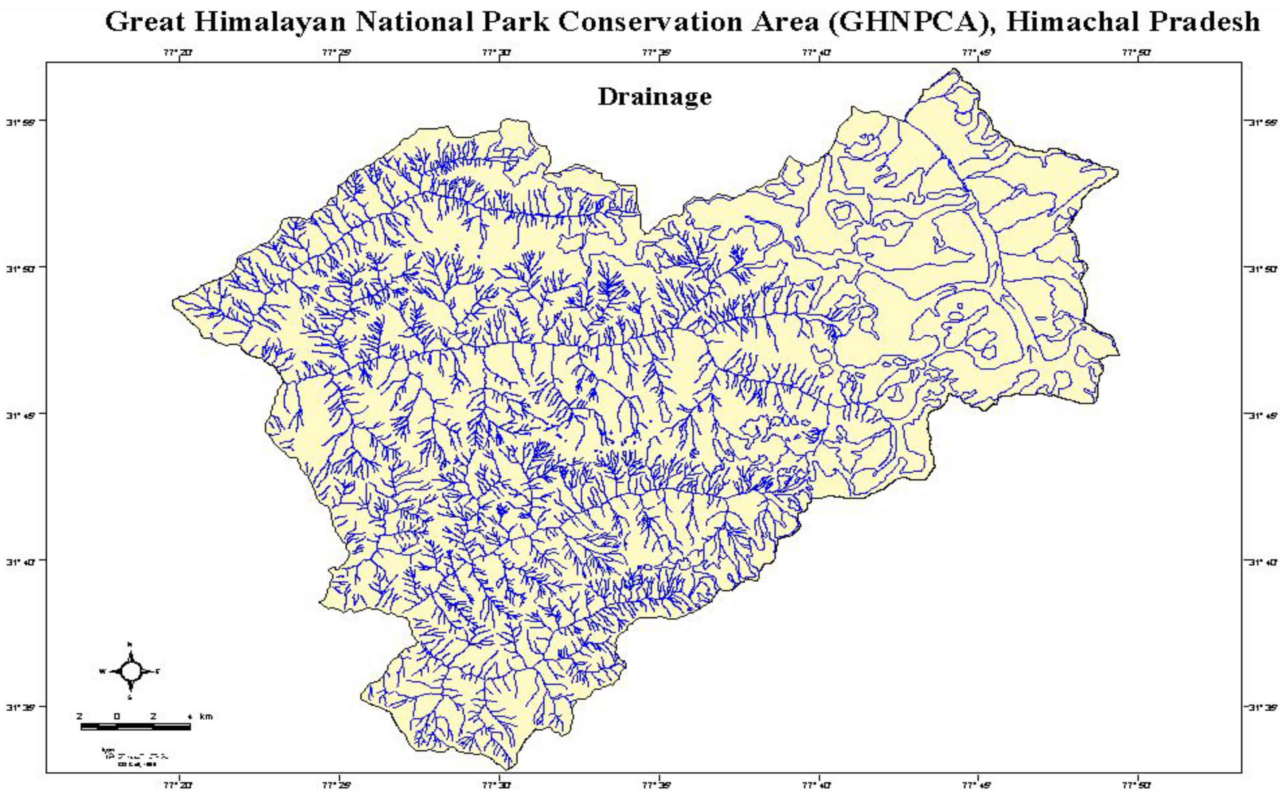
The Great Himalayan National Park Conservation Area comprises of five sub units *viz.* Jiwa, Sainj, Tirthan, Great Himalayan National Park Protected Area and Ecodevelopment Area. The main accessibility by roads in the park is from westward direction in Kullu District i.e., from Mandi to Aut then Larji to Banjar or Sainj. The park area has complex terrain. Most of the area is snow bound.

2.3 DRAINAGE PATTERN

The major tributaries of Beas river *viz.* Tirthan, Sainj, Jiwa and Parvati drain the GHNPCA. Most of the area has dendritic and trellis pattern. In dendritic pattern, controlling factors are homogeneous with equal resistance, compact and hard rocks. Whereas, in trellis pattern, sub tributaries are perpendicular to main stream developed along strike and dip directions reflects the structural controls.

The peculiarity of the GHNPCA is that mostly all sub water sheds are snow bound so all the rivers flowing from the area are perennial *viz*., Tirthan Khad, Sainj Khad, Jiwa Nal along with Parvati Nadi and Palachan Gad. All these Rivers/Khads/Nalas drain water into Beas River. Around 50% of the area lies above 4000m is usually snowbound and acts as a source of perennial river system. The largest river system is Sainj watershed. Snow and glaciers cover around 17% of area and high altitude lakes covers nearly 1% area. The type of drainage and its pattern shown in Fig 2.4.

Fig 2.4.



2.4 SOIL

Basically the Himalayan soils are *in situ* in nature and belong to Podsolic group. The different types of soils in the area are sandy, alluvial, and podsolic. The physical content of the soil are influenced by the climatic conditions, vegetation cover and host of other factors. Alluvial soils are formed due to erosion mainly by water and land slips. In the process the weathered material is transpeciesorted and deposited at places other then its origin. In such cases the underlying rock has a little role to play in influencing the vegetation on the alluvial soils. Such soils are found deposited in the basins of river and along the banks of the rivers. Podsolic soils are found developed in the temperate climates in conifers in the Himalayas. It is found under coniferous vegetation. The soil is covered with thick layer of humus which remains undecomposed due to low temperature and short summer. The leaching medium is acidic because of the presence of humic acid. The microbiological activity is very low. The pH of the soil is acidic. The chlorides, sulphates, alkali and alkaline earth substance get leached. These become degraded soils because of break of nitrogen cycle in the temperate coniferous forests. These soils get improved by the mixture of broad leaved species. Brown forest soils are formed in the temperate climate under broad leaved vegetation cover. There is no accumulation of thick humus on the top and humus is of neutral type. The underlying rocks influences the structure and texture of soils as some rock on the disintegration give rise to fine grained material and other coarse grained material which effects the water holding capacity of the soil and consequently influences the type of vegetation which can come up on various structure and texture of soils. Deodar cannot regenerate on the calcareous parent rock. It requires heavy soil with good moisture retaining capacity while Chir Pine requires course grained sand particles having good drainage. Kail requires shallower soils with the boulders in the subsoil and silver fir and speciesruce come up on all soils and can tolerate more acidic conditions. Cypress prefers to be on calcareous soils. The soil types vary from sandy loam to thick humus beneath Kharsu oak and fir forests. Thus characters of the underlying rock exercise a powerful influence over the composition of the forest vegetation. Quartzite rock which disintegrates into silver sand produces Chir Pine of finest quality but is generally unfavourable to Deodar.

2.5 CLIMATE

The GHNP typically exhibits temperate and alpine climate. Most of the area (approx. 64%) falls above subalpine zone which remains snow covered during winter months Fig. 2.5. Broadly, three season can be recognised for the park area *viz*. summer (April to June), Rainy (July to September) and winter (October to March). Winter is severe and main precipitation is received in the form of snow. Rains are mostly confined to rainy season.

The mean annual precipitation in western Himalaya at middle elevations ranges between 1000-2000 mm and more than half of it falls during rainy season (Gaston *et al* 1981). The mean annual rainfall recorded at Niharni 1800 m in GHNP for the period 1992-94 was 1155.67 mm while at Sainj 1450 m for 1992-94 it was 1158.26, Fig. 2.6. The snowfall depth is 5-7 m in the sub-alpine and alpine area. During February with the rise of temperature snow starts melting in the lower altitudes and by April it remains in isolated patches below 3000 m especially in shaded localities. However, it remains up to May-June in the alpine zone.

Fig.2.5

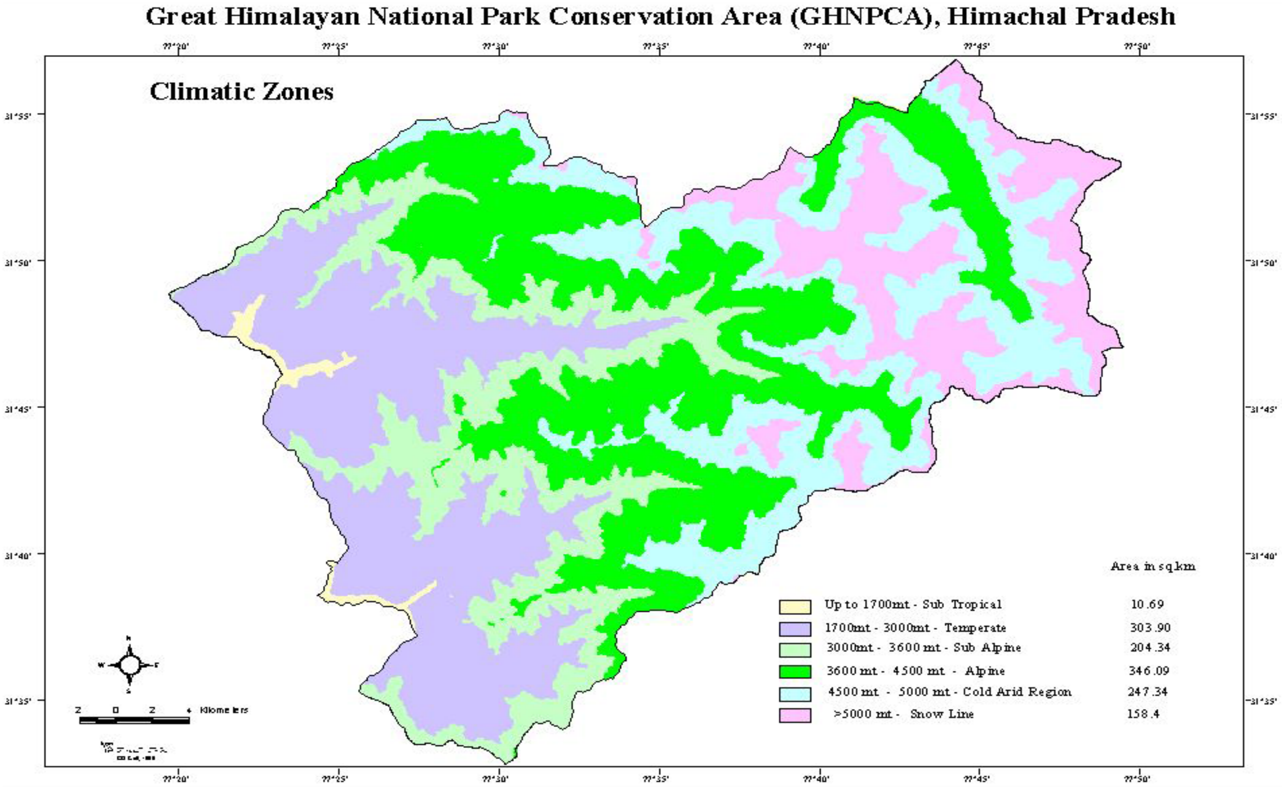
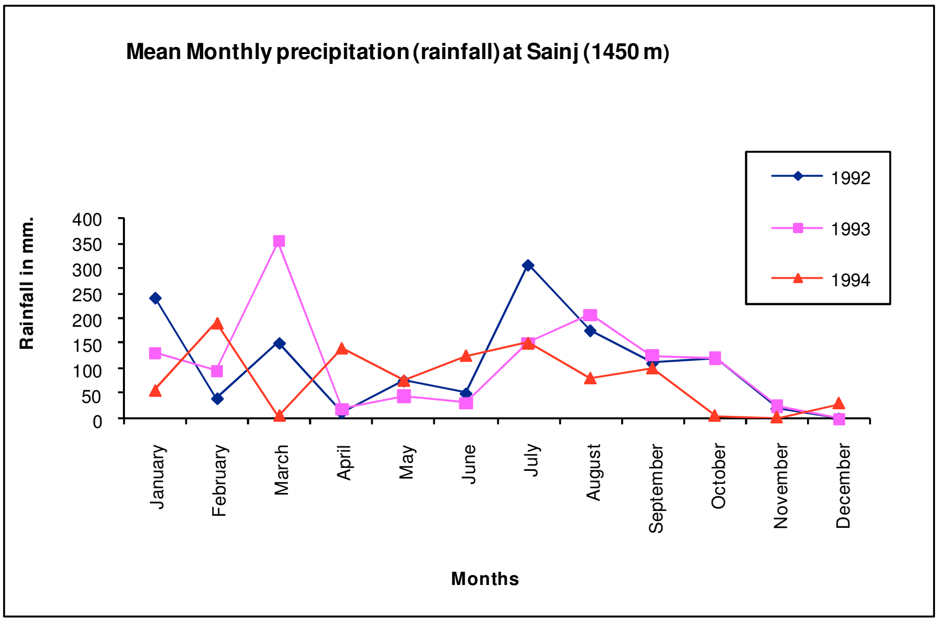


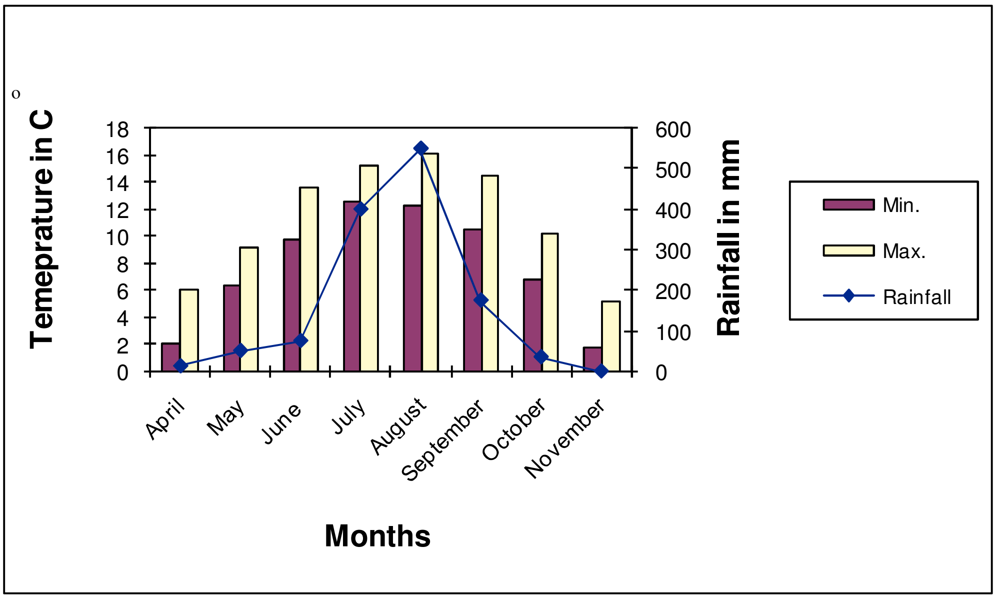
Fig. 2.6 MEAN MONTHLY PRECIPITATION (RAINFALL) AT SAINJ (1450 M) OUTSIDE GHNP (Source: GHNP, 1996)



Temperature is an important factor in determining vegetation types. In general the temperature of the area varies from minus 10°C to 35°C Gaston *et al* (1981). The temperature recorded at the different check-posts in three valleys. The mean minimum and mean maximum temperature in Tirthan, Sainj and Jiwanal valleys was are 12.65°C, 9.59 °C and 9.69 °C and 16.38°C, 15.03°C and 13.46°C respectively in 1996-97. January is the coldest and June is the hottest months of the year.

The temperature in the alpine zone was recorded with the help of the graziers staying there and personal visits during summer months. The mean minimum temperature was 7.73°C and mean maximum temperature was 11.23°C during these months. Low temperature values were recorded in March-April and High values in May-June. The total recorded rainfall during these months was 1298 mm. Fig. 2.8.

Fig 2.8 MEANS MONTHLY RAINFALL AND TEMPERATURE AT TIRTH (3800 M), NADA (3400 M), AND GUMTARAO (3550 M).



2.6 VEGETATION

Based on the physiognomy and dominance of species the following vegetation types can be recognised in the study area ; (i) Temperate broad-leaved forests, (ii) Temperate conifer forest, (iii) Upper temperate broad-leaved and mixed conifer forest, (iv) Subalpine (birch-rhododendron) forest, (v) Alpine scrubs, (vi) Alpine meadows and thaches, (vii) Riverine forest, (viii) Temperate grassy slopes (*ghasanis*) and (ix) Temperate secondary scrub near village pastures and forest edges. According to Champion and Seth's (1968) classification 14 forest types are found in the area *viz.* Ban oak forest 12/C(a), moist-deodar forest 12/C1 (c), western Himalayan mixed coniferous forest 12/C1 (d), moist temperate deciduous forest 12/C1 (e), kharsu-oak forest 12/C2(a), western Himalayan upper oak-fir forest 12/C2, 12/C2(b), montane bamboo brakes 12/DS1, Himalayan temperate parkland 12/DS2, Himalayan temperate pasture 12/DS3, western Himalayan subalpine fir forest 14C1(a), subalpine pasture 14/DS1, birch-rhododendron scrub forest 15/C1, deciduous alpine scrub 15/C2 and alpine pasture 15/C3.

The GHNP has 17.0% of its geographical area under forest cover (Negi, 1996). This is due to preponderance of alpine areas beyond tree line such as meadows, rocky and snow bound areas. The temperate belt is characterised by dense Himalayan moist temperate forest with following dominant species. *Abies pindrow*, *Cedrus deodara*, *Pinus roxburghii*, *Pinus wallichiana*, *Picea smithiana* and *Taxus baccata* are among the conifers and *Quercus leucotrichophora*, *Quercus floribunda*, *Quercus semecarpifolia*, *Celtis tetrandra*, *Aesculus indica*, *Juglans regia*, *Acer specie, Prunus cornuta*, *Betula alnoides*, *Betula utilis*, *Toona serrata*, *Populus ciliata*, *Salix species*, are the common broad-leaved species. *Quercus semecarpifolia* flourishes in the pure stands between 3000-3500 m. Small patches of *Quercus leucotrichophora* are observed between 1800-2400 mt. with *Quercus floribunda* overlapping upper range of *Quercus leucotrichophora* and lower range of *Quercus semecarpifolia*. Generally *Abies pindrow* and *Picea smithinana* are seen in the northern slopes and stands of *Pinus wallichiana*, *Cedrus deodara* and *Quercus semecarpifolia* are seen on the southern slopes. *Alnus nitida*, *Populus ciliata* and *Salix wallichiana* are found near streams. *Arundinaria* species are also found in the moist northern slopes in the Tirthan and Sainj valleys. Under growth and ground cover comprises species of *Indigofera*, *Viburnum*, *Sarcococca*, *Berberis*, *Iris*, *Polygonum*, *Cannabis*, *Impatiens, Rumex*, *Girardinia* etc. The tree line is characterised by birch-rhododendron forest which is replaced by scrubby *Rhododendron* and *Juniperus* species towards higher altitudes interspeciesersed with meadows and rocky outcrops. Alpine pastures are known for preponderance of medicinal herbs such as *Aconitum heterophyllum*, *Picrorhiza kurrooa*, *Jurinea macropcephalla*, *Nardostcgys grandiflora*, *Dactylorhiza hatagirea* etc. Besides in alpine meadows, there are grassy slopes in the eco-development area which have been developed and maintained as "Ghasnis" by the local people for hay.

2.7 FAUNA

The park is well known for its diverse fauna. Till recently, there was no systematic study on these aspects. Singh *et al.* (1990) had reported a total of 309 species including birds from the park.

The fauna of the park comprises 31 species of mammals (Gaston and Garson, (1993); Vinod and Sathyakumar (1999), 183 species of birds Gaston *et al* (1993), Ramesh *et al* (1999), and more than 125 species of invertebrates Uniyal & Mathur (1999). The high altitude mammals are blue sheep (*Pseudois nayaur*), brown bear (*Ursus arctos*), snow leopard (*Uncia uncia*) and Himalayan ibex (*Capra ibex*). Himalayan thar (*Hemitragus jemlahicus*) and *Musk Deer* (*Moschus chrysogaster*), inhabit middle to high altitudes. Low to middle altitude species include serow (*Nemorhaedus sumatraensis*), rhesus macaque (*Macaca mullata*), barking deer (*Muntiacus muntjak*), jackal (*Canis acreus*), and goral (*Nemorhaedus goral*). Certain species have wide range of altitude preference e.g Himalayan black bear (*Ursus thibetanus*), leopard (*Panthera pardus*), yellow throated marten (*Martes flavigala*), langur (*Presbytis entellus*) and flying squirrel (*Petaurista petaurista*). Some the endangered pheasants are *Western Tragopan* (*Tragopan melanocephalus*), cheer pheasant (*Catreus wallichii*) and monal (*Lophophorus impeyanus*).

2.8 HISTORY OF MANAGEMENT

Based on the richness and abundance of wildlife Tirthan valley was notified as sanctuary as in 1976. Subsequently, a part of Tirthan sanctuary was included in GHNP on 1 March 1984 (Notification no. 6 -16-73 - SF -11), a portion of which (Buffer zone) was subsequently, denotified vide letter no.6-16/73 SF-IV dated 30.7.90. The park was named Jawarhar Lal Nehru Great Himalayan National Park in mid 1989, but its original name is still commonly used.

The forest of Kullu district was settled between 1886 and 1896, by Alex Anderson. The area including the study area fall within the following four categories I) Reserved Forest, ii) Demarcated Protected Forest (D.P.F.) iii) Unclassified Protected Forest (U.P.F.) class III and iv) Non Forest Cultivated Land, (Sharma 1987).

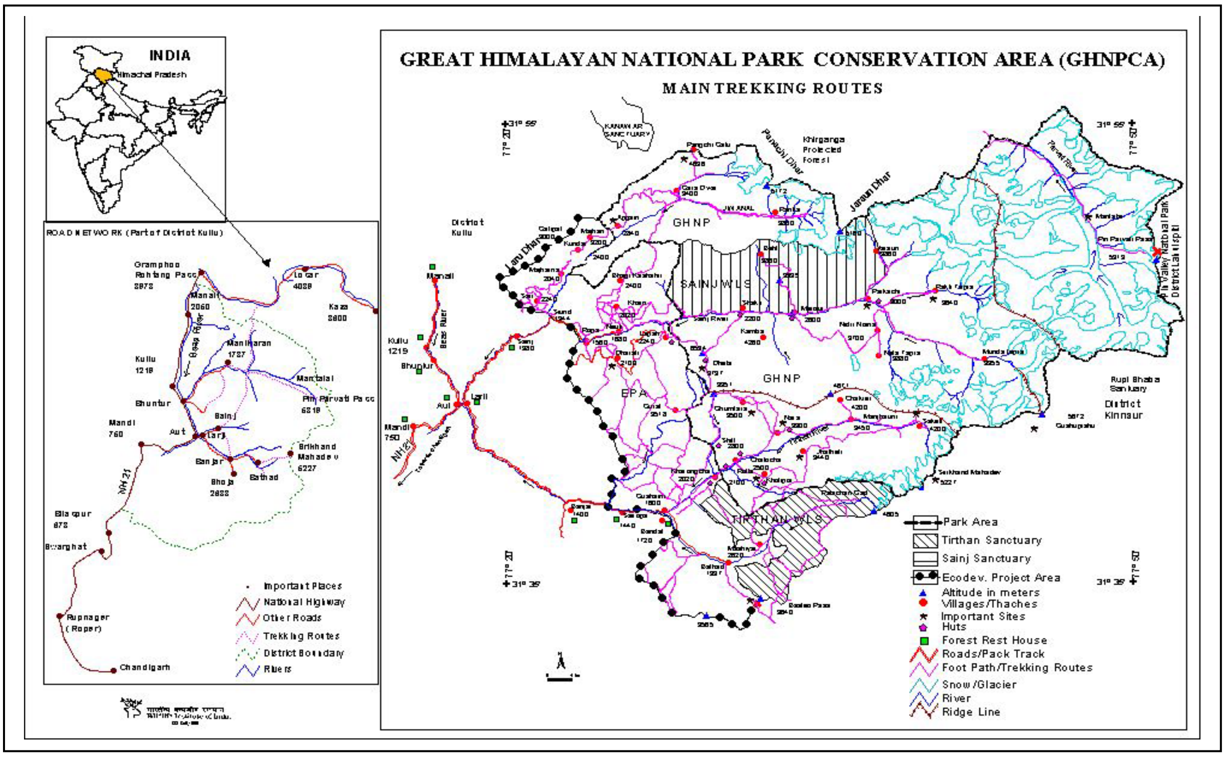
There was little commercial exploitation of the forest in the area prior to World War II, because of the inaccessibility of these forests, (Garson & Gaston 1985). Some felling took place during World War II to meet the increased demand for the timber during war period. Felling of certain species, *notable Abies pindrow* increased between 1949-50 and 1979-80 under the fourth working plan but remained confined to a small area. Tirthan and Sainj are known as inner Seraj forest within the Seraj forest division, while Jiwanal valley was a part of Waziri Rupi, (Gaston *et al* 1981). Though there was a little commercial exploitation of area local people have been using exercising a number of rights in this area. These rights have been recorded in Andersons' settlement report (1986). While only limited rights such as right of way, were allowed in the Reserved Forest, and a large number of rights were exercised in Demarcated Forest II, including livestock grazing, extraction of timber and collection of fuel wood and non forest produce. Local people have unlimited and unsettled rights in the Unprotected Forest class III. New areas were brought under such areas even if this entailed clear felling and burning of forest (Sharma 1987). However, the government has recently suspeciesended the rights to cultivate new areas in the unprotected forest class III and presently people enjoy the rights of herb collection, grazing of livestock and collection of MFP.

The human communities exist only on the western and the north-western boundary of the park and the other side of the park is demarcated by high ridges and peaks. The Himachal State Government imposed a moratorium on felling of timber trees in all the protected areas in 1984 and this has been upheld for this National Park also. Likewise, a ban on hunting was imposed in 1982 which still continues and has shown a favourable result for the wildlife of this National Park. The survey report by Himachal Wildlife Project I and III indicated that GHNP has more wildlife in 1991 than area outside its boundaries did in 1985. Thus from conservation point of view this area has a great significance.

2.9 MAIN TREKKING ROUTES

The main trekking routes of GHNPCA are mostly along the river valleys. The interconnectivity of one water divide to another is by the trails which is also used by the pilgrims, researchers and shepherds who come with their sheep and goats for grazing in appropriate season. Most of the park is inaccessible. Mapped routes by Survey of India are still in existence except few, which have been destroyed by landslides and avalanches. The trekking routes and trails are shown in the Fig 2.10.

Fig 2.9.



INDIA
GREAT HIMALAYAN NATIONAL PARK CONSERVATION AREA (GHNPCA)
MAIN TREKKING ROUTES

3. VEGETATION MAPPING

3.1 INTRODUCTION

The vegetation in the Himalayan ranges, which extend to almost 2500 km in length, experiences great variations in altitude, latitude, rainfall, temperature, humidity and edaphic conditions. Western Himalayas experiences less rainfall and humidity. All these contribute to both diversity and abundance of plant and animal communities.

The Western Himalayas are well known for their climatic, floristic, faunistic and geological diversity. The Great Himalayan National Park represents unique biodiversity of cold region, a typical of Western Himalayas. The area receives good rainfall and moist conditions favour good vegetation growth. Vegetation in park area is mainly temperate, sub-alpine and alpine. Some of the peaks have permanent snow cover. The plant communities in the area mainly are formations of conifer and oak forests. Slope and Aspect have played a major role in the development of forests in the area.

Traditional surveys have been very time consuming and less cost effective. Mapping of natural resources or habitats in particular, using satellite remote sensing provides a latest qualitative as well as quantitative data/information. This technology provides a synoptic coverage and acquires data at a periodic interval. Remote sensing technology is being widely used for forest/vegetation mapping throughout the world and in India, particularly, by various agencies *viz.* NRSA, FSI, IIRS etc., are involved in helping natural resource management through mapping and providing the current status.

3.2 RELEVANCE OF REMOTE SENSING AND GEOGRAPHICAL INFORMATION SYSTEM IN VEGETATION MAPPING

The beginning in satellite based remote sensing was made in 1972 with the launch of Landsat I by NASA, USA. Remote sensing is based on recording, measuring, and analyzing reflected/scattered or emitted radiation in different parts of electromagnetic radiation speciesectrum from various objects. The remotely sensed data provided new opportunity to developing countries to monitor and manage their natural resources within a stipulated time frame. Subsequent, noteworthy developments in sensors with respect to speciesectral and spatial resolutions viz. Landsat - TM (USA), SPECIESOT - I (France) and IRS IA and IB (India) have enhanced the utility of remote sensing. The speciesectral resolution offered by narrow swath sensors enables suitable delineation of vegetation pattern at spatial level.

The appearance of satellites on the scene has given tremendous boost to resource monitoring programmes (Curran, 1988, Lillesand and Kiefer, 1994). "Speciesace" is now being increasingly used as a medium to seek information of the earth. Remote sensing with its unique synoptic perspeciesective is a potential means of monitoring natural resources and environment, vegetation being a surface feature can be more efficiently mapped and analyzed by this technique in comparison to other resources. Characterization of terrestrial vegetation canopies through multi speciesectral data potentially offers a great improvement over conventional techniques, since it allows monitoring of temporal changes.

Remotely sensed satellite data are analogous to a map and can be used to determine the quality and quantity of vegetation because of its sensitivity to canopy parameters. These attributes of remotely sensed data led towards developing methods for vegetation mapping. The two commonly used method are (i) manual i.e., visual interpretation and (ii) machine based i.e., digital analysis. In both cases ground truth data is required for mapping interpretation key or training sites (digital data).

The advantage of satellite data in temporal change detection and mapping and frequent monitoring is that it is cost effective. In Himalayan context, remote sensing technology is playing a key role in survey, assessing the resources and recording the habitat changes, and collecting data both from accessible and inaccessible areas, on a repetitive basis.

For the integration and quick assessment of spatial and non spatial data, there is a need for a tool which can organize the planning, management and monitoring environment i.e., Geographical Information System (Borrough, 1986). This technology provides techniques to capture, store, manipulate, analyze and dispecieslay geographically referenced data. GIS systems are being used in natural resource management and several other multidisciplinary fields.

The technique has been appreciated for its bias-free data, cost and time saving, repetivity, synoptic coverage etc. Launch of a series of IRS satellites by India from 1988 onwards has ensured continuous availability of aerospeciesace data at a low cost. The use of remote sensing data has made it possible to map the extent and intermixing of forest communities' especially in inaccessible areas, which was rather difficult through traditional surveying methods.

3.3 LITERATURE REVIEW

Most of the ecological studies of Himalayan vegetation pertain to Kumaon and Garhwal Himalaya (Gupta, 1972; Singh and Singh, 1987 & 1992). The most significant works include classification of forest formation (Puri, 1960, Champion and Seth, 1968). Botanically, north western Himalaya has been explored thoroughly since 19th century. A number of publications *e.g.* Duthie, 1906, Kashyap, 1925, Blatter, 1927-29, Rau, 1975, Polunin and Stainton, 1984 deal with the floristic and phytogeographical ASPECTSof western Himalaya. More recent studies on the flora and vegetation of high altitude areas of western Himalaya include (Chowudhary *et al* 1984, Rawat *et al* 1986, Pangtey *et al* 1988, Adhikari *et al* 1991, Singh *et al* 1992, Rawat *et al* 1993, Aswal *et al* 1994, Singh *et al* 1994, Rawat, 1994, Rawat *et al* 1996, Kala *et al* 1997). With the advent of satellite remote sensing and with its ever increasing popularity because of its repetitive coverage, mapping of inaccessible and large area within short time, the true picture of area speciesecially of forest vegetation cover map emerges. The use of satellite data in India and abroad has been standardized with reliable accuracy in mapping (Batkin *et al* 1984, Hilderbrandt, 1986, Roy *et al* 1991 & 1992, Roy and Ravan, 1994). Broad vegetation type stratification using Landsat TM and MSS analogous data has been reported by (Pant and Roy, 1992). Satellite data has also been successfully used to delineate different cover boundaries (Tiwari and Kudrat, 1988 and Pant and Roy, 1990). Visual interpretation of IRS data for landuse/cover map has been done by several workers (Jadhav *et al* 1988). Data used for monitoring and landuse changes (Lal *et al* 1991; Pant and Kharakwal, 1995). Satellite data have been widely used for study of wildlife habitat and vegetation monitoring in many parts of the world. Remote Sensing data has been widely used for mapping habitat (Mead *et al* 1981; Kushwaha and Unni 1986; Roy *et al* 1986; Roy, 1996). The use of aerial photographs for wildlife habitat studies started in 1930. In India, studies have been carried out in the field of wildlife habitat evaluation especially vegetation mapping using aerial photographs (Dutt *et al* 1986; Roy *et al* 1986; Unni *et al* 1986 and Porwal and Roy, 1991b).

3.4 VEGETATION MAPPING

3.4.1. Introduction

Forest type map assumes importance basically due to its direct usage as habitat map or ecosystem characterization. These plant community maps form the basis for further delineation of unique habitats in terms of their biological richness and disturbance. Such maps provide locational information and are extremely important to indicate natural habitats for bioprospeciesecting for human welfare. These have found various applications in biodiversity characterization at different levels in natural and man-made ecosystems. Other application areas are habitat mapping for fauna as well as flora, forest management like stock mapping, monitoring, biomass estimation etc. Habitat mapping and biodiversity characterization are very important ASPECTSin conservation strategies for long term monitoring.

Remote sensing technology also offers multi-temporal data for monitoring purposes. Monitoring is most crucial to evaluate the success of the management measures. For this project mapping of communities or habitats has been done to help Park Management to arrive at critical conservation strategies, speciesecially seen in the context of biotic pressure from adjacent settlements for MFP collection, cattle grazing, illegal felling, poaching and encroachment etc. in fast developing tourism and orchard in the valley of Kullu.

To carry out the above mentioned objective data of IRS-1B satellite LISS II sensor have been used. For mapping geocoded FCCs (False Colour Composites) on 1: 50,000 scale for the month of September/October of 1993 year have been used. Forest type mapping has been done through visual interpretation of satellite data of IRS, which has been recommended for better results and information. Hilly areas have shadow effect, hence many times it does not offer any clue except for ground truth collection. And realizing this fact intensity of the ground verification has been increased and information in shadow areas has been collected in the field and incorporated in mapping.

3.4.2. Vegetation types in the study area

As mentioned above the area falls in middle and high Himalayan formations and therefore altitudinal variations, aspect, terrain etc. have played important role in the community developments. Champion and Seth (1968) have described the following forest types.

Sub-tropical Pine Forest (9/C1b): Subtropical pine forests occur in drier parts of the ridges and slopes from 1200 m to 1800 m depending upon the aspect and site conditions. Only pine, *Pinus roxburghii*, trees reach to the top canopy and second storey is very poor and has scattered trees and shrubs of Rhododendron *arboreum, Lyonia ovalifolia* etc. Ground flora is very much affected by the frequent burning (Plate 1).

Temperate Moist Deciduous Forests (12/C1e): Occurs in moist area with altitude varying from 1800 m to 2750 m. The top storey is formed by *Aesculus indica, Betula alnoides, Juglens regia, Acer caesium* etc. Lower storey is formed by *Rhododendron arboreum, Lyonia ovalifolia* etc. (Plate 2). Along the river on the sides narrow belts of riverain forests of *Alnus nitida,* and *Celtis* species etc. are found (Plate 3).

Temperate Broadleaved-conifer mixed Forests (12/C1d; 12/C2b): As the area has very rugged terrain, varying ASPECTSetc, there is mixing of forest types. These are found in altitudes varying from 1900 m to 2500 m and have varying mixture of coniferous and broadleaf species. The top storey is occupied by *Picea smithiana, Cedrus deodara, Abies pindrow, Pinus wallichiana, Aesculus indica* etc. Lower storey consists of *Rhododendron arboreum, Oak* Species *Acer* species etc. (Plate 4).

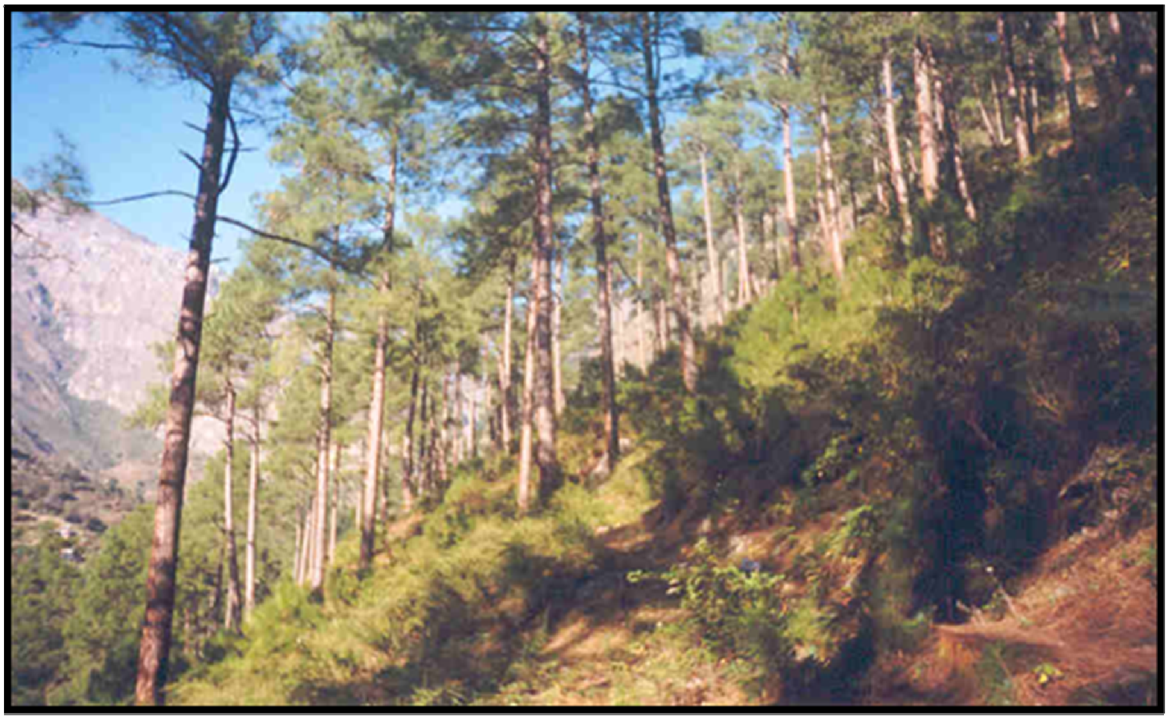


Plate 1- Sub-tropical pine forest near Devri

Plate 2- Temperate Moist Deciduous Forest

Plate- 3 Riverain Forest on way from Nevli to Shakti

Broadleaf mixed with Conifer Forest near Shangarh

Broadleaf mixed with Conifer Forest near Rolla

Plate 4

Temperate Coniferous mixed Forests (12/C3a): Coniferous forests occur in between 2400 m to 3000 m altitudes. Several species of conifer are found growing together in varying degree of mixing. Top storey is of *Cedrus deodara, Picea smithiana, Abies pindrew, Pinus wallichiana* etc. And lower storey is formed by *Rhododendron arboreum,* *Acer species. Betula alnoides* etc. (Plate 5).Conifer Forest mixed with Broadleaved trees is also found in the area. The coniferous tree species are more than (60-) 70% (Plate 6).

Temperate Broadleaved (Evergreen) Forest (12/C2a) Kharsu Oak Forests: Oak formations in the area are quite prominent and extensive. Kharsu Oak forest occur at altitudes varying from 2500 m to 3300 m. Aspect has played a great role in the development of these forests and are found mainly on southern slopes/aspects. Top storey is formed by *Quercus semecarpifolia, Acer caesium* etc. and *Rhododendron arboretum Betula utilis* etc occupy lower storey. (Plate 7).

Himalayan Temperate Secondary scrub: Human activity in some areas has lead to the degradation of forest cover and loss of local tree flora. In such areas secondary formations with scattered trees and shrubs intermixed with grasses have come up. Upper storey is made of trees like *Pinus wallichiana* and *Berberis* species, *Lonicera* species. etc occupy middle storey (Plate 8). Upper regions where the valleys open up have very specific formations of riverain forest or dense scrubs of *Hippophae* species. and *Viburnum* species. Bamboo formations are also found in the moist as well as dry areas (Plate 9).

Birch-Rhododendron Scrub: At places there is mixing of Birch and Rhododendron species between 3000 m to 4000 m. These have been seen on northern ASPECTSin the area. Top storey consists of *Betula utilis* and *Rhododendron campanulatum* and lower storey is of *Rhododendron anthopogon, R. lepidotu, and Berberis* species (Plate 10).

Alpine scrub: *Rhododendron* community is major contributor towards these formations. This community occurs from 3300 m to 3800 m altitudes. Large impenetrable tracts of these are quite unique and are habitat for unique fauna and flora. *Rhododendron campanulatum* is the main species there (Plate 11).

Temperate grasslands: Temperate grasslands or grazing/pasture lands occur between 2500 m to 3500 m altitudes. Locally known as “thatch” are traditionally grazing grounds for wild as well as domestic animals (sheep). Grases like *Themeda triandra, Oplismenus compositues* and several species of *Primula, Gentiana, and other Grasses* etc. occur here (Plate 12), (Plate 13).

Alpine Pastures: Higher reaches of greater Himalayan ranges and interior of the conservation area has vast areas of sub-alpine and alpine grasslands or meadows, commonly known alpine pastures. Pastures have a few species of grasses and several species of Primula, Ranunculaceous (*Caltha palustris, Ranunculus species)*, Brassicaceous (*Thlaspeciesi, Drab* and *Arabis* species.), *Saxifraga* species occur in these areas (Plate 14), and (Plate 15).

3.4.3. Vegetation Mapping

Vegetation is the single most important parameter for evaluation and conservation of biodiversity. Therefore, qualitative and quantitative status of the vegetation is basic requirements for strategy formulation and future monitoring. Aero-speciesace technology is widely used for quick and repetitive coverage in a very cost effective manner. Each vegetation type has its inherent characteristics in terms of species composition, community structure, crown closure, age of plants and phenology. These subtle variations are captured by cameras/sensors and recorded for further analysis. Thus remotely sensed images depict various earth features like vegetation, sand, rivers, barren rocks, agriculture, settlements etc. These images are available at various scales and band combination to the user for further interpretation as per user's requirement or objectives. These images contain enormous information and to obtain these one needs to know the ground realities. In this study vegetation mapping has been carried out using remotely sensed images of September /October data of 1993. In western Himalayas these period data is preferred to obtain maximum contrast among various features on the Earth and vegetation in particular. During this snow cover is minimal for alpine pastures mapping, habitat for many target species and community differentiation is better because of phenological differences.

Mixed Conifer Forest near Shilt

Plate 5

Mixed Conifer Forest at Shilt

Conifer Mixed With Broadleaf Forest around Shangarh

Conifer Mixed with Broadleaf Forest in Tirthan valley

Plate-6

Plate 7 **Broadleaf Forest of Kharsu Oak above Shilt**

Secondary scrub on way from Nevli to Tung

Secondary Scrub on way to Tung

Plate- 8

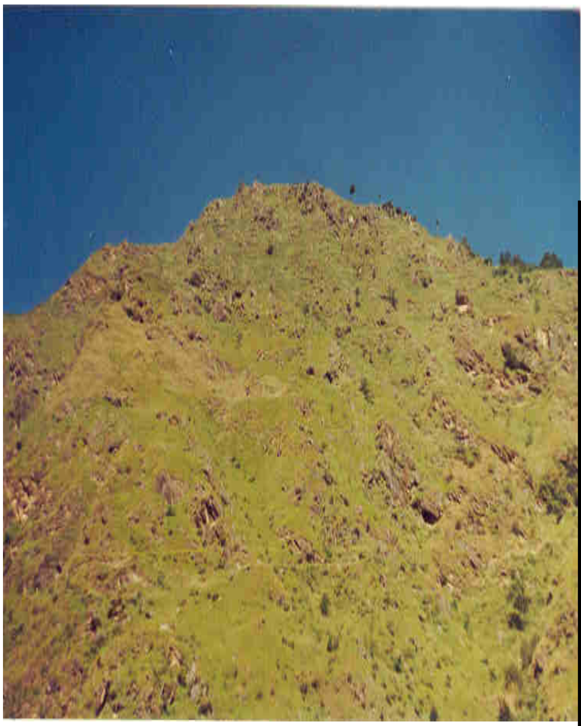
Temperate Riverine near Shakti

Plate 9

Temperate Riverine way to Maror

Plate 10 Betula-Rhododendron Scrub near Basleo Pass

Plate 11 **Rhododendron Scrub near Rhukhundi Top**



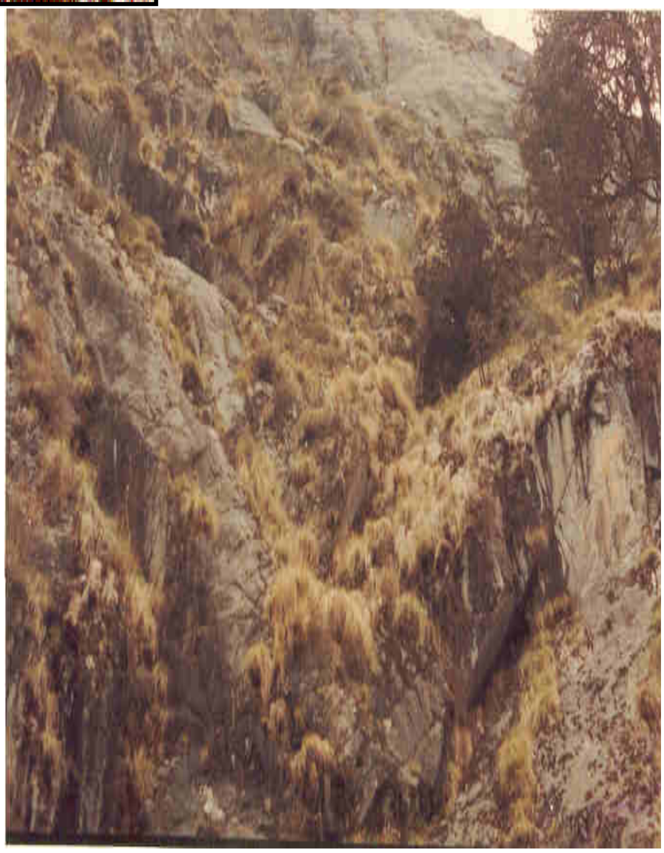
Temperate Grassland near Kharoncha

Plate 12

Plate 13 **Temperate Grassland**

Alpine Grasslands near Basleo Pass

Plate 14



Sub-Alpine Grasses on steep slopes near Gumtrao

Plate 15

3.4.4. Material and methods

Vegetation mapping has been done based on the knowledge of the environmental conditions which govern the land use and land cover and vegetation in particular. Materials used during the vegetation mapping are:

3.4.5. Materials

3.4.5.1. Satellite Data

False Colour Composites (FCC) of IRS –1B LISS II sensor of September/ October of 1993 has been used. LISS II sensor has spatial resolution of 23.5×23.5 m. One scene covers nearly 148×148 km of the ground area. Bands used for generating standard FCC were infrared, red and green i.e. 4, 3, 2. Geocoded data on 1:50,000 scales have been used. The study area is covered in 6 scenes of geocoded data on 1:50,000.

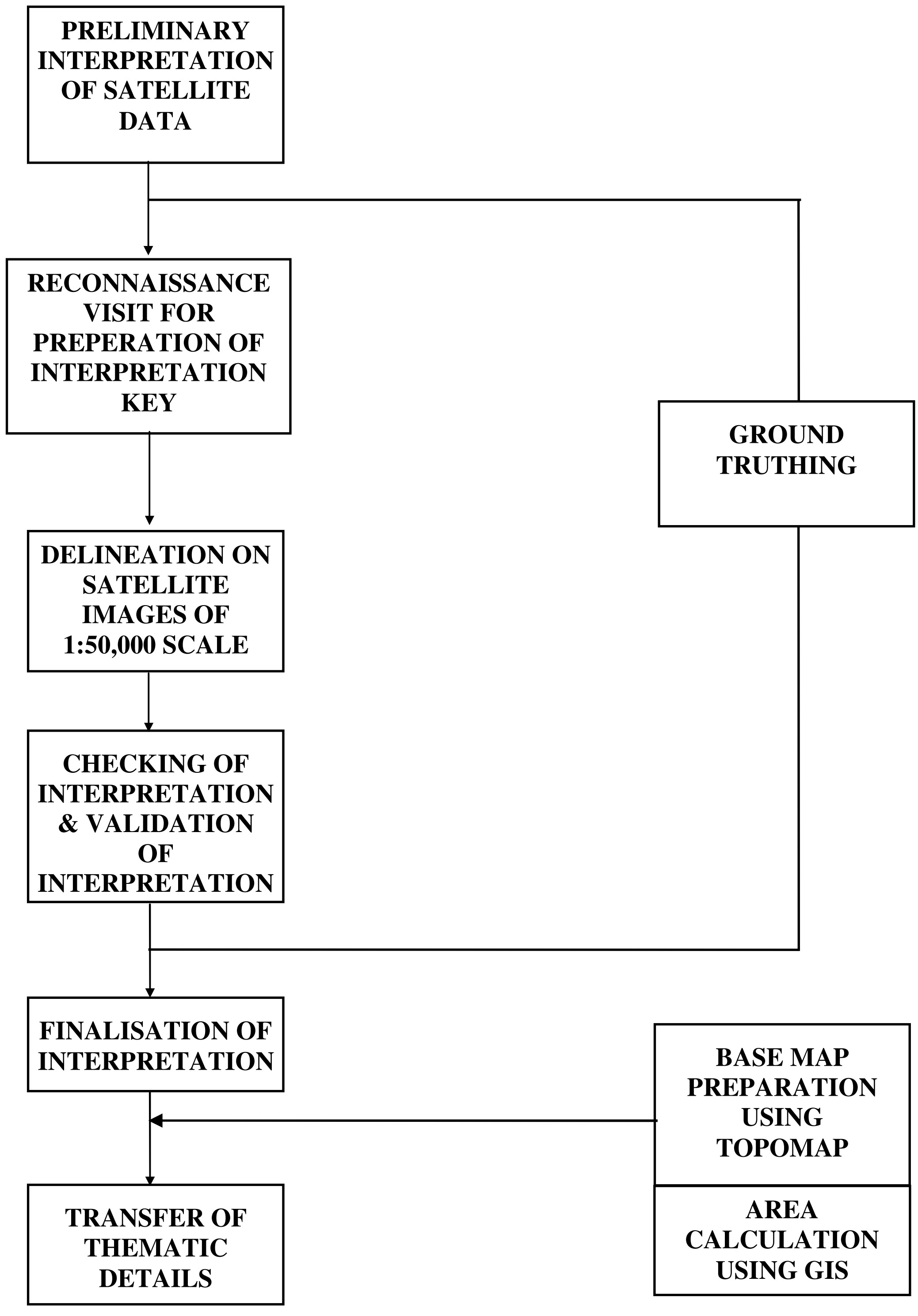
3.4.5.2. Ancillary Data

Mapping need accurate ground truth. Survey of India topo maps have been used during the field and interpretation. Other equipment used during field work is Ranger's compass, hypsometer, altimeter, tape camera and related stationery. During visual interpretation dynascan magnifier, interpretation table etc. have been used. Literature related to the vegetation of the area was of immense use and were used for correct recognition of vegetation types.

3.4.6. Methodology

For vegetation mapping standard methodology of visual interpretation has been adopted. Standard methodology includes use of image elements like tone, texture, shape, location, association, pattern etc. and ancillary information like elevation. These are also called interpretation elements. The approach is shown in Fig.3.1

Fig.3.1 STEPS IN LANDUSE/COVER MAPPING THROUGH VISUAL INTERPRETATION OF SATELLITE IMAGES



3.4.6.1. Base Map Preparation

The mapping exercise began with preparation of base map of the area. Permanent features like road, rivers or any other cultural feature were taken on base map. The area has drainage density therefore only main streams were considered. Next step was to do preliminary interpretation of satellite data and generation of preliminary interpretation key. Then preliminary interpreted maps were taken to field.

3.4.6.2. Reconnaissance Survey

First reconnaissance survey of a short duration was carried out in part of the Tirthan valley in the year 1995. This was done basically to understand the terrain and vegetation of the study area. Further, reconnaissance surveys were carried out in other areas to get a mental picture of the area and vegetation types and their associations. During this process interpretation was tested and rectified where ever necessary.

3.4.6.3. Ground Truth data Collection

The Earth features on a satellite data appear in different tones and textures. For correct identification it is extremely important to correlation image elements and ground features. Field trips were conducted to collect ground truth throughout the study area.

Routes followed were:

(a) **In Tirthan valley** - Ghusaini-Rolla-Shilt-Rukhundi Top-Gumtarao and beyond and back was surveyed twice.

(b) In Palachan Gad- Ghusaini-Bahtad-Chipni-Galiyar- Basleo Pass- and back to Bathad/Ghusaini through different valleys was surveyed once.

(c) **In Sainj Valleys**- Nevli-Tung-Nevli was surveyed once. And area of Sainj-Shangarh-Lappa-Baha-Shakti-Maror was criss-crossed through the forests once. Shakti-Hemkhundi area was surveyed once.

(d) **In Jiwanal Valleys** - Sainj-Jiwanala to some distance and back and once surveyed.

Many more field tours were taken up to collect ground truth. During these trips information on vegetation type's speciesecially in shadow areas were taken and incorporated in the mapping. Almost every vegetation types have been covered during these surveys. Every time interpretation was tested and improved.

3.4.6.4. Vegetation Mapping

Interpretation key was finalized and then the images were interpreted as per the objectives of the project and agreed classification scheme with other users as well as project team. All thematic details have then been transferred to base map on 1: 50,000 scale.

3.4.6.5. Ground Check

Ground check is most essential part of the mapping. It is important for user to know the accuracy of mapping. Final interpreted map was taken to field for ground check. 100 points were marked randomly on the map for checking purpose before going to the field. These were selected keeping in mind the ground realities. Mapping accuracy has been estimated using these point information. Wrongly interpreted features or vegetation have been corrected after the ground check.

3.4.6.6. Classification scheme

The classification scheme has been designed to meet the study objectives. A few forest types like upper and lower temperate broadleaf forests have been merged. Similarly, temperate and alpine grasslands have been put together. However, these can be separated in GIS domain by taking a appropriate contour height. However, sampling for describing community structure has been done in all classes. Two forest density classes have been attempted. Vegetation with > 40% canopy cover has been delineated as closed forests and < 40% as open forest. Non-forest land cover has also been delineated keeping in mind the requirement of wildlife habitats for future planning.

A. Forest

(a) Conifer forest (Chir Pine Forest)
(b) Broadleaf forest (Ban Oak and Kharsu Oak)
(c) Broad leaf mixed with conifer (Broadleaf > 60%)

(d) Mixed Conifer (Western Mixed Coniferous Forest)
(e) Conifer mixed with Broadleaf (Conifers > 60%)
(f) Secondary Scrub (Chir Pine and Berberis)
(g) Alpine Scrub (Rhododendron and Betula)
(h) Slope Grasses
(i) Grasslands and Forest Blanks (Both temperate, sub-alpine and alpine pastures)
(j) Riverain
(k) Plantations

B. Non-forest

(l) Agriculture/Settlement/Orchards
(m) Exposed rock with slope grasses
(n) Escarpment
(o) Alpine Exposed Rocks with Slope Grasses
(p) Landslide
(q) Morainic Island
(r) Glacier
(s) Moraine
(t) Permanent Snow
(u) Lakes
(v) River

C. Density classes

(a) Closed Forest (Crown Closure > 40%)
(b) Open Forest (Crown Closure 10 - 40%

3.4.6.7. Final Interpretation

The area has great altitudinal variations, deep valleys and steep slopes. High hills have shadows on the northern aspects. Elevation has impact on the vegetation. Interpretation of satellite was finalized based on the correlation established between image elements like, tone, texture, association, location etc. and the ground features as per the classification scheme. Attempt was made to check the ground features in shadow areas. Appropriate rectification was performed in these areas. Vegetation map finalized after proper annotations on 1:50,000 scale.

3.4.7. Results and discussion

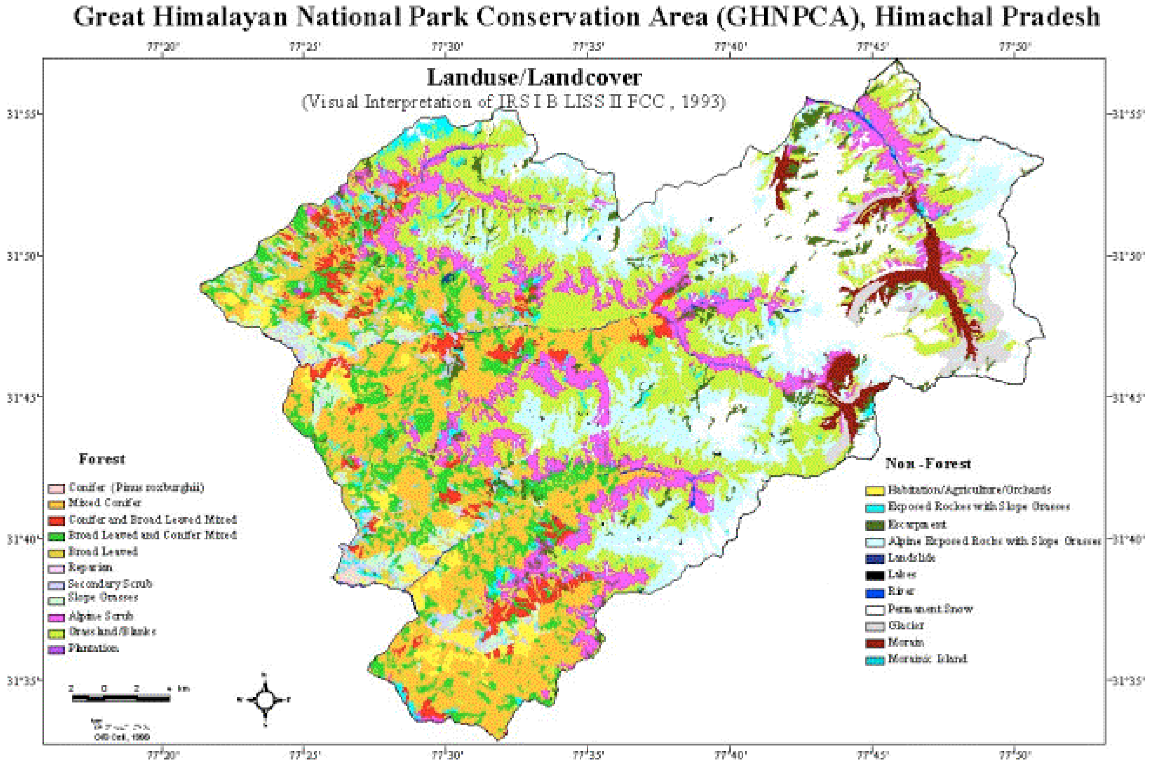
Satellite data provide synoptic coverage of the land features. Therefore, it had advantages over traditional method of vegetation mapping. Vegetation maps provides locational information and area can be estimated. Interpretation of images has been using standard methods of visual interpretation as per the classification scheme mentioned above.

3.4.8. Mapping

The study area was visited for ground truth collection in various seasons. To familiarize with ground features and terrain the reconnaissance survey was conducted. The basic requirements of the visual interpretation were met by preparing interpretation key based on photo-elements like tone, texture etc. and the ground information like elevation. Consideration of elevation became necessary as the vegetation changes with change in altitude. Thus final interpretation has been done based on these parameters. The details of the interpretation are given in Table 3.1a, 3.1b. and Land Cover and Landuse map of the GHNP Conservation area has been prepared and shown as Fig 3.2.

The study area is full of Mountain Peaks; therefore, lot of area is was under shadow. On FCC shadow areas appear very dark or black hence cannot be interpreted. Shadow areas, mainly on northern and northern-western aspects, were interpreted and delineated in the field using natural features after matching with satellite images. This was done in all valleys (Tirthan, Sainj etc.).

Fig.3.2



Vegetation has been mapped into broad forest classes *e.g.* broadleaf forests of temperate zone have been put together. Similarly riverain forest of subtropical and temperate are mapped together. It has been done assuming that the various forests types can be broadly separated in GIS using elevation as the criteria. However, for characterization of communities of vegetation observations and sampling have been done in each forest type. Categorization of vegetation has been done first into forest and non-forest classes. Forest has then been subdivided into 11 different types. Grasslands have also been treated as part of forest as these are most important in wildlife conservation and management. These can either form vast areas or are found in patches locally known as 'Thatch' or forest blanks. Equal importance to non-forest features is also given keeping again the requirement of the project for wildlife management for conservation. Eleven features have been delineated for this purpose.

3.5 AREA ANALYSIS

Accept Jiwanal, the other two valleys i.e., (Tirthan and Sainj) are having good forest. Total area of the conservation area is 1171 km^2. The area has been estimated using dot grid method, digital planimeter and GIS after careful digitization and proper projection. Two measurements of dot grid gave an area of 1239.49 and 1245.94 km^2 (average 1242.5

km^2). In GIS the area was 1270 km^2. This is based on the base map which was prepared from SOI sheets on 1:50,000 scale and then digitized. However, having accepted official figure of area i.e. 1171 km^2 error has been distributed accordingly among all the classes. Northern ASPECTShaving higher moisture contents harbor very rich unique flora. The area has varied land cover and land use. Ecodevelopment Zone has agricultural fields and orchards as the main land use. About 25% of the areas is dominated by lofty mountains and peaks with either permanent snow or experience snow fall during winter. Middle region has either thick forests of broadleaf, conifers or mixture of both. Area analysis of the Conservation area is given in Table 3.2.

Table 3.1a INTERPRETATION KEY FOR (a) FORESTS CLASSES FOR VISUAL INTERPRETATION

S. N.	Class (Mapping)	Tone	Texture	Physio-graphy	Altitude (m)	Forest Type	Vegetation association
1	Conifer Forest	Bright Red	Medium to coarse	Moderate to steep slopes	600-1700	Subtropical Chir Pine Forest	Chir Pine *Pinus roxburghii*
2	Broadleaved Forest	Bright red to deep red	Medium to coarse	Gentle to medium slopes (bouldery land)	1500-3300	Himalayan Moist Temperate and Kharsu Oak Forest	*Quercus floribunda, Aesculus indica, Betula alnoides, Prunus* species. *Quercus semecarpifolia*
3	Broadleaved mixed with conifer	Various shades of red to brownish red	Medium to coarse	Gentle to medium slopes, speciesurs with good soil	1500-3000	Himalayan Moist Temperate Forest	*Acer species., Quercus semecarpifolia, Betula utilis, Abies pindrew, Taxux, Prunus cornuta*
4	Temperate Mixed Conifer	Brownish red to dark brown	Medium to coarse	Moderate to steep slopes and aspects	1500-3000	Western Mixed Conifer and Moist Deodar Forest	*Pinus wallichiana, Picea smithiana, Abies Pindrew Cedrus deodara*
5	Conifer Mixed with broadleaved	Brownish red to bright red	Medium to very coarse	Gentle to medium slopes on good soils	1500-3300	Himalayan Moist temperate Forest	*Pinus wallichiana, Abies Pindrew, Cedrus deodara, Quercus floribunda, Aesculus indica,*
6	Secondary Scrub	Light Pink -shades of brown	Medium to coarse	Medium to higher slopes,	1500-3300	Temperate Secondry Scrub	*Berberis chitria,* Indigofera, Rosa, *Pinus wallichiana*
7	Alpine Scrub	Pinkish red / cyan yellowish	Medium to coarse	Gentle to moderate slopes (moist)	3000-3600	Moist Alpine Scrub	Birch-Rhododendrons formations
8	Slope Grasses	Whitish yellow to light pink	Medium to coarse	Steep Slopes	1500-2500		Poa and mixture of other of grasses
9	Grassland	Whitish yellow to light pink	Smooth to smooth	Gentle to moderate slopes	1500-3600	Temperate, subalpine and alpine grasslands	Poa species., Agrostis species., and other herbaceous plants like Primula species., Gentiana species., Aster species., Brassicaceae
10	Riverain	Light to brownish red	Medium to coarse	River beds and on sides slopes	1500-2500	Himalayan Moist and Dry Temperate Forest	Alnus nitidia, Alnus nepalensis Hippophae species., Myricaria species.
11	Plantation	Redish brown	Fine to medium	Medium to higher slopes	1500-3300	Temperate zone plantation	*Pinus wallichiana*, with Abies, Acer species.

Table 3.1b INTERPRETATION KEY FOR (b) NON-FOREST CLASSES

S N.	Class (Mapping)	Tone	Texture	Physio-graphy	Altitude m	Type	Vegetation association
12	Agriculture /Settlement /Orchards	Light pink to dark cyan to yellowish red	Medium to coarse	Very Gentle to Medium slopes	1300-2500	Temperate zone (Moist)	Wheat, Potato, Elucine, Apple, Peach etc.
13	Exposed rocks with slope grasses	Yellowish white to dark cyan	Medium to coarse	Steep to moderate slopes	1500-2500	Temperate zones	Various species of grasses with cliffs, rocks exposed
14	Escarpment	Dark cyan to dirty blackish	Medium to coarse	Very steep slopes	1500-2500	Temperate zone	Exposed Cliffs with scattered grasses
15	Alpine Exposed rocks with slope grasses	Yellowish white to dark cyan	Medium to coarse	Steep slopes	2500-3600	Alpine zone	Various species of grasses, Asters, Primulas, Crucifers, Scrophularia ceae
16	Land-slides	Cyan to bluish cyan	Smooth to medium	Steep to moderate slopes	1500-3600	Throughout	Exposed sand and boulders
17	Morainic Islands	Grey to dirty brown	Medium to coarse	Middle or margin of moraines	Above 3600	After and within moraine	Small pebbles
18	Glaciers	White	Fine	Upper most reaches	Above 3600	Above moraines	Glacier
19	Moraine	Grey to dirty grey and white	Medium to coarse	Medium to higher slopes in upper reaches	Above 3600	Below snow line in valleys	Morrain
20	Permanent Snow	White to dirty white	Smooth to fine	Gentle to medium slopes of N and NW aspect	Mostly above 3000	Above snow line	Permanent snow
21	Lakes	Dark blue to black	Smooth to fine	Pene plain	2000-4000	Higher reaches	Water bodies
22	Rivers	Dark blue to black	Medium	Valley bottom	1500-3600	Throughout	Water channel and sand

Table No.3.2 AREAL ESTIMATION OF LANDCOVER/USE IN GHNPCA

S.No	Type	Area in Km^2
1	Conifer (*Pinus roxburghii*)	2.08
2	Mixed conifer	127.98
3	Conifer and Broad Leaved Mixed	33.16
4	Broad Leaved	66.62
5	Broad Leaved and Conifer Mixed	83.36
6	Riperian	0.14
7	Slope Grasses	25.92
8	Grasslands/ Blanks (Temp. sub Alpine & Alpine)	221.80
9	Secondary Scrub	22.28
10	Alpine Scrub	117.62
11	Plantation	0.16
12	Habitation/Agrculture/Orchards	25.55
13	Exp.Rocks with Slope Grasses	27.60
14	Alpine Exp. Rocks with Slope Grasses	149.73
15.	River	4.35
16.	Lakes	0.87
17.	Escarpments	33.82
18.	Landslide	0.41
19.	Snow	184.01
20.	Morian	24.24
21.	Morainic Islands	0.48
22.	Glaciers	18.82
	Total	**1171.00**

3.6 LANDUSE/LANDCOVER MAPPING (SPECIESECIALIZED CATEGORIES)

Extraction of other classes through Geographical Information System

Although the data has been visually interpreted and nine forest and fifteen non forest classes have been delineated but for habitat characterization (analysis) as per the species preferences (*Western Tragopan* and Himalayan *Musk Deer*), the specific forest types and grasslands have been extracted. The logical knowledge based approach has been applied in grid module with the help of climatic zoning through GIS domain using ARC/INFO software. The basis of extraction was on altitudinal variations.

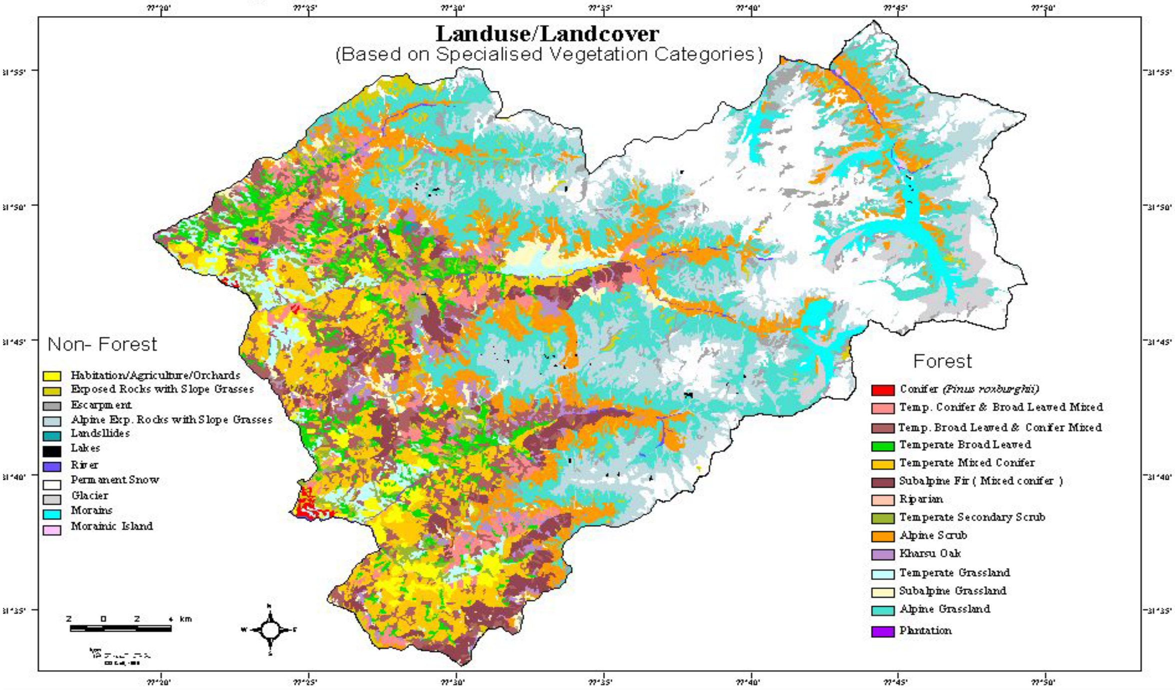
The general types of Broad-leaved forest and Grasslands have been extracted into sub-tropical to sub-alpine broad-leaved forest and sub-tropical to alpine grassland respectively. On the basis of users choice this approach can be applied for extracting the different categories as per the different objectives. The landluse / landcover map and area of forest types and grasslands along with extracted classes through GIS can be seen through Fig 3.3 and Table No. 3.3

Table No.3.3 AREAL ESTIMATION OF VEGETATION MAP DEFINING ADDITIONAL CLASSES USING GIS

Class	Area in km^2	Percentage
Pinus Roxburghi	2.1	0.18
Temperate Mixed conifer	82.39	7.04
Subalpine Fir	39.11	3.34
Temp. conifer and broad leaved Mix	33.21	2.84
Temp. Broad leaved and conifer mixed	83.44	7.13
Temp. broad leaved forest	42.95	3.67
Kharsu forest	23.7	2.02
Temp Grassland	31.7	2.71
Subalpine grassland	22.25	1.90
Alpine grassland	193.89	16.56
Reparian	0.14	0.01
Temp. secondary scrub	22.26	1.90
Alpine scrub	117.71	10.05
Plantation	0.16	0.01
Non-forest		
Habitation/Orchard Agriculture	25.53	2.18
Escarpments	33.69	2.88
Exposed Rocks with slope grasses	27.54	2.36
Alpine Exposed Rocks with slope grasses	149.89	12.80
Land slides	0.42	0.04
River	10.78	0.92
Morrain	24.25	2.07
Lakes	0.86	0.07
Moranic island	0.48	0.04
Glacier	18.68	1.58
Snow	183.87	15.70
	1171.00	100.00

Fig.3.3

Great Himalayan National Park Conservation Area (GHNPCA), Himachal Pradesh



3.7 DISCUSSION

In Ecodevelopment zone, Subtropical forests of Chir Pine (*Pinus roxburghii*) cover about 0.18% of the total area. Good patches of forest can be seen in the lower reaches amidst orchards and agricultural fields. Understorey flora is less and is subjected to frequent fires. Tremendous biotic pressure is on these forests and at some places tree density is very low. Chir Pine forest occurs around Rolla, Sainj and Nevli. Towards Sangah from Sainj and Nevli very good forest of Chir Pine can be seen. At some places is mixed with other species.

Broadleaf and conifer forests occupy majority of the forested land cover maximum area is under temperate conditions. Broadleaf forests have of lower and upper temperate have been shown together and cover about 5.6% of the total area. Oaks are predominant species of these forests along with *Acer* species, *Juglens regia, and Rhododendron* species etc. Very good high density forests of this type grow in the moist slopes (northern aspects). Under storey is very rich in herbaceous plants. *Taxus wallichiana* is also found scattered in these forests. Tirthan valley between Ghusaini and Rolla has very good forests. Broadleaf forests between Lappa and Shakti are also good. The area has more of *Acer* trees. Kharsu oak form the upper belt of broadleaf trees in both Sainj and Tirthan valleys. The upper belt of both valleys has extensive forests of Kharsu Oak. Kharsu forests do not have very good ground flora. Moist broadleaf forests have high potential of minor forest produce. Kharsu oak is found around Shilt, upper reaches of Tung, Shakti, and Hemkhudi thatch and towards Basleo Pass. Moru oak forest near Shangad, Kharongcha, above Bathad is heavily lopped. The mature and old tree formations of different sizes of *Acer* species near Lapah and above Rolla can be seen. *Rhododendron arboreum* formations grow around Kharongcha.

Mixing of broadleaf and coniferous forests is very predominant in complex terrain between subtropical and alpine areas. Narrow gorges and valleys have higher moisture availability and support broadleaf forests whereas coniferous forests are confined to drier regions on the ridges. These forests form about 7% of the total forested area. The mixing of these patches could vary in proportions however broadleaf species are denser. Broadleaf species like *Aesculus indica, Quercus semicarpifolia, Acer* species., *Prunus cornuta, Juglens regia* etc. and coniferous species like *Picea smithiana, Pinus wallichii, Cedrus deodara, Abies pindrew* etc.

Coniferous forest cover is maximum in the conservation area and forms about 10.9% of the total area. Conifer forest has intermixing of several species. Middle temperate zone is occupied by with this type of forest. Pure patches of *Cedrus deodara* with scattered trees of *Picea smithiana* and *Pinus willichii* are found around Shangarh. Grazing of these forests around Shangarh is very high and under-storey is not so good. These mixed forests of conifers have trees of *Picea smithiana, Pinus willichii, Taxus wallichiana* along with varying inter-mixing of broadleaf species as well. Broadleaf trees like *Prunus* species, *Betula*, species, Quercus species might also occur scattered. Rolla-Shilt area also has pure patches of *Cedrus deoadara* and *Pinus wallichii*. *Taxus wallichiana* occurs scattered in these forests. In our sampling we found it forest near Lappa and towards Basleo Pass. Conifer forest towards Tirthan is very dense and phytodiversity is also very rich.

Coniferous forest also has in some areas high mixture of deciduous or evergreen broadleaf trees. About 2.8% of the area has this type of mixed forests. Varying degree of species like *Cedrus deodara, Picea smithiana, Abies pindrew, taxus buccata, Quercus semecarpifolia, Acer acuinatum, Betula alnoides and Celtis species* along with *patches* of bamboo also occur. Extensive bamboo patches can be seen from Shilt to Rukhundi. Ground flora is quite rich in these forests. Lichens grow very well in these areas.

Secondary scrub is found mainly in the subtropical and lower-temperate zone in all three valleys. The area covered by these is about 1.9% and are associated with human activities. These are the areas subjected to overgrazing or cultivation and then abandoned. Extensive scrub of *Berberis aristata* occurs on the southern slope from Nevli to Tung. In Palachan Gad around Bathad, Mashiyar, Galiyar and Chipni area *Lonicera* species and *Indigofera* species scrub vegetation grows on the bunds and abandoned agricultural fields in the areas of Chipni and Galiyar. Scattered trees of *Pinus wallichiana* can also be seen in the steep sloppy areas.

Alpine scrub is found in the higher reaches throughout the GHNPCA and forms about 10% of the total area. It is a transition between temperate forest and alpine vegetation. The dominant species are *Betula utilis* and *Rhododendron companulatum*. Each of these can be seen growing gregariously in the area. *Betula utilis* scrub occurs in pure patches on northern ASPECTSnear Basleo pass and around Rukhundi top. Gumtarao surroundings have extensive growth of *Rhododendron companulatum* scrub, more so on the eastern and north-eastern aspects. Dhela thatch area also has very good scrub of Betula-Rhododendron. These area experience heavy snow fall every year and plants are adapted to these conditions.

Slope grasses mainly occur on the southern ASPECTSon very steep slopes and form about 2.2% of the area. Extensive patches of these can be seen after Baha towards Shakti in Sainj Valley. In Palachan Gad large patches of these grow above Chipni and on the steep slopes of before Rukhundi top from Shilt. Tall grasses like *Themeda triandra, Vitiveria ziznoides* etc. grow in association with non-graminaceous plants.

Grasslands form the highest cover in the GHNPCA and cover about 18.9% of the total area, which is a very good from wildlife point of view. The grasslands locally known as ‘thatch’ are mainly the resting sites used by shepherds or local grazers. These are mainly associated with peaks and ridges. Well known thatches are Hemkhundi, Dhela, Gumtarao, Manoni etc. Grasslands of subtropical, temperate and alpine zone have been mapped together. These can however separated out in GIS by using elevation criterion. These thatches have a mixture of herbaceous plants. Grasses like *Themeda triandra, Agrostis pilosila, Andropogon* species, *Chrysopogon echinulatus, Oplismensus compositius, Paspeciesalum* etc. are commonly found.

Riverain forest occurs in subtropical and temperate zones and occupy about 0.011% of the area. In subtropical forest these can be seen around Ghusaini, Sainj, Nevli and riverbeds of Palachan Gad stream and lower reaches of Dhela khad near Lappa and Rupa nala. Mapping of these areas has been difficult firstly because of the shadow and secondly because these forest occur in very narrow belts along streams or on islands. Subtorpical riverain have *Alnus nepalensis* and *Alnus nitida* as the dominant species along with *Prunus* species and *Pyrus* species, *Girardinia* species and *Berberis* species. Temperate riverain scrub of *Hippophae* occurs before and after Shakti towards Maror. These grow gregariously flat on raised riverbeds and along streams. The main species are *Hippophae salicifolia, Sorberia tomentosa* and *Rosa webbiana*. An interesting patch of Viburnum species scrub occurs along riverbed in between Shakti and Maror in very moist and shady conditions.

Plantation is not much in the area and it forms only 0.014% of the area. Old plantation of *Pinus wallichiana* is in Jiva nala in Ecozone area.

Most of the conservation area is without vegetation i.e. about 40% of the total area. Some of these areas are equally important from wildlife point of view. Exposed rocks with scanty cover of grasses (about 2.5%), Escarpments (2.89%), Alpine exposed rocks with slope grasses (12.78%), Moraine islands (0.041%), Glaciers (1.6%), Moraine (2%), Permanent Snow (15.7%), Lakes (0.074%) etc. are important habitats for wildlife for fodder, shelter and breeding grounds. In some areas there are a few landslides. Landslides occur in very disturbed and non-forested area.

Ecodevelopment zone has a very complex land use. Habitation is associated with Agriculture and Orchards and relatively gentle slopes (fan-shaped fluvial deposits) and land with soil are under cultivation (unlike forested areas which have rock crop-outs, boulders and stones). About 2.18% of the area is under this land use.

3.8 CONCLUSION

Remote sensing technology offers quick and cost-effective method of mapping land features. IRS satellite data have been used successfully to map the landcover and landuse of the GHNP Conservation area as per study objectives. The technology provides quick assessment of the areas for conservation planning. GHNP has very rugged terrain and accessibility is difficult. Remote sensing technology has been of much help because we were able to map even inaccessible areas. Landcover and landuse information is most important for decision making and management and to know the current status of the vegetation. Baseline information on their location, distribution and area has been generated. And 11 forest/vegetation types and 11 non-forest features have been mapped using this technology. Area analysis has been done for each class. About 60% of the areas is under forests whereas non-forest area cover about 40% of the area. The area calculated through a base-map prepared using SOI sheets on 1:50,000 were about 100 km^2 higher than the official figure. The error has been distributed proportionally.

It may be concluded from the findings that GHNPCA has very good temperate broadleaf and coniferous forests. Alpine pastures are the sites for many wild animals to graze. Snow covered area offer home for many animals.

3.9 CHANGE DETECTION ANALYSIS

3.9.1. Introduction

Ecodevelopment Area is one of the important sub units of Great Himalayan National Park Conservation Area. This is the main habitation zone within the conservation area. The area bears maximum biotic pressure and puts pressure in GHNPCA too in the form of migratory sheep and goat grazing, extraction of medicinal plant, collection of Guchhi mushroom, fuelwood etc. For management point of view it is essential to monitor the area regularly.

For the ecodevelopment Area the vegetation mapping has been done with the help of Remote Sensing and GIS. Because remote sensing capabilities to analyze with reliable accuracy and efficiency in geographical information system i.e., ARC/INFO GIS domain. This technology provides techniques to capture, store, manipulate, analyze and dispecieslay geographically referenced data. The study used socioeconomic data to monitor change in Landuse/Landcover with respect to the population between 1961 to 1991.

3.9.2. Land use and people of the area

There are about 123 hamlets in 13 revenue villages with 2465 households with total population of 11715 in Ecodevelopment Area of GHNP (1991 census) is shown in Table 3.4 and the map of village locations can be seen on Fig 3.4

Table 3.4

POPULATION AND NUMBER OF HAMLETS IN THE REVENUE VILLAGES OF EDA

TEhsils/ Waziri	Kothi	Phati	No. of hamlets	No. of House-holds	Total Population
Banjar/ Inner Seraj	Tung	Chipnio Mashyar	5 8	245 220	1537 1280
"	Nohanda	Pekhri Tinder	13 6	187 123	1098 677
"	Plach	Srikot Kalwari	7 9	78 195	417 1132
"	Sarchi	Shili	4	137	812
Sainj/Inner Seraj	Banogi	Suchen	6	202	1212
"	Shangarh	Shangarh Lapah	13 4	111 37	618 222
Sainj/Rupi	Sainshar	Sainshar Garaparli	22 7	302 116	1606 592
Kulu/Rupi	Balhan	Railla	19	512	512
Total	8	13	123	2465	11715

The population growth statistics for the period 1981, 1991 and projections for the year 2001 are given in Table 3.5.

Table 3.5 POPULATION GROWTH STATISTICS OF EDA

Name of villages	Total Population (1991)	1981	Growth Rate (%)	Total proJECTED Population 2001
1. Chipni	1537	1187	2.94	1982
2. Mashyar	1280	948	3.50	1728
3. Pekhri	1098	841	3.05	1427
4. Tinder	677	541	2.51	846
5. Srikot	417	339	2.3	513
6. Kalwari	1132	978	1.57	1313
7. Shili	812	618	3.14	1064
8. Suchen	1212	914	3.26	1600
9. Shangurh	618	462	3.38	822
10. Lapah	222	173	2.83	284
11. Sainshar	1606	1183	3.58	2184
12. Garaparli	592	490	2.08	716
13. Raila	512	426	2.00	614
Total	11715	9100		15093

Source : *Computed from Census Data 1981 and 1991 for Kullu District.. The social structure of the population in the EDA is given in Table 6.4. A detail assessment of the socio-economic conditions and the resource dependence on GHNPCA has been studied as part of the WII research component by Nangia and Kumar, 1999.*

Fig.3.4

Great Himalayan National Park Conservation Area(GHNPCA) Ecodevelopment Area : Human Settlement

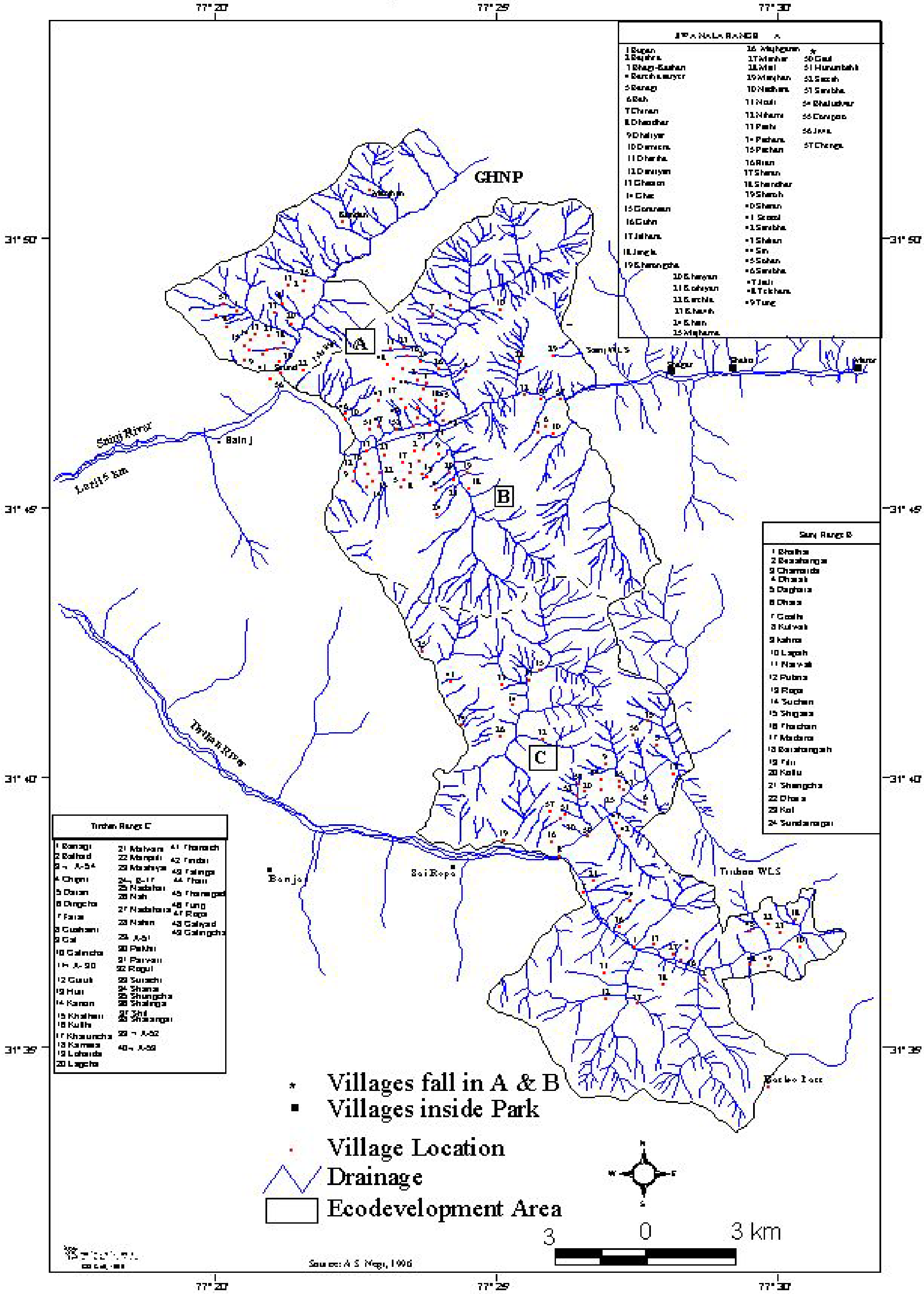


Table 3.6 SOCIAL STRUCTURE OF THE POPULATION IN EDA

NAME OF VILLAGE	TOTAL POPULATION	MALES	FEMALES	SEX RATIO	TOTAL SC POPULATION	SC MALES	SC FEMALES	% OF scS TO TOTAL POPULATION	TOTAL stS POPULATION	TOTAL LITERATES	MALE LITERATES	FEMALE LITERATES	% OF LITERATE RATES TO TOTAL POPULATION
Chipni	**1537**	**793**	**744**	**938**	**536**	**247**	**262**	**35**	**0**	**490**	**352**	**138**	**32**
Mashyar	**1280**	**647**	**33**	**978**	**376**	**200**	**176**	**29**	**4**	**230**	**171**	**59**	**18**
Pekhri	**1098**	**577**	**521**	**903**	**165**	**92**	**73**	**15**	**6**	**396**	**293**	**103**	**36**
Tinder	**577**	**364**	**313**	**860**	**96**	**50**	**48**	**14**	**1**	**219**	**169**	**50**	**32**
Srikot	**417**	**230**	**187**	**813**	**84**	**49**	**35**	**20**	**0**	**174**	**135**	**39**	**42**
Kulwari	**1132**	**537**	**595**	**1108**	**412**	**199**	**213**	**36**	**0**	**518**	**322**	**196**	**46**
Shill	**812**	**432**	**380**	**879**	**175**	**97**	**78**	**21**	**0**	**223**	**177**	**45**	**27**
Sudhan	**1212**	**636**	**576**	**905**	**392**	**199**	**193**	**32**	**0**	**396**	**279**	**117**	**33**
Shangarh	**618**	**321**	**297**	**925**	**224**	**109**	**115**	**36**	**0**	**223**	**170**	**53**	**36**
Lapah	**222**	**108**	**114**	**1055**	**26**	**15**	**11**	**12**	**0**	**63**	**54**	**9**	**28**
Shansha	**1606**	**829**	**777**	**937**	**887**	**458**	**429**	**55**	**0**	**468**	**345**	**123**	**29**
Garaparli	**592**	**312**	**280**	**897**	**175**	**93**	**82**	**29**	**0**	**27**	**27**	**0**	**4**
Raja	**2822**	**1462**	**1360**	**930**	**644**	**321**	**323**	**23**	**11**	**959**	**689**	**270**	**34**
Total	**13925**	**7248**	**6777**		**4192**	**2129**	**2038**		**22**	**4386**	**3183**	**1202**	

Source : *Census of India 1991, Block Development Officer, Banjar.*

The literacy of the area is 6.8% (based on 1991 census data). The main occupation of these people is agriculture along with horticulture. Villages mostly grow maize and ogal in rainy season as a food crop. After rainy season wheat and barley grows on lower areas whereas in winters only maize grows there, but the overall production is poor. Rearing sheep and goat fetches a good income.

The medicinal plants and mushrooms extractions are means of secondary income and in some cases even contribute about 70% of the total income. Rearing sheep and goat is still practiced on a fairly large scale as being a traditional profession of villagers.

Horticulture is becoming more popular in the area and raising orchards of apple, plum, walnut and cherry etc. is being taken up on a large scale.

In addition to the collection of fodder, fuel wood, minor forest products (MFP), the main pressures on the area are due to the collection of herbs, edible mushrooms, grazing of sheep and goat in summer. Presently about 20000 sheep and goats are grazing in this area (Mathur, P. K. and Mehra 1999). Local people as well as people coming from as far as Anni Tehsil graze their livestock in the park.

Thousands of people are engaged in herb mushroom collection because of their high price and value. The mushroom (*Morchella esculanta*) is mainly collected from February to May in the lower altitude and about 1,200 people scan the forest floor (Singh & Rawat 1999).

The fodder collection from the area is done only by those villages which are close to PA boundary. *Quercus leucotrichophora*, *Q. floribunda*, and *Q. semecarpifolia* are lopped during the winter months. Besides this, grasses are also collected and stored for winter stall feeding when the area is covered with snow. The other species which are collected for fodder are *Morus serrata, Celtis tetrandra*, *Acer* Species. *Corylus jaeguemontli* and some shrubs like *Indigofera Species.*, *Desmodium* Species. *Thalmnocalamus speciesathiflora* and *A. falcata* are also collected from the PA.

Minor forest products collection includes honey, bamboo, nuts and fruits, bark of birch, leaves of *Rhododendron anthopogon* and bark of *Taxus baccata*. The villages near the PA collect fuelwood throughout the year except during January – February. The herb collectors and graziers visit alpine pastures for collecting the subalpine species - *Quercus semecarpifolia*, *Betula utilis*, *Rhododendron* Species and the alpine *Juniperus* Species and *Rhododendron* Species.

3.9.3. Ecodevelopment Area : Landuse/Landcover

The complete details of the landuse/landcover mapping of the study area have already been discussed in section 3.4.3. The landuse/landcover map of EDA is given in Fig. 3.5 and the area estimation under different categories has been provided in Table 3.7.

Table 3.7

AREAL ESTIMATION UNDER DIFFERENT LANDUSE/LANDCOVER CATEGORIES

S.No	Type	Area in sq.km
1	Conifer (*Pinus roxburghii*)	2.08
2	Mixed conifer	73.49
3	Conifer and Broad Leaved Mixed	13.48
4	Broad Leaved	33.03
5	Broad Leaved and Conifer Mixed	48.29
6	Riperian	0.13
7	Slope Grasses	26.09
8	Grasslands/ Blanks (Temp. sub Alpine & Alpine)	8.61
9	Secondary Scrub	16.50
10	Alpine Scrub	6.72
11	Plantation	0.16
12	Habitation/Agriculture/Orchards	26.07
13	Exposed Rocks with Slope Grasses	8.35
14	Alpine Exp. Rocks with Slope Grasses	0.07
15.	River	1.03
17.	Escarpments	1.34
18.	Landslide	0.07
	Total	**265.6**

3.9.4. Ecodevelopment Area: Change Detection Analysis

Significant changes in the population and landuse patterns have occurred in the EDA in the last four decades. In order to understand the nature and quantum of these changes a "Change Detection Analysis" was carried out as part of this study. Vegetation Mapping was carried out for Ecodevelopment Area using visual Interpretation Mapping of Remotely Sensed Data. Area Estimation with Change Detection was carried out for the period between 1961 –1993 in GIS Domain using ARC/INFO software package.

METHODOLOGY

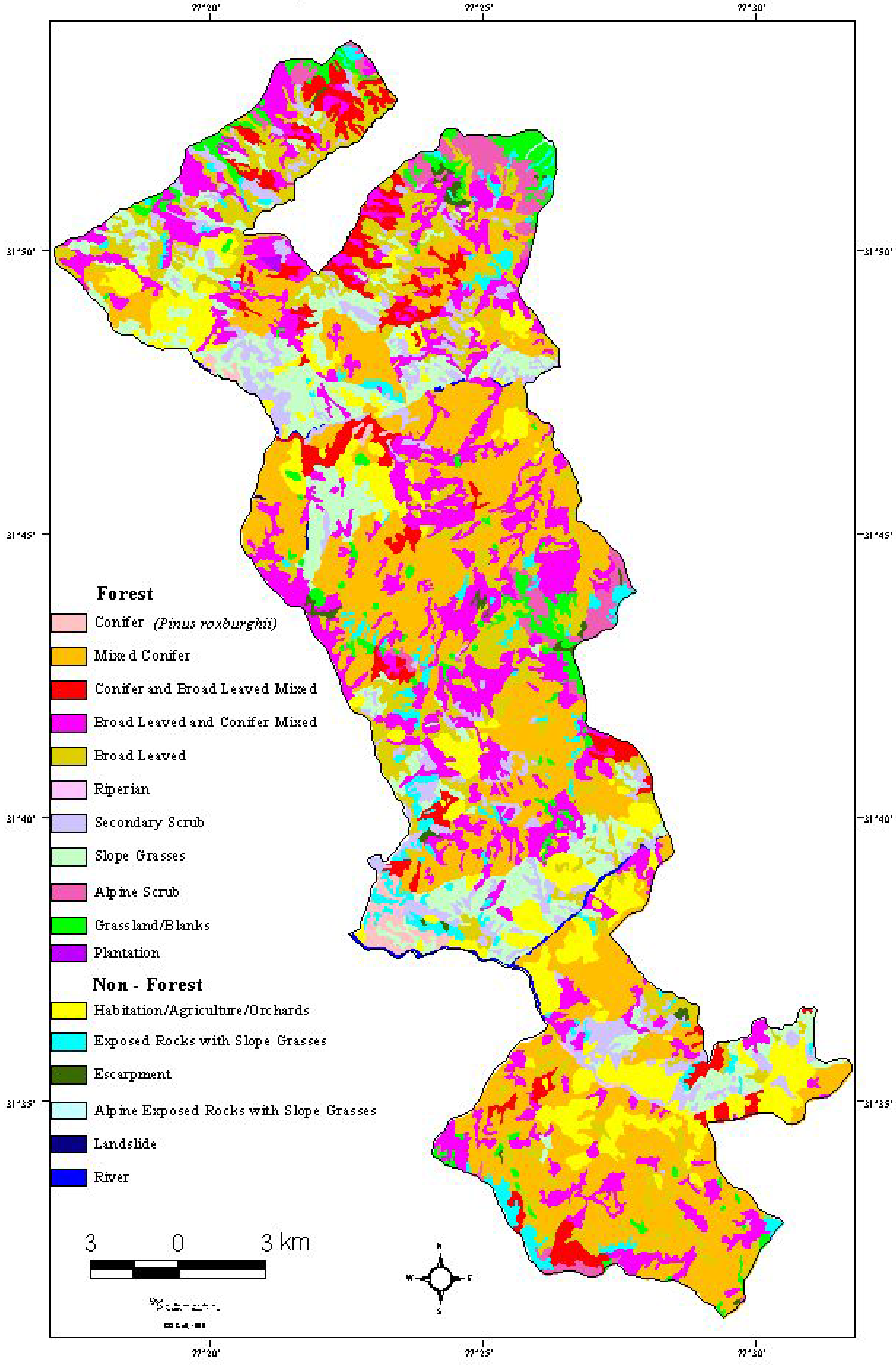
FOR THE CHANGE DETECTION ANALYSIS THE FOLLOWING DATA SOURCES WERE USED:

(I) SOI TOPOSHEET 1961 (II) SATELLITE IMAGERIES 1993 (III) CENSUS DATA 1961 AND 1991

The methodology used in detecting changes in landuse/landcover is shown in Fig. 3.6.

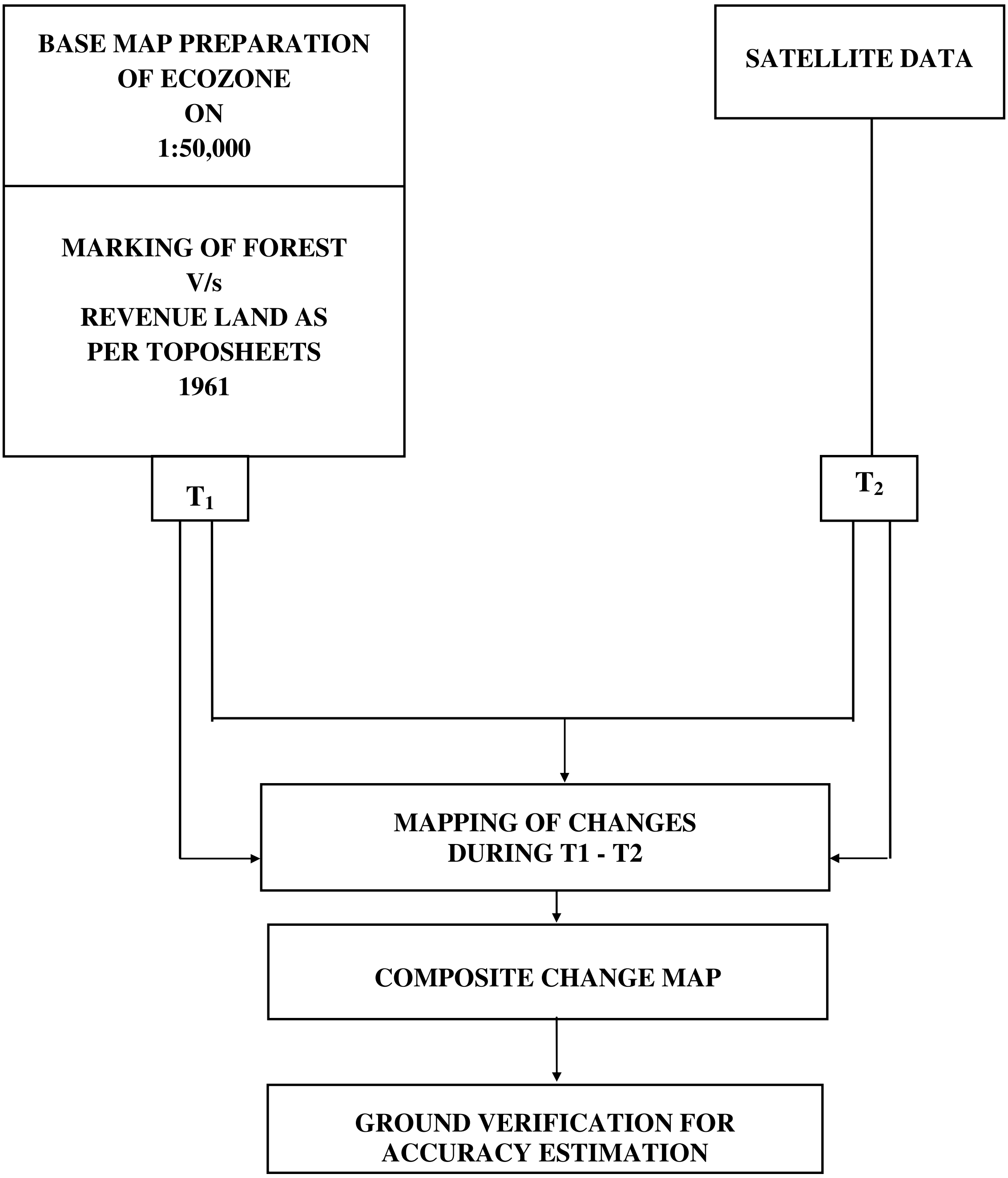
Fig.3.5

Great Himalayan National Park Conservation Area(GHNPCA) Ecodevelopment Area : Landuse/Landcover



METHODOLOGY

Fig.3.6 FLOW CHART OF CHANGE DETECTION IN LANDUSE/COVER MAPPING



3.9.5. Results and discussions

The maps related to change detection analysis has been given in Fig. 3.7 to Fig. 3.9. The total area of Ecodevelopment is estimated 265.6 km^2. Of which 26.07 is under man made feature and remaining is under forest and non-forest classes. The mix coniferous forest comprises of 73.49 km^2 whereas total grasslands are about 34.70 km^2. The main upper story species are *Pinus Wallichina, Abies Pindro, Picea Smithiana, Cedrus Deodara* whereas middle story (shrubs) is composed of *Rosa Species* and *Berberis Speciesecie* whereas on the southern aspect *Arundinaria Species* and *Viburnum Species* on western aspect. Increase in area of man made features (Habitation /Agriculture/Orchard) was estimated 8.48 km^2, while 4.31 km^2 was found not cultivated as was practiced in 1961.

The overall change in area was about 12.79 km^2. It was also observed that deterioration of vegetal cover is unidirectional i.e. towards forest. The area has been correlated with population dynamics and fuel and fodder consumption between 1961 – 1991 as shown in Table 3.8.

Table No.3.8 ECODEVELOPMENT AREA: CHANGE IN BIOMASS CONSUMPTION DURING 1961-1991

Watershed Sub Water Shed	No. of Household, 1961	No of of Household, 1991	Fuel Wood consumption, 1961(00 Kg)	Fuel Wood consumption 1991(00 Kg)	%change in Fuelwood consumption Between 1961-1991	Fooder Consumption 1961 (00kg)	Fodder Consumption 1991 (00kg)	% change in fodder consumption between 1961-1991
Jiwa sws	512	930	74393	135725	82.44	58522	106299	81.63
Sainj sws	213	350	30948.9	50855	64.33	24346	40005	64.31
Tirthan sws	639	1185	92846.7	172180.5	84.44	73038	135446	85.44
Total	1364	2465	198188.4	358760.5		82941	281750	

Source: *Calculated from census data 1961 & 1991 per house hold, fodder and fuelwood consumption taken from research study titled "ongoing assessment of the social impacts of Conservation of Biodiversity project activity by Milind Saxena 1998.*

The number of households in EDA HAS increased from 1364 in 1961 to 2465 in 1991 and the fuelwood consumption has also registered 78% increase during this period.

Similarly, the fodder consumption has also increased during this period. The habitation/agriculture/orchard areas in EDA in 1961 and 1993 are shown in Fig. 3.7 and 3.8 respectively and the changes occurring are depicted in Fig. 3.9 and Table 3.9. There has been an increase of about 9 km^2 in the areas under habitation/agriculture/orchard and a decline of about 4 km^2 of forest area during the period 1961 to 1993.

The above table describes the biomass consumption in the Ecodevelopment Area of Great Himalayan National Park Conservation Area. Although it is assumed that consumption of biomass (Fuelwood/Fodder) per household has not changed substantially in the area, however due to high increase in the total no. of households the total quantities of biomass required by the households has changed substantially.

The table reveals that the fuel wood consumption in the area experienced a significant increase of near about 80%. In other watersheds the Tirthan experienced the highest increase of near about 85%in fodder consumption while Sainj showed the minimum increase of 64% over this period. The table also reveals that fuelwood consumption has experienced almost similar trend in increase over this period.

Table No. 3.9

ECODEVELOPMENT AREA: POPULATION CHANGE IN EDA ALONGWITH AREAS UNDER HABITATION/AGRICULTURE/ORCHARDS.

EDA Population 1961	EDA Population 1991	Name of Watershed	Total Area Sq.km	Change between 1961-91 sq.km	% Increase	Area not Currently Under cultivation As used in 1961	% Decrease	% Increase Population (1961-91)
3041	2710	Jiwa	23.5	1.16	4.93	.34	1.44	-10.88
1235	2052	Sainj	106.23	2.31	2.17	1.28	1.20	66.15
4155	6953	Tirthan	125.27	5.01	3.99	2.69	2.14	67.34
8431	11715	Total	255.00	8.48	3.7	4.31	1.59	38.95

Source:

- *Population change calculated by using census data of 1961 and 1991 of Kullu District.*
- *Change detection in area under Habitation/Agriculture/Orchards calculated by using ARC/INFO GIS domain from 1961 SOI sheets.and 1993 FCC IRS IB LISS II Data.*
- *The study has been conducted before the award of new area for 255 sq.km.*

The above table shows that in the 30 years (1961-91) there has been nearly 9 km^2 increase in the area under the Habitation/Agriculture/Orchards in the Ecodevelopment Area among the different watersheds. This change is maximum (5km) in Tirthan sub-watershed compare to only (1.16sqkm) in the Jiwanal sub-watershed, However if we see in proportion Jiwa has experienced a maximum increase of 4.93% followed by Tirthan (3.99%) and Sainj (2.17%).

The table further shows that in this period there has been some area, which was in use in 1961 but was not found in use (visual interpretation) in 1991(1.6%). The table reveals that there has been near about 39% increase in the total population of Ecodevelopment Area between 1961 to 1991. Out of this Tirthan has experienced maximum (67%) closely followed by Sainj (66%) Strangely enough the Jiwa watershed area has experienced a negative population; this seems to be due to heavy out migration from the area.

Fig. 3.7

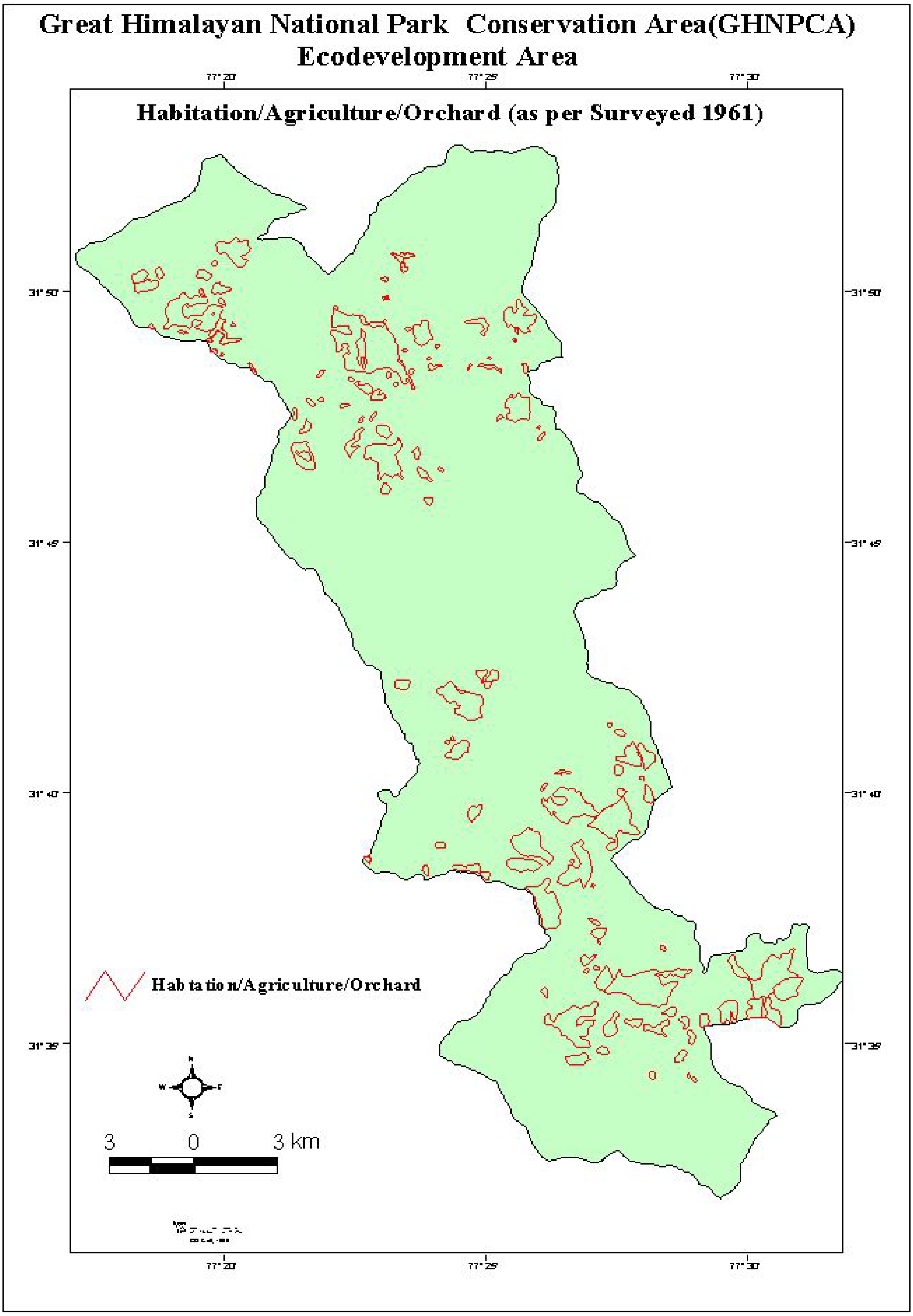

Great Himalayan National Park Conservation Area(GHNPCA)
Ecodevelopment Area
Habitation/Agriculture/Orchard (as per Surveyed 1961)
Habtation/Agriculture/Orchard
3 0 3 km

Fig. 3.8

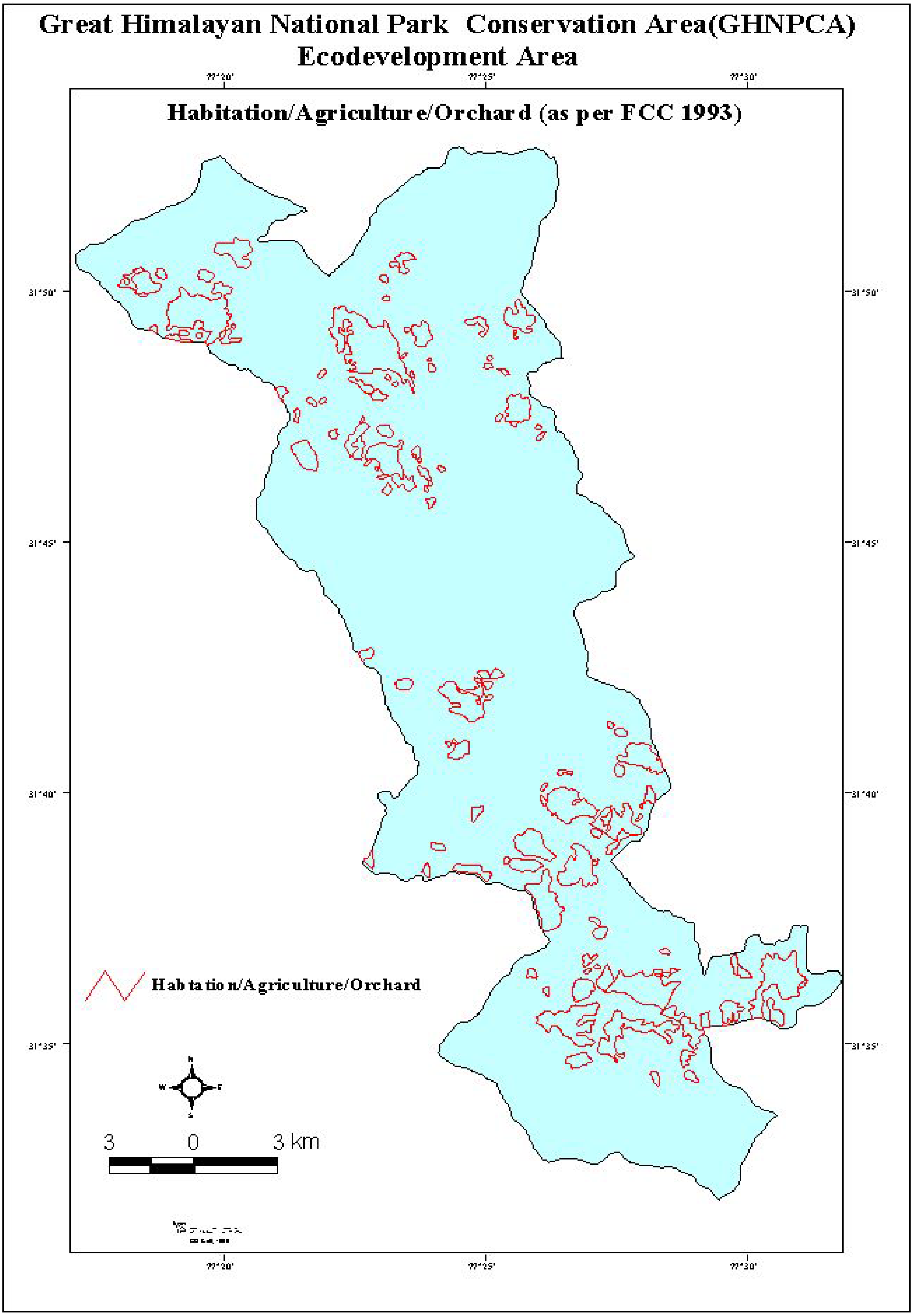
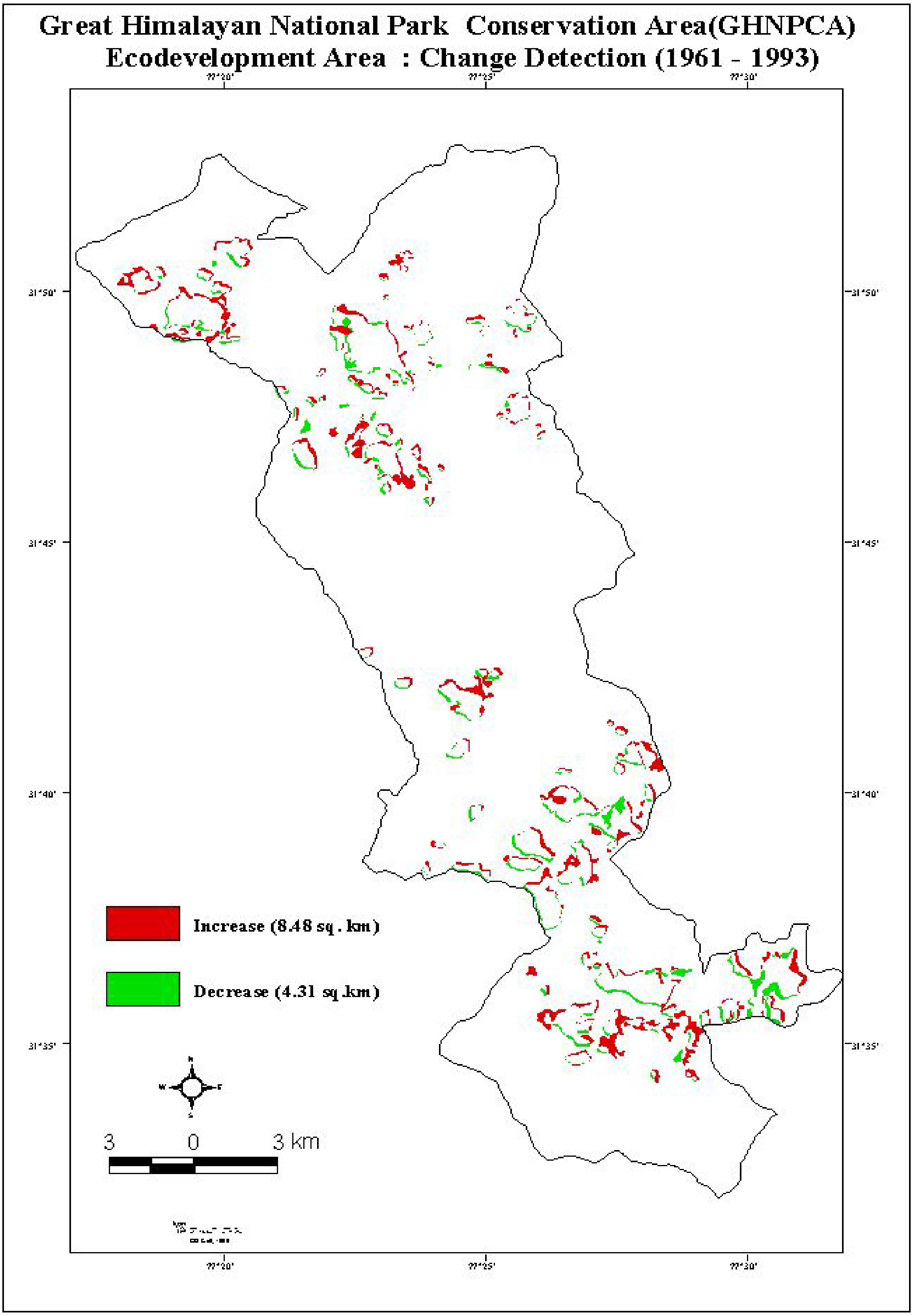

Great Himalayan National Park Conservation Area(GHNPCA)
Ecodevelopment Area
Habitation/Agriculture/Orchard (as per FCC 1993)
Habitation/Agriculture/Orchard
3
0
3 km

Fig. 3.9


Great Himalayan National Park Conservation Area(GHNPCA)
Ecodevelopment Area : Change Detection (1961 - 1993)
Increase (8.48 sq . km)
Decrease (4.31 sq .km)
3
0
3 km

3.10 VEGETATION CHARACTERISATION THROUGH PROFILE DIAGRAM

3.10.1. Introduction

The range of Himalayan Mountains varies greatly in height, ASPECTSand topography, thus creating wide variety of microclimatic conditions. Distribution of vegetation is governed by climatic, edaphic and topographic conditions. Fragile ecosystem in the Himalayan region needs protection from changes in land use patterns. Change in land use pattern influences the composition of surrounding vegetation. Introduction of exotic species, especially weeds, has influenced ground flora in the Indian subcontinent. Therefore, monitoring of vegetation composition becomes a quite important aspect in forest management.

Community is a local association of several populations of different species. Phytosociological studies have been done to characterize vegetation structure and composition. Composition of vegetation can be described by the number of species present in all growth forms in vegetation. Traditionally vegetation composition has been based on ground surveys and laying of transects along or across the gradients. Listing of species at each level is primary requirement to carry out primary and secondary analysis of vegetation. Structure of vegetation can be described as to how these species are arranged vertically or horizontally or occupy the speciesace in any ecosystem. Plants occupy various positions in the community to meet their requirements like sun illumination, moisture, nutrients etc. Such an analysis gives an idea about the ecological importance and role of the species in an ecosystem. As we all know the role of tree species in regulating the ecosystem is maximum mainly due to their long life and efficiency to accumulate biomass (forage as well as woody) for further use by animal and human beings.

Advent of remote sensing has provided the possibilities to look at the spatial distribution and arrangement of plant communities. It also provides visualization of different physiographic and topographic variations of the terrain and thus facilitates such studies. Richards (1952) stressed the need to depict community structure in semi-schematic profile diagrams. In India, phytosociological studies using remote sensing have been carried out by, Roy, *et al.* (1992) in Andaman Islands, Singh (1993, 1994, 1995) in Madhya Pradesh and Sikkim Himalayas. Profile diagrams are one the best methods to provide visualization of different strata in the community and their spatial arrangements. This method of portraying the vertical vegetation stratification and structural association of plants provides immediate insight about the community. Community structure is depicted in three dimensions - height, depth (relative position) and crown cover.

3.10.2. Approach

In the present approach traditional as well currently used methods of studying community composition and structure have been followed. Stratified map of vegetation, obtained from remote sensing data, and ground based enumeration of species is subjected to phytosociological analyses. Structure of the vegetation has been shown through profile diagrams. In the present approach inputs from remote sensing technology have come in the form of stratified map of vegetation. Aerospeciesace data provides information at community level and stratification of vegetation provides the opportunity to go for optimum sampling. Stratified random sampling is cost effective method of vegetation sampling.

Photographic evidence is the best proof. Photographs of various communities have been obtained. Photos have scanned and attached for posterity. Micro-environmental conditions lead to some change in species composition. Therefore, sampling has been done at different places to assess the variability as far as possible.

3.10.3. Materials used

Materials required for studying the composition and structure are mainly vegetation map, Survey of India maps, hypsometer, graph paper, measuring tape and related stationery like graph paper.

3.10.4. Methodology

Vegetation map prepared through visual interpretation provided the locational and spatial information about the different major plant communities. For community analysis profile diagrams have been made. Keeping in mind the accessibility, time and representatives, sample plots of were laid in each vegetation type. Size of plots was determined based on species area curve. After a few trials it was decided that plot size of 20×20 m size would be appropriate for forested areas and 1 x 1 m for grasslands for depicting the variability in composition and structure within the community. Ground flora varies in different seasons. Observations recorded here are for the months of May and November.

For each vegetation type a plot of 25×10 m was laid along the gradient. Sketch or line drawing of each tree inside the plot has been drawn on graph sheets at an appropriate reduced scale (1 mm = 20 cm) or smallest division of graph sheet is equal to 20 cm. Tree diameter was taken using ruler. Slope of the plot was obtained using hypsometer. Branching patterns, relative horizontal location, crown size etc. have been depicted for each community type along the gradient. Canopy has been depicted to give an idea of the crown shape and closer. The illustration made in the field was then drawn on fair tracing paper for the purpose of multiplication with appropriate scale. Species found in upper, middle, lower stories and ground flora have been listed. The plants which could not be identified in the filed were preserved and identified later using relevant flora and with the helps experts. Local names were also noted.

3.10.5. Information Collected

Following information were collected for each sample plot.

- Vegetation type (community type)
- Location (position)
- Species name: trees, shrubs, herbs, climbers etc.
- Slope (%)
- Average tree of each canopy layer
- Circumference at breast height
- Aspect
- Ground flora (in May)
- Crown diameter
- Altitude

- Climber, lianas etc.
- Phenological stage

3.10.6. Laying of Sample plots

Vegetation of an area can be expressed qualitatively as well as quantitatively. Various methods like line transact, systematic sampling, point method etc. are employed to study the structure of the vegetation. Most of these methods are time consuming and not economical and some of them are generally attempted in smaller study areas. In the present investigation stratified random sampling has been done. Satellite data has been classified through visual interpretation as per the classification scheme based on the reconnaissance survey and land cover/land use classes in the area. Sampling was done on homogeneous units. Samples plots were laid along the gradient and reference to North direction has been provided. For structural analysis normally 20×20 m plots are laid for woody vegetation and 1×1 m for grasslands and same has been followed here. As far as possible representative sites were selected for this purpose and marked on SOI maps.

3.10.7. Results and Discussion

A total of 66 sample plots were laid in the covering all communities. Of these 46 were in communities with trees and shrubs and 20 were for grasslands. Following discussion is based on preliminary analysis based on the ground data collected and profile diagrams or illustrations made during the fieldwork.

(a) Chir Pine Forest: (Subtropical Pine Forest: Himalayan Chir Pine Forest, 9/C1b)

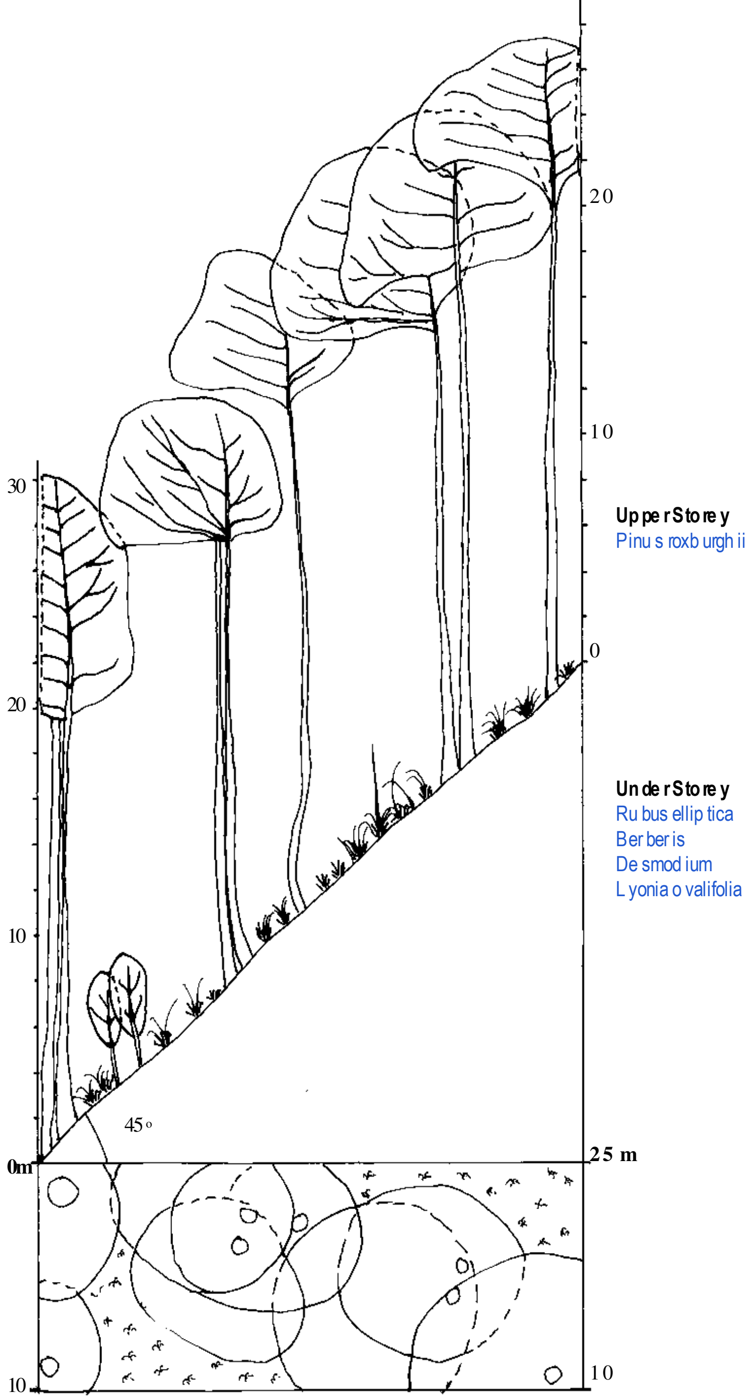
In the study area west and south-west has subtropical vegetation. Chir Pine (*Pinus roxburghii*) is the dominant forest species from Sai Ropa to Ghusaini and Southern ASPECTSin Tirthan Valley up to Kharongcha. Forest around SaiRopa on the hills is good to disturbed. In Sainj valley very good forest can be seen on both sides on slopes Shangarh. At few places towards Shangarh from Sainj these are mixed with other broadleaf species. The ground flora is quite disturbed and subjected to grazing and fire. The density of trees is very less on slopes of Tung village and slopes around Nevli. Biotic pressure is high on these forests. Following is list of the species occurring in subtropical pine forest. (Plate 1), (Fig 3.10)

Table 3.10 LIST OF SPECIES OF FOUND CHIR PINE FOREST

Trees	**Herbs**
Pinus roxburghii	*Hydrangium anamala*
Lyonia ovalifolia	*Oplismenus composites*
Shrubs	*Centella asiatica*
Rubus brunonii	*Inula cappa*
Berberis chitria	*Pilea umbrosa*
Rubus ellipticus	*Pteris cretica*
Berberis aristata	*Sonchus aspeciesera*
Herbs	*Gnaphalium hypoleocum*
Desmodium triflorium	*Smilax aspeciesera*
Galium rotundifolium	*Salvia macrofitiana*

Top storey is of *Pinus roxburghii*. Upper and middle storey is generally absent. Burnt stems of Pines indicate high disturbance due to frequent fires. Under stroey flora of shrub and herbaceous species is open to dense depending upon the biotic interference and boulders. Scattered shrub species like, *Lyonia ovalifolia, Rubus ellipticus* along with *Berberis* Species are the main species. Herbaceous plants include grasses and other common species, as listed in Table 3.10.

Fig. 3.10. Subtropical Chirpine Forest near Dewri village



(b) Broadleaf forest

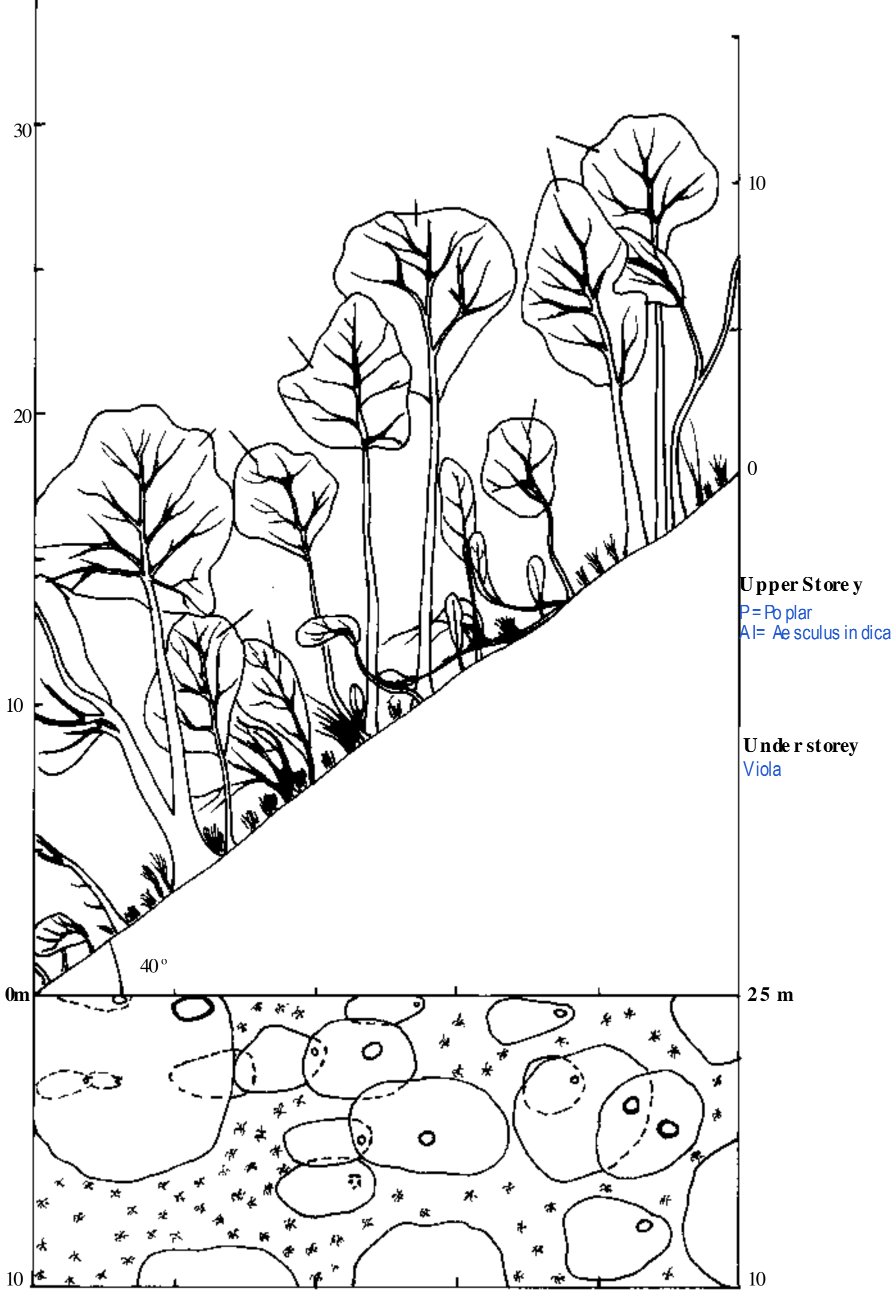
Broadleaf forest of lower temperate and upper temperate vary in species composition. Lower temperate forests have Aesculus *indica*, Populus *ciliata* and *Quercus dilatata* as the top storey trees. *Rhododendron arboreum* forms first storey. Middle temperate boradleaf forests have trees of *Acer* species, *Betula alnoides, Juglens regia, Prunus cornuta* etc. Scattered trees of *Taxus wllichiana* occur in the lower storey. Under storey consists of plants like, *Berberis, Impatiens, Strobilanthes, Polygonatum, Hedea* etc. Regeneration of Aesculus indica is quite good as is evidenced from the presence of different age group plants. (Plate 2), (Fig 3.11)

Broadleaf forest of Kharsu Oak Forest (Himalayan Moist Temperate Forest: Upper Himalayan Western Forests, 12/C2a) occur in the upper reaches bordering alpine zone. Upper hills have very extensive stretches of “Kharsu” oak (*Quercus semecarpifolia*) and grow on very steep to almost cliff slopes especially along seasonal shallow streambeds. Upper storey is of 20 m tall plants of *Quercus semecarpifolia*, and *Acer caesium* trees and can sometimes grow taller and share the top storey and in lower ecotone zone *Picea smithiana* and *Cedrus deodara* are also found. *Rhododendron arboreum* and *Acer caesium* occupy lower storey. Ground flora is relatively less thick and plants like, *Carex, Polystichum aculeatum, Viola, Polygonum, Cheilanthes farinosa, Rosa sericea, Viburnum, Geranium, Podophyllum, Polystichum squamossus, Lonicera,* etc. and young plants of *Quercus semecarpifolia and Rhododendron arboreum*. (Plate 7), (Fig. 3.12)

Table 3.11 PLANTS OCCURRING IN BROADLEAF FORESTS

Trees	*Ainsliea aptera*
Viburnum nervosum	*Desmodium triflorum*
Prunus cornuta	*Senecio rufinervis*
Lyonia ovalifolia	*Berginia ciliata*
Quercus leucotrocophora	*Bidens pilosa*
Rhododendron barbatum	*Hedera nepalensis*
Taxus wallichiana	*Senecio chrysanthenoides*
Acer cappadocicum	*Impatiens sulcata*
Acer acuminatum	*Carex nubegina*
Celtris australis	*Phacelurus specieseciosus*
Quercus semicarpifolia	*Polygonum affinis*
Quercus floribunda	*Galium aprine*
Shrubs	*Saussurea graciliforus*
Desmodium elegans	*Cynoglossum glochidiatum*
Rosa serecia	*Polygonum amplexicaulis*
Astible rivularis	*Pilea umbrosa*
Prinsepia utilis	*Oplimenus undulatifolius*
Indigofera heterantha	*Erigeron canadensis*
Berberis chitra	*Iris milesii*
Viburnum nervosum	*Rubus niveus*
Cotoneaster affinis	*Adiantum venustum*
Pyrus pashia	*Coniogramme affinis*
Herbs	*Diplazium esculantum L.*
Iris milesiii	*Oplismenus compositus*
Fragaria vesca	*Helictotrichon viresceus*
Viola biflora	*Salvia nubicol*
Clematis montana	*Parochetus communis*
Viola serpens	*Onichyum cryptogrammoides*
Onychium japonicum	*Centella asiatica*
Girardinia diversifolia	*Achyranthus aspeciesera*
Orygopsis aegviglomis	

Fig.3.11. Broadleaf Forest (Moist temperate deciduous forest between)



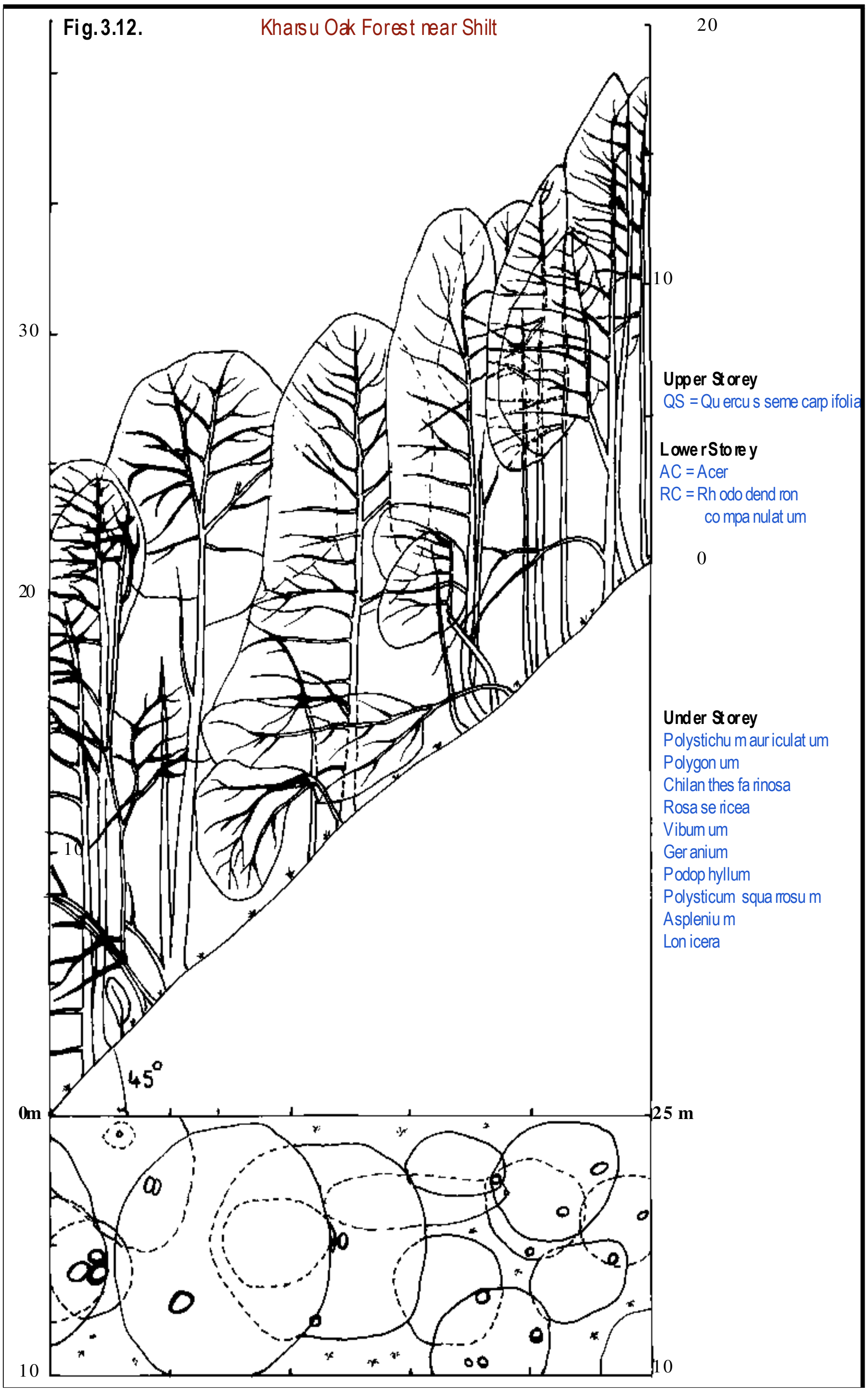


Fig.3.12. Kharsu Oak Forest near Shilt

(c) Broadleaf Mixed with Conifers Forests: *(Broadleaf mixed with conifer)*

Mixed coniferous forests occupy relatively large areas and mixing of broadleaf and coniferous plants occurs. Top canopy is occupied by *Abies pindrew, Aesculus indica* and *Aesculus indicia*. Very tall trees of *Abies pindrew* grow mixed with *Aesculus indica*. Abundance of *Aesculus indica* is more and middle aged trees of this occupy the middle storeys. Other species which are mixed share top canopy or upper storey are *Prunus cornuta, Juglens regia, Picea smithiana* etc. Ground flora is very rich because of thick humus layer and moist conditions and consists of *Polystichum, Hedera helix, Impatiens, Gallium, Adiantum, Urtica, Coniogramme fraxinea, Dryopteris species., Cyrtomium species., Aspeciesaragus species., Vitis species., Pteris cretica, Daphne papyracea, Clematis, Houtainya cordata, Calanthe, Pieris polyphylla, Smilacina* etc. A clump of bamboo is also recorded. There are a few dead trees (top part missing). (Plate 4), (Fig 3.13)

Table 3.12 LIST OF SPECIES IN BROADLEAF MIXED WITH CONIFER FOREST

Trees	**Herbs**
Prunus cornuta	*Diplazium fieldinzianum*
Pinus wallichii	*Aspeciesaragus filicina*
Acer acuminatum	*Clematis barbata*
Juglans regia	*Fragaria vesca*
Aesculus indica	*Oxalis acetosa*
Abies pindrew	*Pteris critica*
Quercus semecarpifolia	*Adiantum venutum*
Picea smithiana	*Malva verticillata*
Shrubs	*Aconitum tetrasepala*
Viburnum nervosum	*Senecio graciliflorus*
Herbs	*Leucas lanata*
Urtica species.	*Calanthe tricarinata*
Coniogramme fraxinea	*Smilacina purpurea*
Dryopteris speciesarsa	*Urtica dioca*
Cyrtomium caryotideum	

(d) Mixed Conifer: (Temperate Coniferous Forest)

Park has very extensive stretches of coniferous forest and play a very important role in the temperate ecosystem and grow on steep slopes. Phytodiversity of these forests is very high. Dominant species are *Cedrus deodara*, Abies pindrew, and *Pinus* *wallichiana*, which form the top storey, and trees up to 35 m tall can be seen. Huge trees of coniferous plants occur in the conservation area. At places these mixed with other plants like *Acer acuminatum, Picea smithiana* and form the first storey. Lower storey is *of Taxus wallichiana, Acer* species *and Rhododendron arboreum*. In the under storey species like *Pteridium aquilinum, Geranium, Rubus ellipticus, Ranunculus, Dryopteris, Viola, Podophyllum emodi, Acer, Aspeciesaragus, Indigofera, Hedera helix, Rubia, Diplazium maxima, Carex, Impetiens, Fragaria vasca*, Oplismensu compositus etc. In shaded area the ground flora is very rich whereas drier southern slopes have less ground flora. *Pteridium acquilinum* is indicator of the disturbance in these forests. Occurrence of Podophyllum is important. Plants of Podophyllum are very rare. These forests do not have thick shrubby middle layer and look cleaner. *Rhododendron arboreum* forms the lower storey (Plate 5), Fig 3.14 and Fig. 3.15.

Fig. 3.13. Broadleaf Mixed Coniferous Forest near Rdla

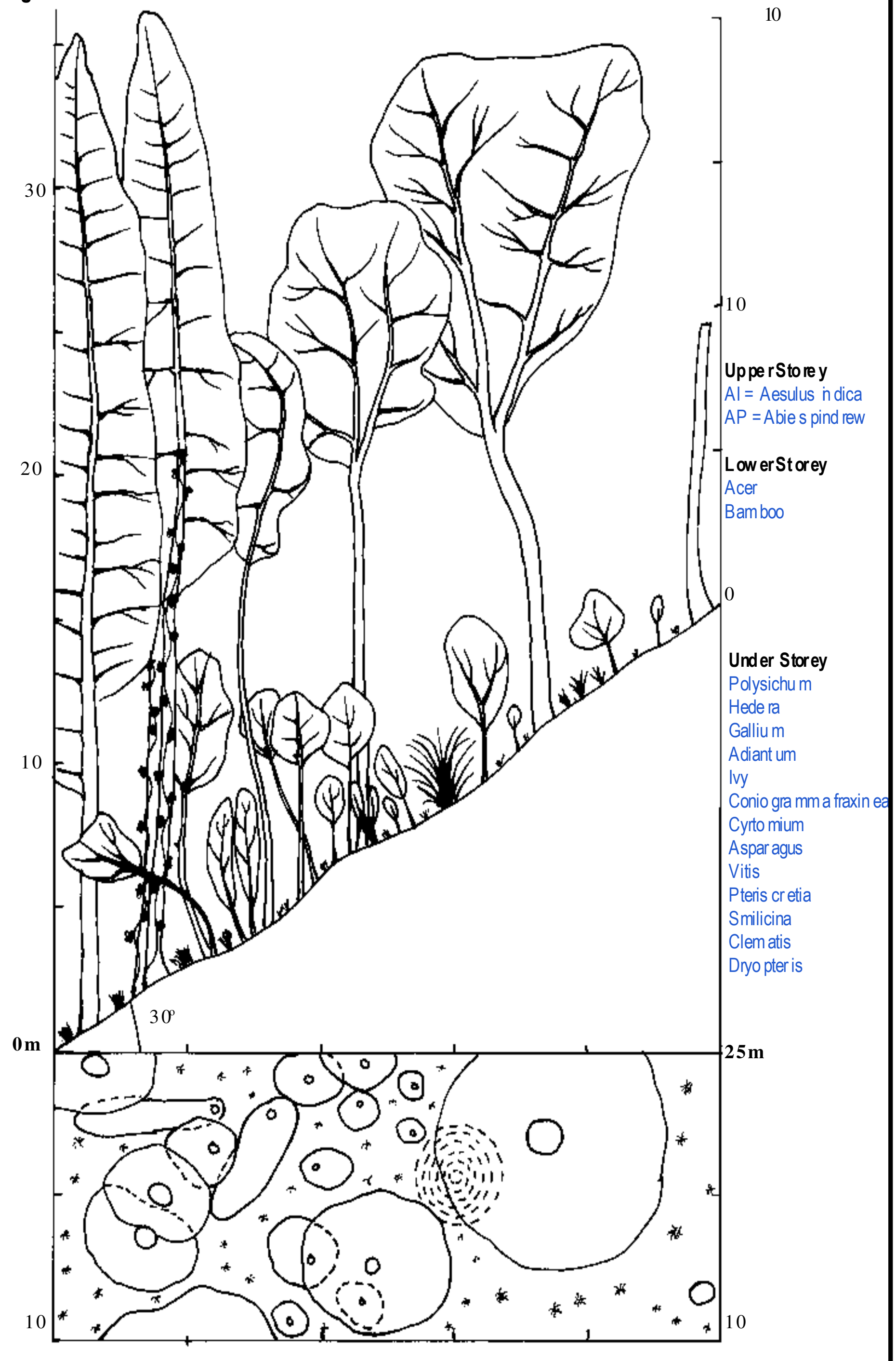


Fig. 3.14. Temperate Conifer Mixed near Shilt

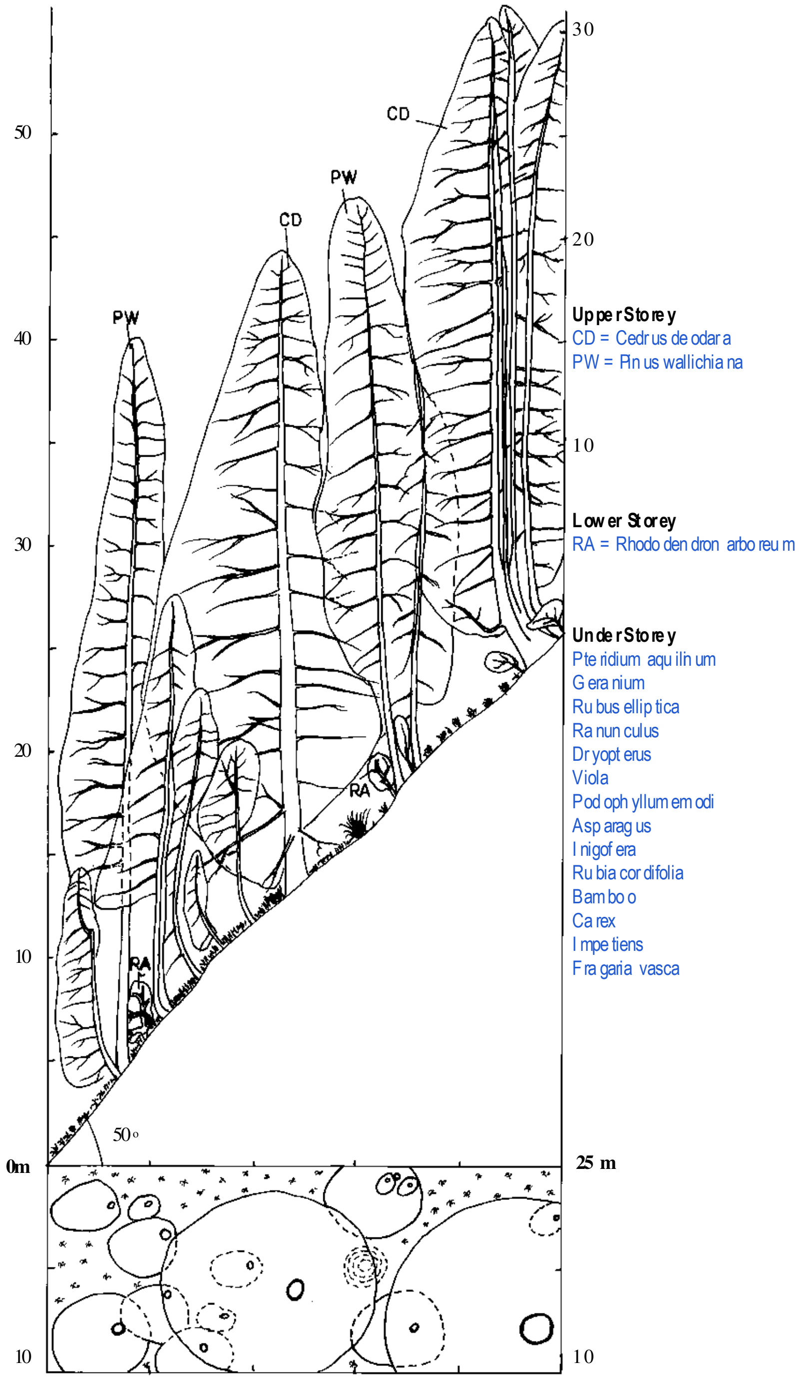


Fig. 3. 15 Temperate Conifer Mixed with Broadleaf near Galiyar

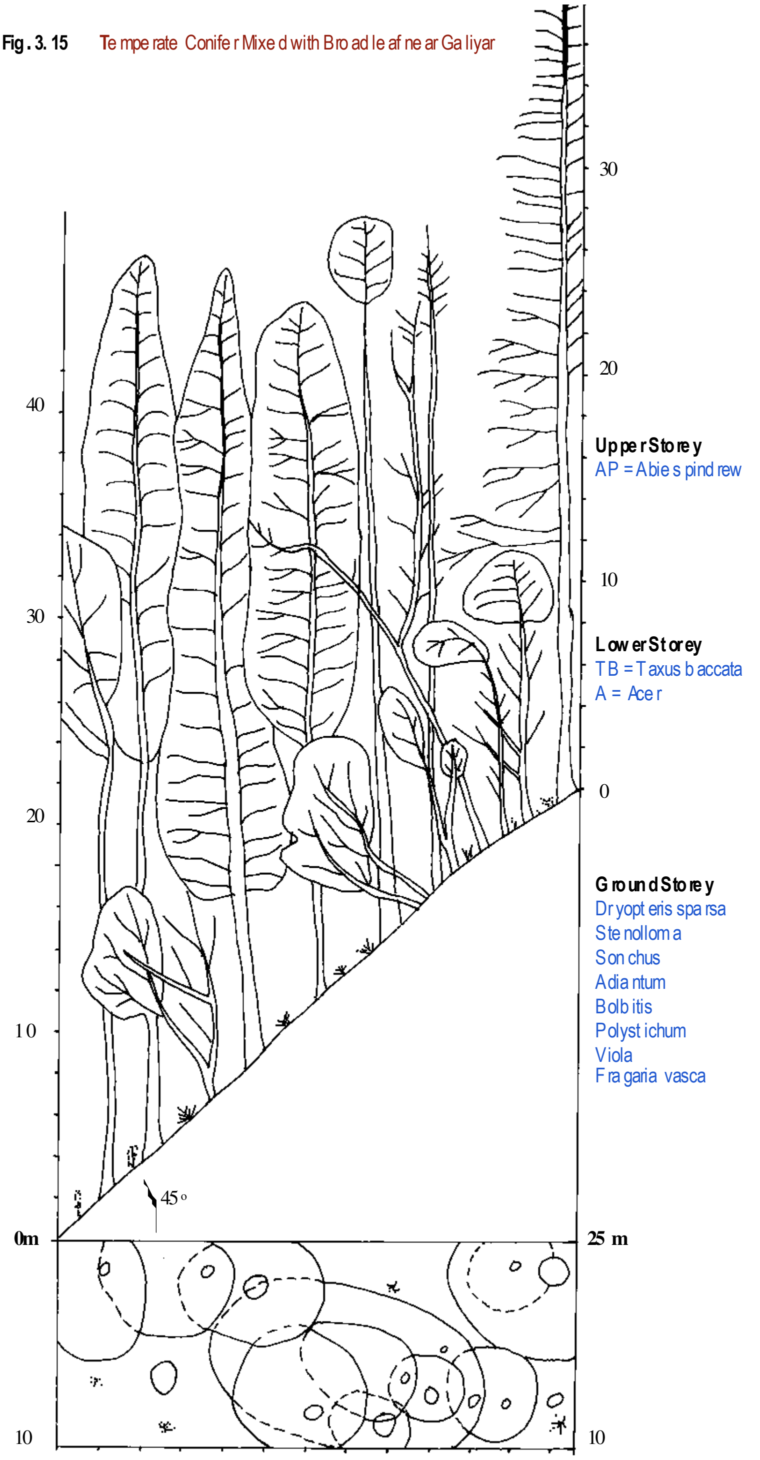
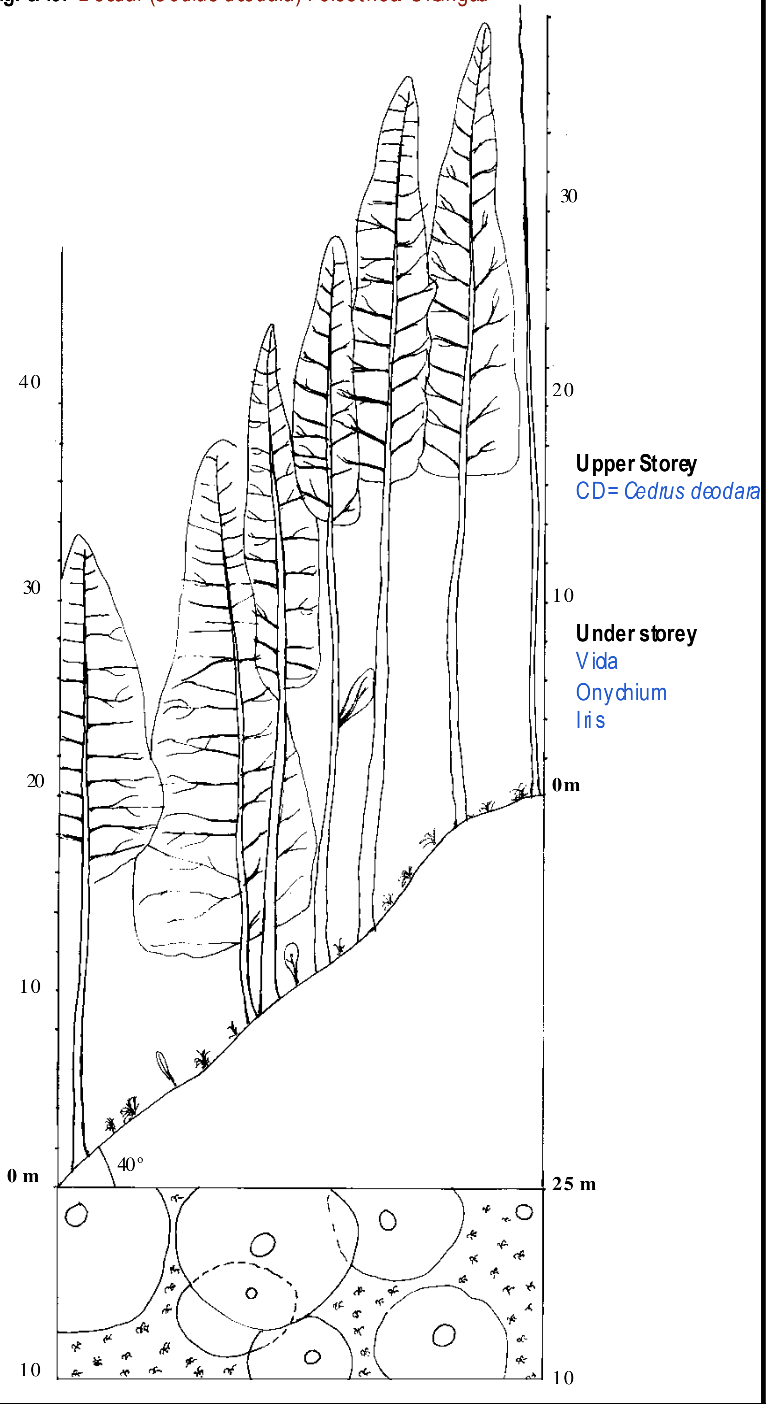


Table: 3.13 MIXED CONIFERS FOREST

Trees	**Herbs**
Cedrus deodara	*Fragaria vesca*
Pinus wallichiana	*Geranium nepanesis*
Juglans regia	*Rubus ellipitcus*
Rododendron arboretum	*Acheranthus aspeciesera*
Pisea smithiana	*Anemone rupicola*
Herbs	*Onychium contiguum*
Phacelurus specieseciosus	*Oplismenus composites*
Carex foliosa	*Impetiens species.*
Podophyllum emodi	*Aspeciesaragus recemosus*
Clematis montana	*Iris milesii*
Rosa webbiana	*Galium apparine*
Rubia cordifolia	*Diplaium maxima*
Specieshenomeris chinensis	*Polystichum prescottianum*
Carex cruciata	*Dryopteris speciesarsa*
Smilicina purpurea	*Oxalis corniculata*
Adiantum venustum	*Hedera nepalensis*
Senecio gracilis	*Desmodium elegans*
Senecio rufinervis	*Indigofera heterantha*
Pteris critica	*Pteridium acquilinum*
Viola serpens	*Solidago virga-aurea*

Pure formations of *Cedrus deodara* are found around Shilt and above Shangarh, around Hemkhundi Thatch and between Shakti and Maror. Wild monkeys were sited in coniferous forest near Maror (Fig 3.16)

Fig. 3.16. Deodar (*Cedrus deodara*) Forest near Shangad



(e) Conifers Mixed with Broadleaf Forest

Coniferous trees are more in proportion than broadleaf trees. This type of mixed can be seen after Shangarh towards Lappa. Coniferous trees of *Cedrus deodara, Picea smithiana, Pinus wallichiana, Taxus wallichiana* etc. form the top storey. Intermixed with these are species of Acer, Prunus etc. Ground storey is more like that of broadleaf mixed with coniferous forests. (Plate 6)

Table 3.14 LIST OF SPECIES OF CONIFER MIX WITH BROADLEAF

Trees	**Herbs**
Cedrus deodara	*Oxalis corniculata*
Quercus glauca	*Thelictrum foetidum*
Picea smithiana	*Geranium wallichiana*
Abies pindrew	*Impatience sulcuta*
Quercus floribunda	*Potentilla microphylla*
Taxus wallichiana	*Pilea umbrosa*
Quercus semicarpifolia	*Adiantum venustum*
Acer acuminatum	*Astrobilanthus atropurpures*
Acer cappadocium	*Oplismenus compositus*
Acer caesium	*Viola biflora*
Shrubs	*Hedera nepalensis*
Principia utilis	*Grardiana diversifolia*
Viburnum nervosum	*Iris mellessi*
Jusminum humile	*Stipa roylei*
Daphne papyracea	*Anemone rivularis*
Lonicera purpuresence	*Geranium nepalensis*
Rosa webbiana	*Polygonum affinis*
Herbs	*Dryopetris speciesarsa*
Goldfusia dalhousiana	*Oxalis acetosa*
Crotolaria cytosoidies	*Smilicena purpurea*
Onychium japonicum	*Fragaria vesca*

(f) Secondary Scrub: (Himalayan Temperate Parklands, 12/DS2)

In Eco-development zone southern slopes have long been put to lot of biotic pressure. Secondary scrubs are found intermixed with agriculture. Scrubby one has replaced original vegetation. *Berberis* species forms the top storey*. Artimisia, Carex, Hypericum, Rubia, Indigophera* etc. are other plants, which form the ground flora elements. Occasionally scattered trees of *Pinus wallichiana* are also seen (Plate 8), (Fig 3.17).

Fig.3.17. Himalayan Temperate Scrub

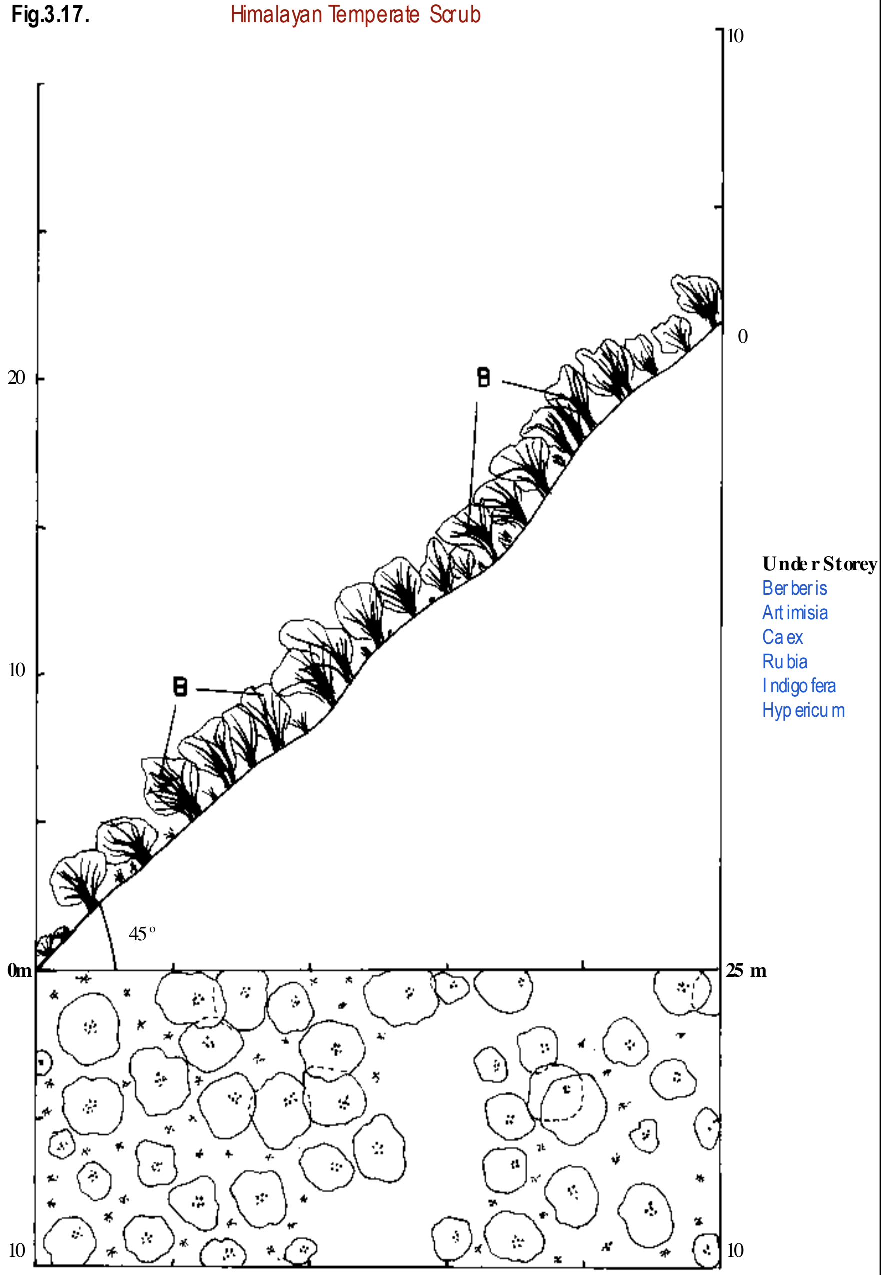


Table 3.15 LISTS OF PLANTS OF SECONDARY SCRUB

Trees	**Herbs**
Pinus wallichiana	*Epilopium latifolium*
Prunus cornuta	*Swertia ciliata*
Buxus wallichiana	*Senecio chrysanthomoides*
Shrubs	*Micromeria biflora*
Pyrus pashia	*Anaphalis busua*
Indigofera heterantha	*Naphalium affine*
Princepia utilis	*Themeda anthera*
Berberis aristata	*Vitivaria zizinoides*
Cotoneaster microphyllus	*Erigeron alpinus*
Sorbaria tomentosa	*Verbascum thapsus*
Speciesiraea canesence	*Rubia cordifolia*
Lonicera purpuresence	*Salvia microffitiana*
Astible rivularis	*Trifolium repens*
Rosa webbiana	*Clematis cornuta*
Indigofera atropurpurea	*Potentilla nepalense*
Berberis chitra	*Draba astusa*
Herbs	*Selinum vegenatum*
Potentilla argyrophylla	*Valerina parvifolia*
Aspeciesaragus racemosus	*Viola serpens*
Plectranthus rugosus	*Plantago erosa*
Pteris subquinata	*Pimpinella diversifolia*
Aster thomsonii	*Artimisia maritina*
Artemisia nilagirica	*Polygonum amplexicaulis*
Salvia hains	*Viola biflora*
Fragaria vesca	*Athyrium atkinsonii*
Polygonum decumbens	*Geranium nepalense*
Galium aparine	*Oxalis corniculata*
Cynoglossum glochidiatum	*Onychium contigium*
Sonchus aspecieser	*Microstigium nudum*
Boehmeria platyphylla	

Viburnum Scrub: A very interesting community of Viburnum was located on way to Maror from Shakti. A more or less pure formation of Viburnum grandiflorum Patch is quite dense and pants are up to 5 m tall. Other species are listed in the table below.

Table 3.16 LISTS OF SPECIES IN VIBURNUM SCRUB

Shrubs	**Herbs**
Viburnum grandiflorum	*Polystihum setosum*
Herbs	*Pilea species.*
Dryopteris speciesarsa	*Rubus niveous*
Adiantum caudatum	*Lecanthus peduncularis*

(g) Subtropical Riverain Forest

Even though the valleys are narrow, riverbed at some places is quite wide. These riverbed and side slopes have different species composition. These are the formations of riverain forest. Two types of riverain forests have been located in the study area.

Subtropical riverain forests have *Alnus nitida* and grow in narrow belts. Since these are very narrow and were under shadow on satellite data therefore could not be delineated. These are found in the riverbeds quite frequently from Ghusaini to Bathad and up to Rolla speciesecially at the bends of rivers. In Sainj Valley riverbeds of Nevli and towards Baha areas have these types of forests. Good forest of this type can be seen along Rupa nala and Sainj River. Dela Khad after Lappa has moderately less disturbed forests of *Alnus nitida, Celtis tetrandra, Pyrus* species etc. *Girardinia diversifolia, Diplazium esculentum* etc. very common and grow abundantly. (Fig 3.18)

Fig. 3.18 Subtropical Riverain Forest near Ghusaini

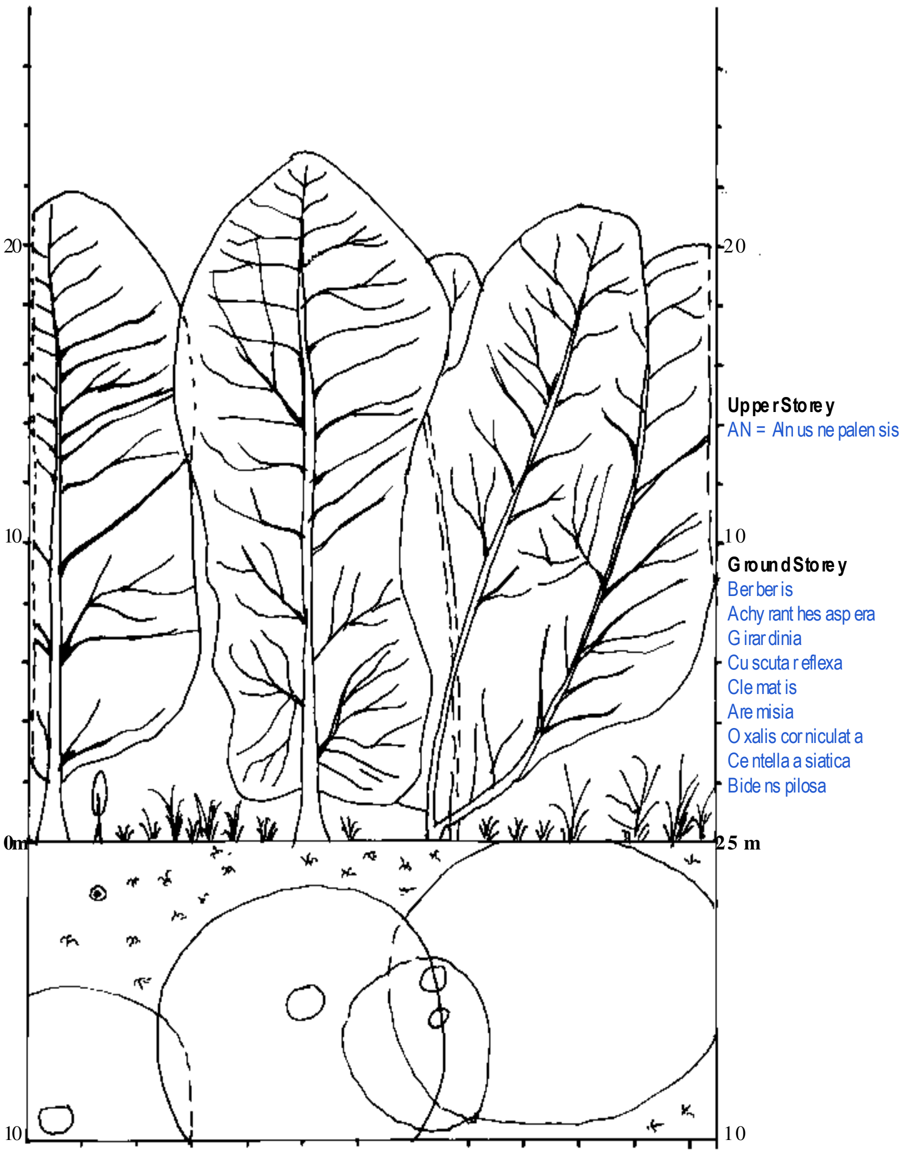


Table 3.17 LIST OF PLANTS SUBTROPICAL RIVERAIN FOREST

Trees	**Herbs**
Alnus nitida	*Oxalis corniculata*
Srhubs	*Salvia macrofftiana*
Berberis chitria	*Achyranthus aspeciesera*
Sorberia tomentosa	*Plectranthus rugosus*
Rubus paniculatus	*Diplazium fieldinziana*
Prinsepia utilis	*Diplazium esculantum*
Desmodium triflorum	*Polygonum recumbens*
Herbs	*Oplismenus compositus*
Cuscuta reflexa	*Solanum tuberosum*
Tagetis minuta	*Sonchus aspecieser*
Artemisia parviflora	*Cannabis sativa*
Girardinia diversifolia	*Pteris cretica*
Galinsoga parviflora	*Fragaria vesca*
Themeda anthera	*Cyperus compressus*
Chenopodium ambrosoides	*Apluda mutica*
Clematis gouriana	*Bidens pilosa*

(h) Temperate Riverain Forest (Hippophae Scrub)

Pure disturbed as well as undisturbed patches of Hippophae salifolia are found around Shakti village. These found along the riverbed either on little elevated land or quite close to water. Trees are up to 8 m tall. Top canopy is *Hippophae salicifolia* (about 5 m tall). Presence of *Girardinia diversifolia* and *Cannabis sativa* indicates biotic disturbance. Epiphytic fern *Pleopeltis* is found in these patches. Other associates are *Sorberia tomentosa*, *Rosa webbiana* etc. Species found are listed in table below. (Plate 9).

Table 3.18 LISTS OF SPECIES IN HIPPOPHAE SCRUB

Hippophae salicifolium	*Achyranthus aspeciesara*
Sorberia tomentosa	*Strobilanthus atropurpureous*
Herbs	*Cnetella asiatica*
Rosa webbiana	*Girardinia diversifolia*
Polygonum capitata	*Oplismenus compositus*
Urtica parviflora	*Diplazium fieldenzinum*
Viola serpens	*Cannabis sativa*
Fragaria vasca	*Cyathula tomentosa*
Sorbus foliolosa	*Siegesbeckia orientalis*
Ivy species.	*Pleopeltis species.*

The inner Himalayan region in the Sainj valley important and unique formations along the riverbed is found. These are temperate riverain forests and are found in patches about 2 km before the Shakti to 5 km after towards Maror.

(i) Alpine Scrub: (Birch-Rhododendron Scrub Forest): (Dwarf Rhododendron Scrub)

Above the tree line occurs dwarf vegetation formed by Rhododendrons and *Betula utilis*. These are thick sometimes-impenetrable areas bushy vegetated areas. *Betula utilis* forms the top storey and first storey is formed by *Rhododendron companulatum*. Because of the pressure from snow most of the plants are bending towards down slope. Ground flora is mainly of *Rhododendron anthopogon*, Rosa webbiana, and young to middle aged *Rhododendron companulatum* plants. Ground flora is mainly of species of *Primula, Potentila* etc. (Plate 10), (Fig.3.19 and 3.20)

Fig. 3.19 Betula Forest near Basleo Pass

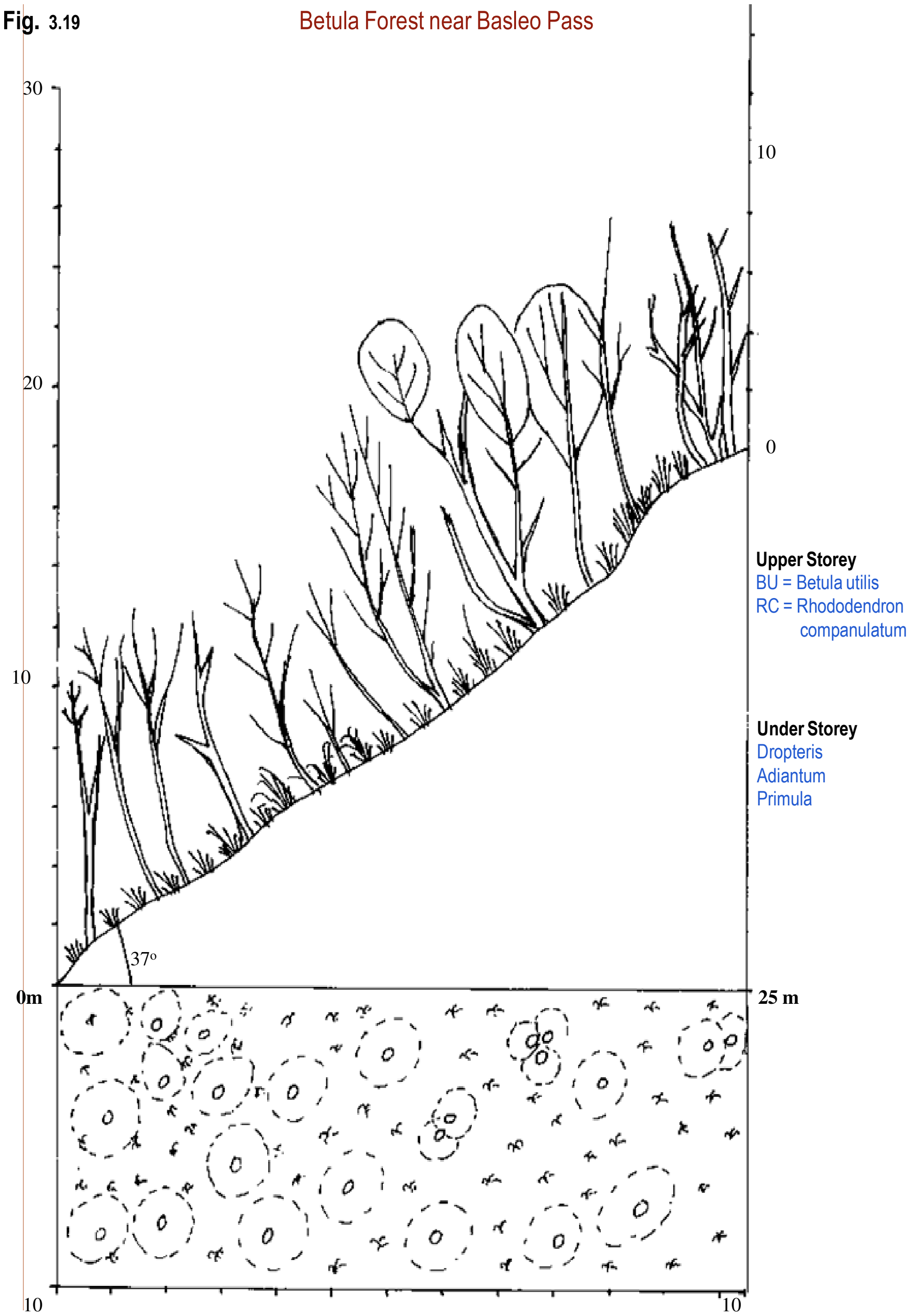


Table 3.19 LIST OF PLANTS IN BIRCH-RHODODENDRON SCRUB

Shrub	Herbs
Betula utilis	*Agrostis pilosula*
Rosa webbiana	*Adiantum venustum*
Rododendron campanulatum	*Dryopteris komarovii*

(i) Alpine Scrub (Deciduous Scrub)

Alpine scrub is mainly dominated by *Rhododendron companulatum* and *Rhododendron anthopogon.* These bushes can grow up to 4 m tall. Stems are much branched and slanted because of the pressure of snow i.e. adaptation to snow. The branching is very profuse and almost difficult to negotiate. Good formations can be seen Around Dhela Thatch, Gumtrao and Rukundi top in small patches around Basleo pass. These are more or less pure formations, however sometimes *Betula* and *Quercus* trees might occur. (Plate 11), (Fig 3.21)

(j) Slope Grasslands

On steep slopes around Shakti and upper reaches of Tirthan and Palachan Gad have extensive grasslands. The terrain is rugged and steep. Grass plants of Themeda triandra, Oplismenus, Agrostis etc.and other plants like Aster, Cheilanthes farinosa, Sedum, Colebrookia oppositifolia etc. occur intermixed. These are also pature areas (Plate 12).

(k) Grasslands /Blanks/Alpine Pastures

Grassland may be very extensive as well as small as forest blanks. In forest blanks these are the camping sites of shepherd. Alpine grasslands commonly known as “thatch” are found either growing extensively or mixed with alpine scrub of Rhododendron on relatively protected slopes. Various species of *Primula, Potentilla, Carex, Gentiana*, etc. found abundantly. Grasslands near Chipni are quite extensive and used by villagers for grazing and fodder. Near Gumtarao these are the habitats of wild animals like *Musk Deer* (Plate 14) and (Fig 3.22).

Table 3.20 LIST OF SPECIES OF PLANTS IN TEMPERATE AND ALPINE GRASSALNDS

Herbs	*Diplazium maxima*
Themeda triandera	*Erigeron multiradiatus*
Verbascum thapsus	*Salvia lanata*
Rumex acetosa	*Desmodium triflorum*
Cheilanthus bicolor	*Origanum vulgare*
Artimisia parviflora	*Brassica juncea*
Erigeron canadansis	*Selinum vaginatum*
Campanulla argygrotricha	*Achillium millefolium*
Micromeria biflora	*Galinsoga parviflora*
Viola serpens	*Grardiana diversifolia*
Vetiveria ziznoides	*Onychium contigum*

(l) Habitation /Agriculture/ /Orchard (Apple Orchards)

Himachal Pradesh has found tremendous potential in horticultural crops. Apple orchards are everywhere and have become a ‘big’ source of income. Terraces with orchards are very common sites. Indigenous plants grow only on bunds and along nala or streams. Iris species is most commonly found. In agroforestry practices *Pyrus malus* (apple) and peach are grown along with various cereal crops like, wheat, maize, Elucine corcana, paddy, ‘karnkhan’ etc. (Fig. 3.23), (Plate 16).

(m) Exposed Rocks with slope Grasses

Rocks are covered with scattered growth of grasses. Found in alpine zone above tree line. *Themeda triandra*, *Oplismenus compositus*, *Agrostis* species etc. are the grasses found in these slope grasslands (Plate 15).

Fig.3.20 Betula-Rhododendron Scrub after Rukhundi top towards Gumtrao

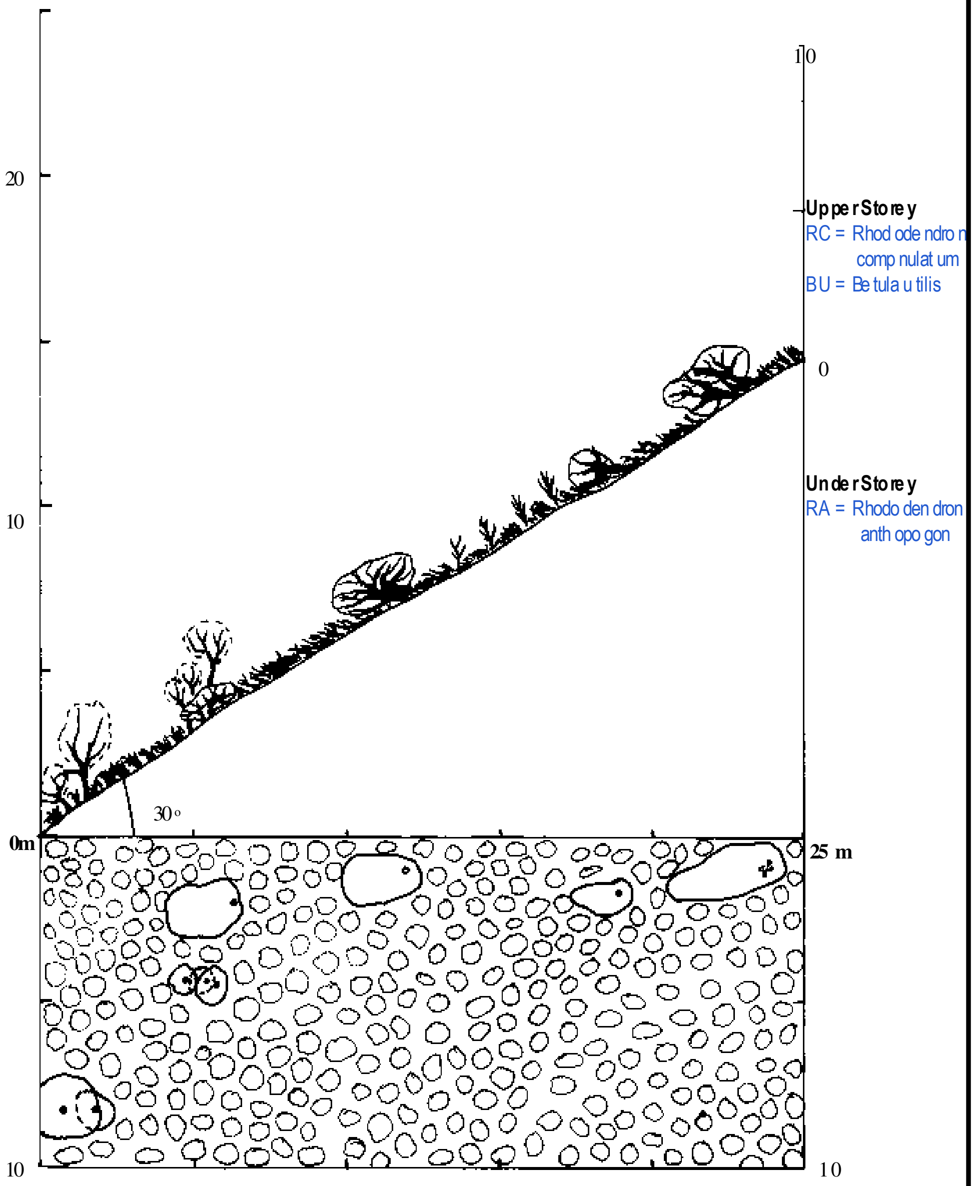


Fig. 3.21 Alpine Scrub and Alpine Grassland near Gumtrao

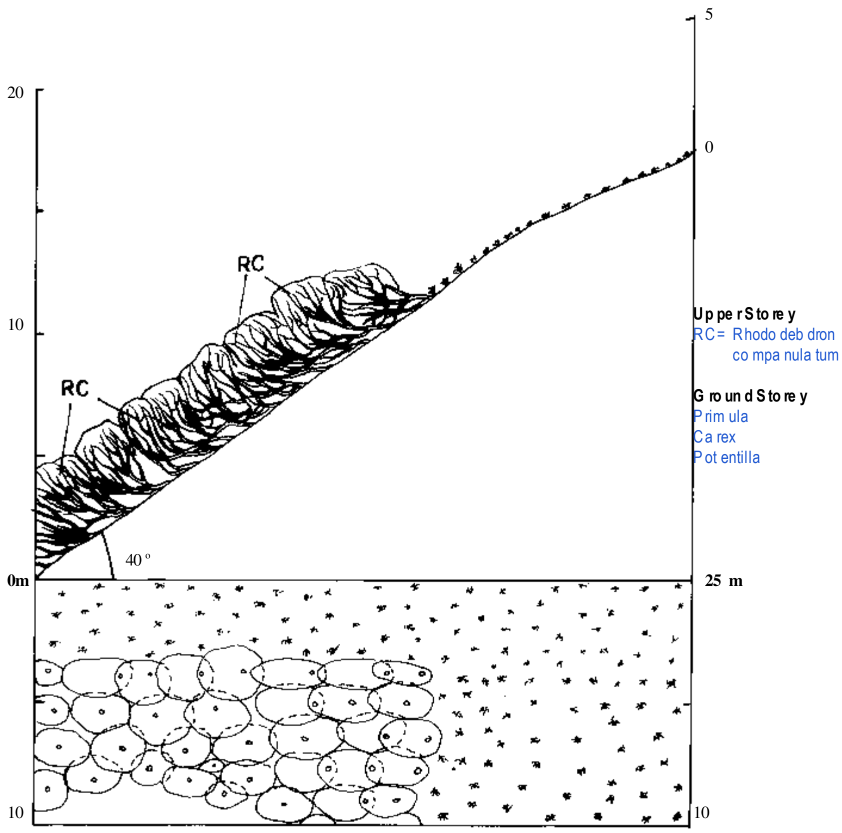


Fig. 3.22 Temperate Grasslands hill around Chipni

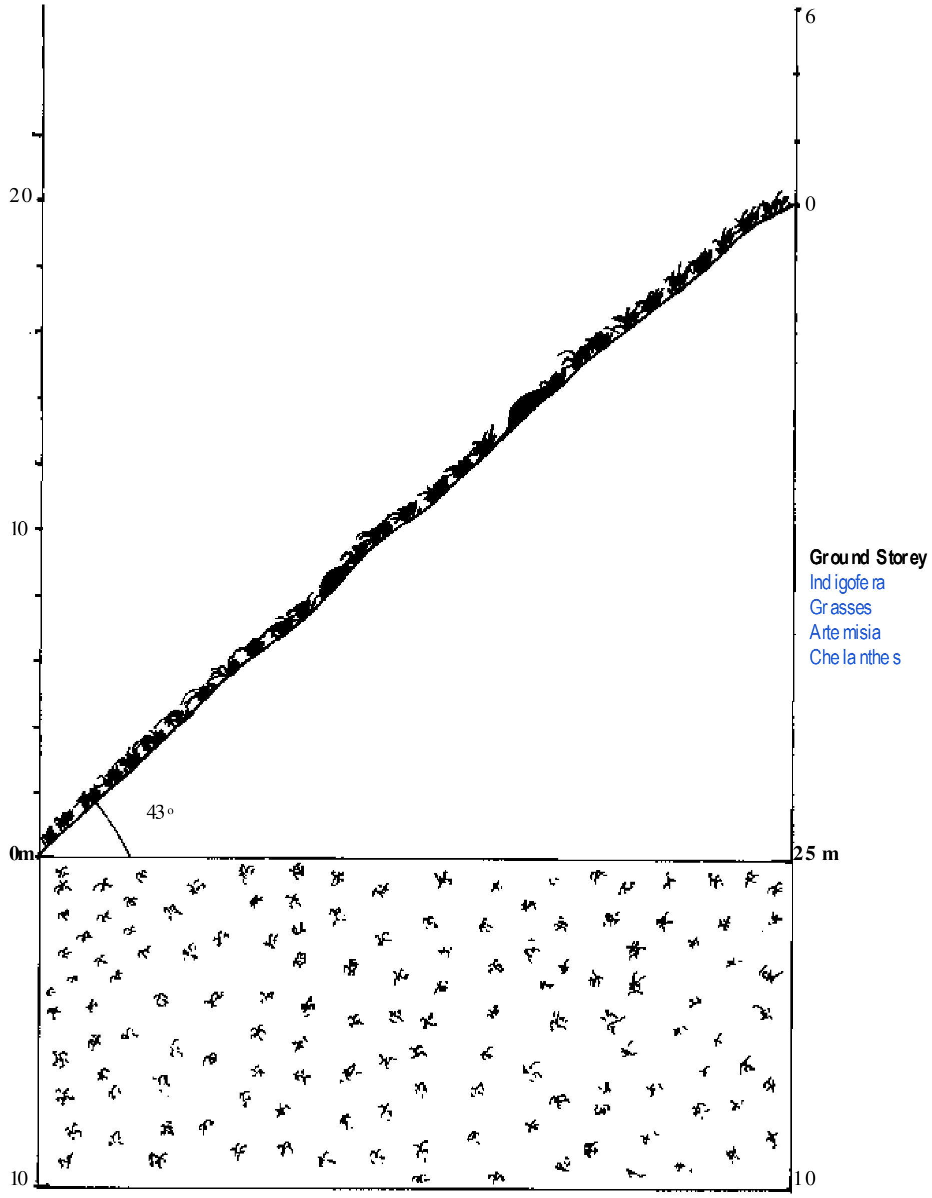


Fig. 3.23. Orchard near Tilhara village,Tung

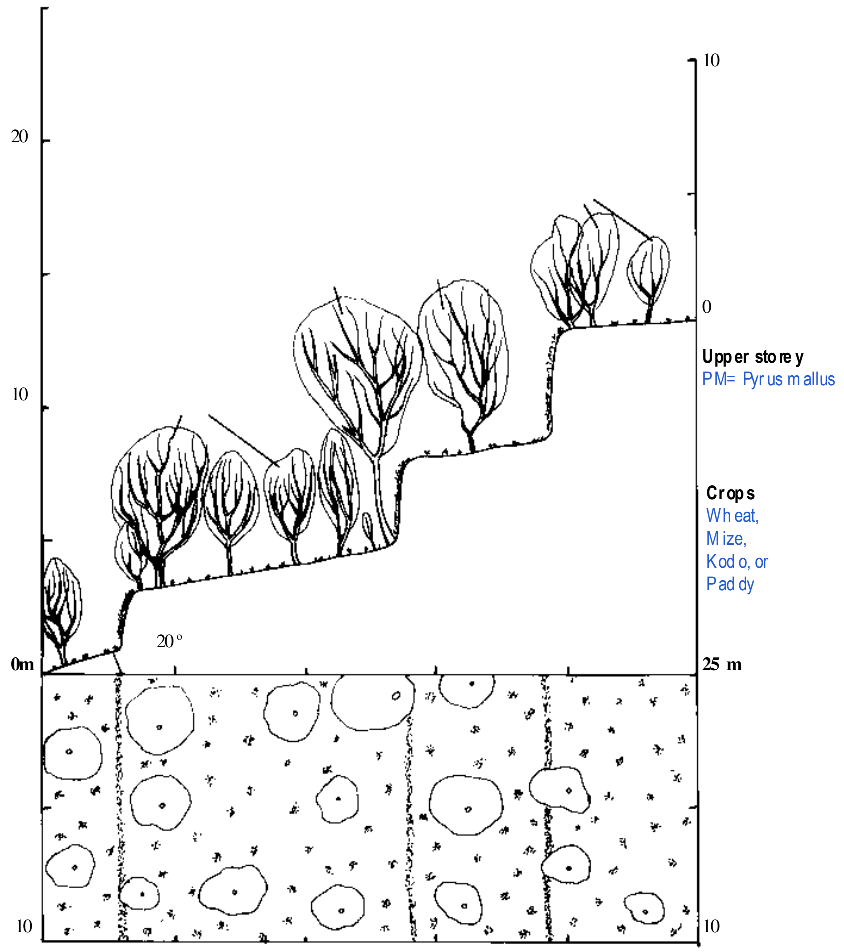


Plate – 16 **Agriculture/ Orchard near Tung**

4. GEOMORPHOLOGICAL MAPPING

4.1 INTRODUCTION

The science that deals with surface features of the earth, their forms, nature, their origin and development is termed as geomorphology. Davis (1912) first projected the concept of geomorphic cycle. According to Baulig (1950), the role of factors that are important to understand the geomorphology are lithology, stratigraphy, climatic variation and the regional basis for the development of land forms.

The geomorphology is primarily concerned with present day landscape. As far as the Himalaya is concerned, its geomorphology was shaped with its evolution from middle Miocene to Recent on continent to continent collision. Himalaya is still active, that is why landforms are dynamic in nature with many climatic factors influencing them. The most important causes of damage to natural forest ecosystems in Himalayas are both natural and man made. The former includes lithology and competency of rocks, inclination and orientation of slopes (aspect), shape of land and surface seismic and other tectonic activities. The human factor includes indiscriminate deforestation through felling, burning, grazing and cultivation (Pandey & Singh 1984; Singh *et al* 1984). The increasing application of geomorphic interpretation through aerial photographs and satellite data facilitates the understanding of the relationship between landforms and visible biotic factor like vegetation.

This study aims to integrate remote sensing data with other multidisciplinary thematic maps in order to study the geobotanical trends which further can be utilized for wildlife conservation, habitat evaluation and management.

The various landforms can influence a conservation area in many ways like slope gradient, elevation and aspect, affect the quantity of solar energy, water, nutrients and other materials, while the slopes affect the flow of materials. Slope is also the deciding factor of intensity of disturbance, such as fire and wind, which are strongly influenced by the presence of vegetation (Swanson *et al* 1988).

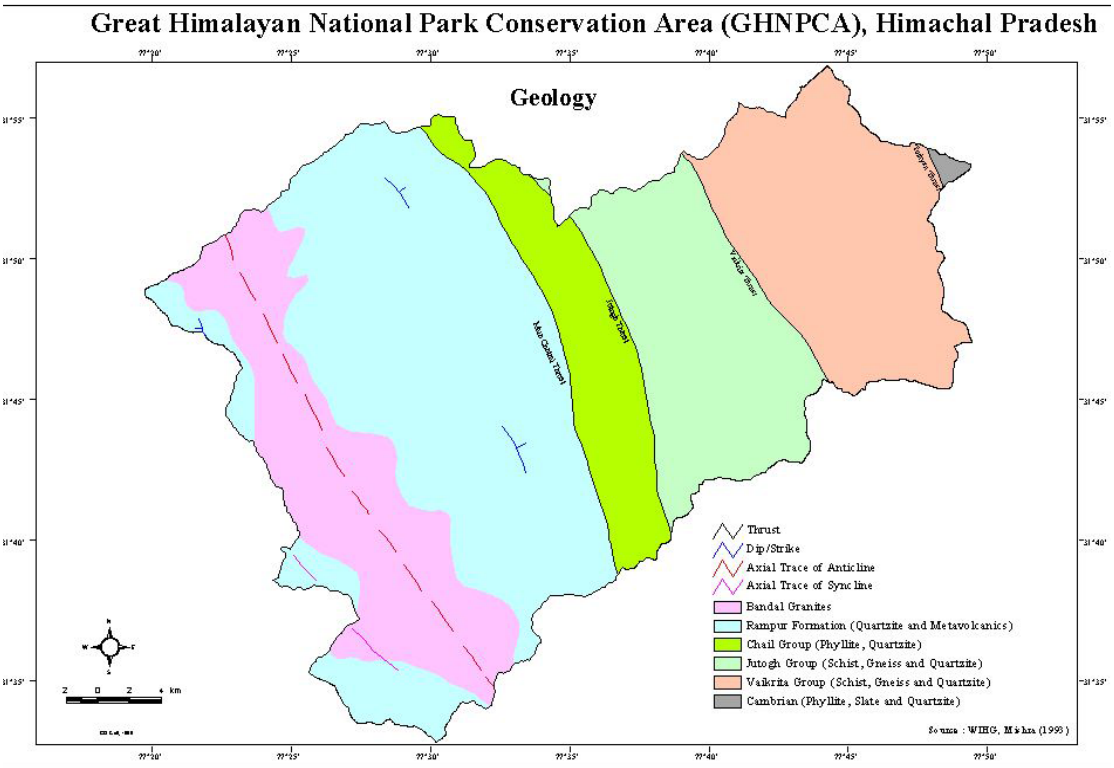
4.2 GEOLOGICAL FRAMEWORK

The study area forms a part of Inner Himalayas in Great Himalayan National Park (GHNP) in Kullu district, Himachal Pradesh. A number of workers have made an attempt to resolve the geological complexity of the region, mainly Auden 1935 & 1955, Wadia 1957, Sharma 1977, Sinha 1977, Valdia 1980 and Mishra 1993. However Sharma, (1977) first time tried to establish a complete geological account of Kullu Rampur belt covering an area of about 2500 km^2. The work was referred by many workers including (Mishra 1993), who broadly emphasised the deformational set up as a result of different tectonic phases in Sutluj and Beas valleys. As per the geological map the major rock types in the area are quartzite, phyllite, slate, schist and gneiss along with granite having a regional strike trend of NW-SE with a varying amounts of dip due NE. These rocks have been folded, faulted and thrusted as consequences of different tectonic episodes.

For preparing the geological map of the study area, the geological map of Sutluj and Beas valley (Mishra, 1993) has been taken as a basic data. The study area was digitised in ARC/INFO GIS domain as shown in Fig. 4.1.

The lesser Himalayan sedimentary and volcanics are exposed in the form of window. These are tectonically overlained by the crystalline sheets of the higher Himalaya separated along the Main Central Thrust (MCT) in the north. In the north the Haimanta group of Tethyan Himalaya tectonically rests over the Vaikrita group. The description of tectonostratigraphic succession is shown in Table -4.1 that has been described by (Mishra, 1993) as follows:

Fig 4.1



Larji Formation: The Larji formation is exposed in the form of a small tectonic window (Larji window) enclosed within a larger Rampur window below the Chail metamorphics. This formation lying west of Sainj is exposed around Larji in Bias valley. It is made up of orthoquartzite-carbonates sequence. This formation is divided into three members namely Naraul slate, Hurla quartzite and Aut dolomite at the top (Sharma, 1977), but Naraul is only locally mapable so the Larji formation has mainly two subdivisions. This formation is lying outside of the study area.

Rampur Formation: The major rock-types in this formation are metavolcanics and quartzite, intruded by Bandal granite supposed to be 1800 Million year old. (Frank 1974) roughly extending from Bandal to north of Manihar. These rocks are forming an antyformal structure. They also show sedimentary structures like cross bedding, ripple marks and bedding cleavages. This formation extends approximately from Rampur to Manikaran area. The Rampur formation appears to be older then Bandal granite (Mishra1993).

Central Crystalline Complex of Higher Himalaya: This zone is situated between two great thrusts, *viz.* the MCT in the south and Tethyan thrust in the north. This zone comprised of Chail, Jutogh, and Vaikrita groups lying one upon another and dipping towards northeast at low to moderate angles.

Chail Group: The major rock types of this group are serisite-chlorite, phyllite, quartzite, and carbonaceous slate and mylonisized gneiss. The Chail group shows three generations of fold. The rocks were developed as nappe and have moved southwards along the thrust and a band of mylonisized augen gneiss is extensively developed showing pronounced crumpling, crushing and shearing. According to Mishra (1993), the Larji Rampur window is surrounded by the low-grade metamorphics of Chail group. This group extends to the west around Nirth Pandow and Kullu upto Malana and south upto Jhakri in Satluj valley.

Jutogh Group: The low-grade metamorphics of the Chail group is tectonically overlained by the medium grade metamorphics of Jutogh group along Jutogh thrust. A persistent band of garnetiferous chlorite- biotite phyllite phillonite and Carbonacious Schist follows the thrust throughout the belt. The Karchham quartzite is sandwiched between the interbeded sequence of garnet-biotite, schist banded gneiss and carbonacious schist of the Jutogh group.

Vaikrita Group: The Vaikrita thrust is demarcated by an abrupt change in grade of metamorphism and the composition of the lithology. The Vaikrita group consists of high-grade crystalline rocks mainly coarse grained kynite silimanite schists and gneiss. The rocks of Vaikrita and Jutogh group together show three phases of deformation. In Vaikrita group the folds are isoclinal, recumbent to open to tight, along with asymmetrical cross folds in all three phases of deformation.

Haimanta Group: This overlies the Central crystallines (Vaikrita group) along a tectonic contact (Tethyan thrust). These low-grade metasediments are exposed in the vicinity of the thrust zone as sericite-chlorite schists showing pronounced crumpling, crushing and even shearing. The Tethyan thrust is marked by a break in metamorphism. Vaikrita group shows kyanite, silimanite zones of metamorphism, whereas biotite grades metamorphism found in Haimanta group. The areal estimates of geological formations (analysed in ARC/INFO GIS domain) are given in Table 4.2.

Table 4.1

TECTONOSTRATIGRAPHIC SUCCESSION IN GREAT HIMALAYAN NATIONAL PARK, HIMACHAL PRADESH (MISHRA, 1993)

Tectonic Zone	**Tectono-stratigraphic Unit**	**Lithology**	**Age**
Tethys Himalayan	Haimanta Group	Sericite-chlorite phyllite, carbonaceous slate and quartzite	Late Pracambrian and 500 Ma granite
—— Tethyan Thrust ——			
	Vaikrita Group	Kyanite-sillimanite bearing garnet-biotite schist and gneiss, quartzo-feldspeciesathic banded gneiss and quartzite	Precambrian, Lower Palaeozoic granite and Miocene leucogranite
—— Vaikrita Thrust ——			
Central Crystallines of Higher Himalaya	Jutogh Group	Garnet-biotite schist and gneiss, Carbonaceous schist and quartzite.	1800-2000 Ma gneiss
—— Jutogh Thrust ——			
Central Crystallines of Higher Himalaya	Chail Group	Sercite-chlorite phyllite, quartzite, carbonaceous slate and mylonitized gneiss	1200-1400 Ma gneiss and 500 Ma granite
—— Main Central Thrust (MCT) ——			
Larji-Rampur Window Group of Lesser Himalaya	Rampur Formation	Quartzite and metavolcanics	2500 Ma metavolcanics and 1800 Ma granite
—— Garsah Thrust ——			
Larji-Rampur Window Group of Lesser Himalaya	Larji Formation	Dolomite, stromatolitic limestone, shale and slate	Middle Riphean (1300-1000 Ma)

Table No. 4.2

AREAL ESTIMATION OF GEOLOGICAL FORMATIONS IN THE STUDY AREA

Formation	Area in km^2	Percentage
Haimanta group	3.02	0.25
Vaikrita group	211.68	18.08
Jutogh group	187.66	16.03
Chail group	114.04	9.73
Bandal granite	205.26	17.53
Rampur formation	449.35	38.36
	1171.00	100.00

The relation between geology and vegetation has been observed by overlay analysis in GIS domain and is described below.

4.3 GEOBOTANICAL RELEVANCE

Though geology can explain the interrelationship of rocks and vegetation, it has been realized that it is not the only source by which a clear-cut explanation can be made. The relation of topographic forms and vegetation can also help in improving the understanding. The northeast portion of GHNP is snowbound. There is hardly any vegetation except in the valleys up to certain limits, governed by altitude and temperature. In the present study, mostly the landform characters (slope, aspect, drainage density, and form of the slope, it's shape and terrain complexity) have been studied for determining the relationship with vegetation, on the basis of overlay analysis in GIS. It has also been reported by earlier studies that vegetation communities are highly influenced by various topographical features (Puri, 1950a, Roy & Jugran, 1986 and Warner, 1991). Hence the emphasis has been laid on such features in relation to the spatial distribution of vegetation. As stated by Troup (1921) in hilly regions, variations in the forests are observed with the changes of aspect and configuration of slopes where underlying rocks does not change".

Landscape is the mosaic of landform, vegetation and landuse (Urban *et al* 1987; Noss, 1990; Kim and Weaver, 1994). Therefore, landscape ecology has emerged as an important discipline to study the landscape structure, its functions and changes. Each landscape is composed of several landscape elements, each of which has its own significance in the ecosystem and is important in evaluating the landscape structure (Oliver & Larson, 1990).

The rocks and soils affect the vegetation of an area by influencing moisture regime, structure and texture of the soil (Puri, 1950a). Landform factors that mainly influence vegetation are slope, aspect and inclination. After knowing the relationship of these factors with elements of landscape the habitat analysis can be made more precise.

The importance of geology in the study of vegetation has been stated by Puri (1950 a). According to him the geology of a region affects the vegetation in two ways: - (i) by presence or absence of minerals, and (ii) by structural variations in rocks and nature of the slope, viz. dip versus scarp slopes.

Geobotanical relationships are highly complex. Geology is linked through soil to vegetation and climate and the relief affect both. Troup (1921) also described the effect of geology in local distribution of blue pine and chirpine near Bandal in the Tirthan valley. The absence of chirpine community in high altitudinal zone from the Beas valley is because of the absence of quartzites. The presence of blue pine at lower and higher zones of flood plain deposits or on scarp slopes of mica schist/ sandstone has found. This is more closely related to rock type than to climate or a slope-aspect. The importance of geomorphology in the distribution of forest communities is now well recognized.

4.4 LITERATURE REVIEW

Speciesoradic work in relation to geology and forest vegetation in some parts of India has been carried out by Puri (1949, 1950a and 1950b). In the western Himalayas, Troup (1916) found that chirpine communities were mostly confined to quartzite rocks whereas blue pine was mostly found on mica schist. He gave a number of examples to show the relation between geology, soil and vegetation. Mohan & Puri (1953) investigated the relationship between vegetation and geological features in Kullu Himalayas. Suri and Wright (1922), Osmaston (1931), Suri (1933) and Mohan (1933) stressed on the climatic factors and studied on distribution and succession of conifers in Kullu Himalaya. With the advent of RS and GIS several studies have been made on geology, geomorphology and geo botanical trend analysis. Roy and Jugran (1986) have reported the mapping of geology and geomorphology using LandSat TM and MSS analog data in Kanha National Park, Madhya Pradesh. Gugan and Dowman (1988) have done the topographic mapping from SPECIESOT imagery. Davis *et al*, (1989) have made a successful use of Landsat TM for rock discrimination in the complex geologic environment. For characterization of topographic surfaces GIS has been widely used by Falcidieno and Speciesagnuols (1991). Using digital elevation data, a geobotanical trend has been reported by Warner *et al* (1991). Aerial photographs have also been used to delineate geology and land slide zones by Tiwari *et al* (1986). The IRS-IB LISS II data has been used for geomorphological mapping by Tripathi, *et al* (1996). For geology and geomorphological studies, the IRS-IC data have been used by Rao et al (1996). Krishnamurty (1997) has used the IRS digital data widely for lithological and structural mapping.

4.5 GEOMORPHOLOGICAL MAPPING

The geomorphologic map of entire project area has been prepared mainly through IRS IB LISS II 1993-94 satellite data on 1:50,000 scale. Some physiographic details were transferred from toposheets (waterdivide/speciesurs) to the base map along with the interpreted units through satellite data.

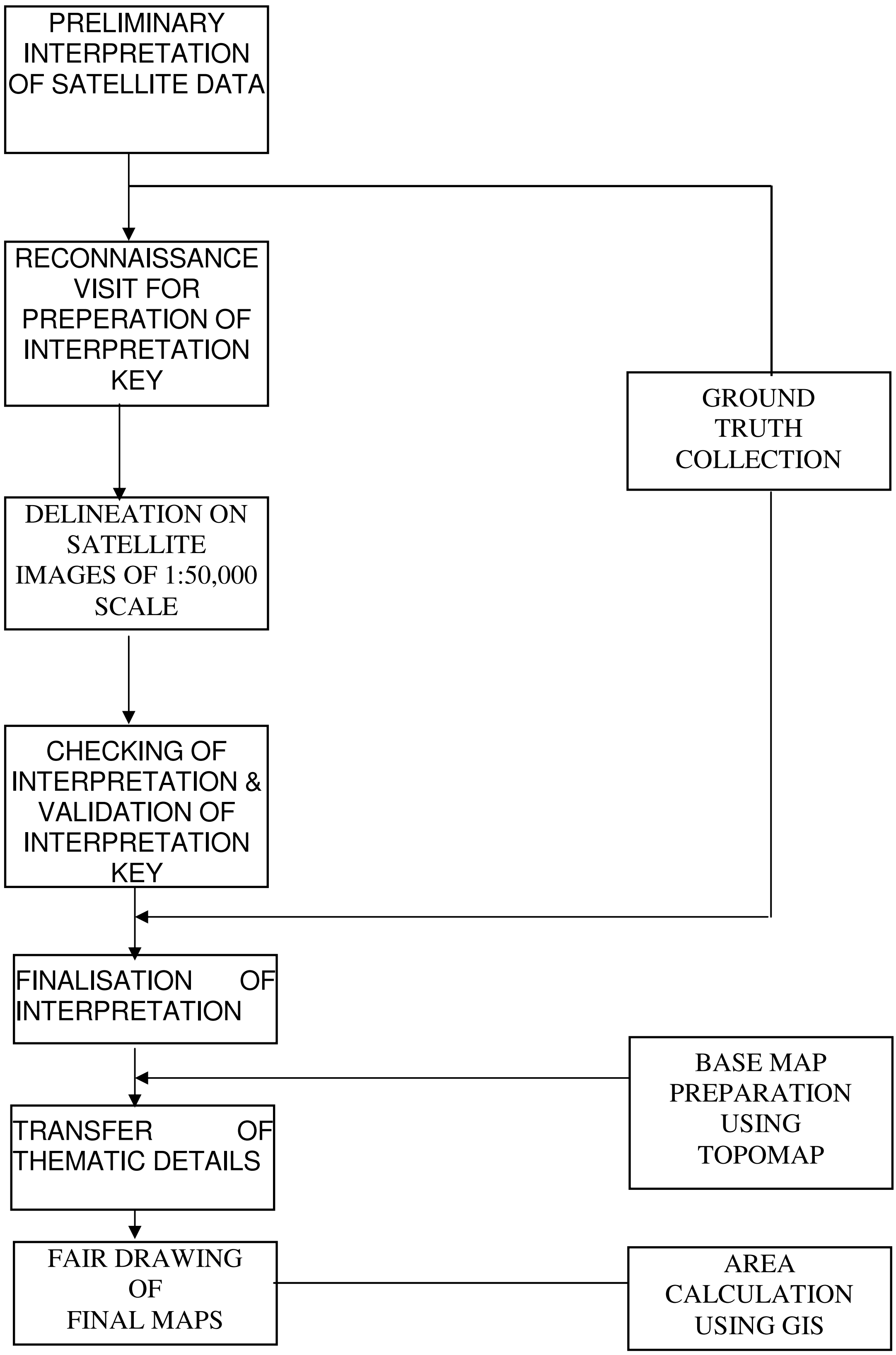
4.5.1. Methodology

The interpretation work was carried out systematically in following order.

- Satellite data interpretation.
- Ground truthing for mapping and other details.
- Base map preparation through topographic maps.
- Incorporation of other thematic details through topographical maps for final map preparation.

- Information transfer to base map.
- Field investigations and correction.
- Preparation of geomorphological map on 1:50,000 scale through satellite image and some other details incorporated through Survey of India toposheets.
- Analysis using Geographical Information System (ARC/INFO). The details of methodology are given in Fig 4.2.

Fig. 4.2 STEPS IN GEOMORPHOLOGAL MAPPING THROUGH VISUAL INTERPRETATION OF SATELLITE IMAGES



Spatial maps for the entire study area have been prepared on 1:50,000 scale using IRS IB LISS II (False Color Composite) of 1993 with topographic maps 53 E/6, E/9, E/10, E/13 and E/14 on 1:50,000.

4.5.2. Data Used

September and October season was selected for collection of data. These two months were found appropriate for doing studies in the higher Himalayas.

a. Satellite data: IRS-113 LISS II FCC 2, 3, 4, Geo-coded hardcopy of September/October 1993.
b. Ancillary data: The secondary and other collateral data used in the study are as follow: Survey of India topographical maps No. 53 E/5, 53 E/6, 53 E/9, 53 E/10, 53 E/13, and 53 E/14
c. Base map
d. Existing thematic geological map (Mishra, 1993).
e. Field data: with the help of photo characters of limited ground check.

4.5.3. GIS Database

Using ARC/INFO UNIX based GIS, several other information were generated as given below:

- With the help of contours, the desired slope map and aspect maps were generated.
- The terrain complexity map was developed using contour.
- Digitization of thematic layers and labeling/attribute assignments.
- Generation of Digital Elevation Model (DEM) using GIS.
- Analysis of area calculations for management zones using GIS.

4.5.4. Instruments

The following instruments were used to prepare the map

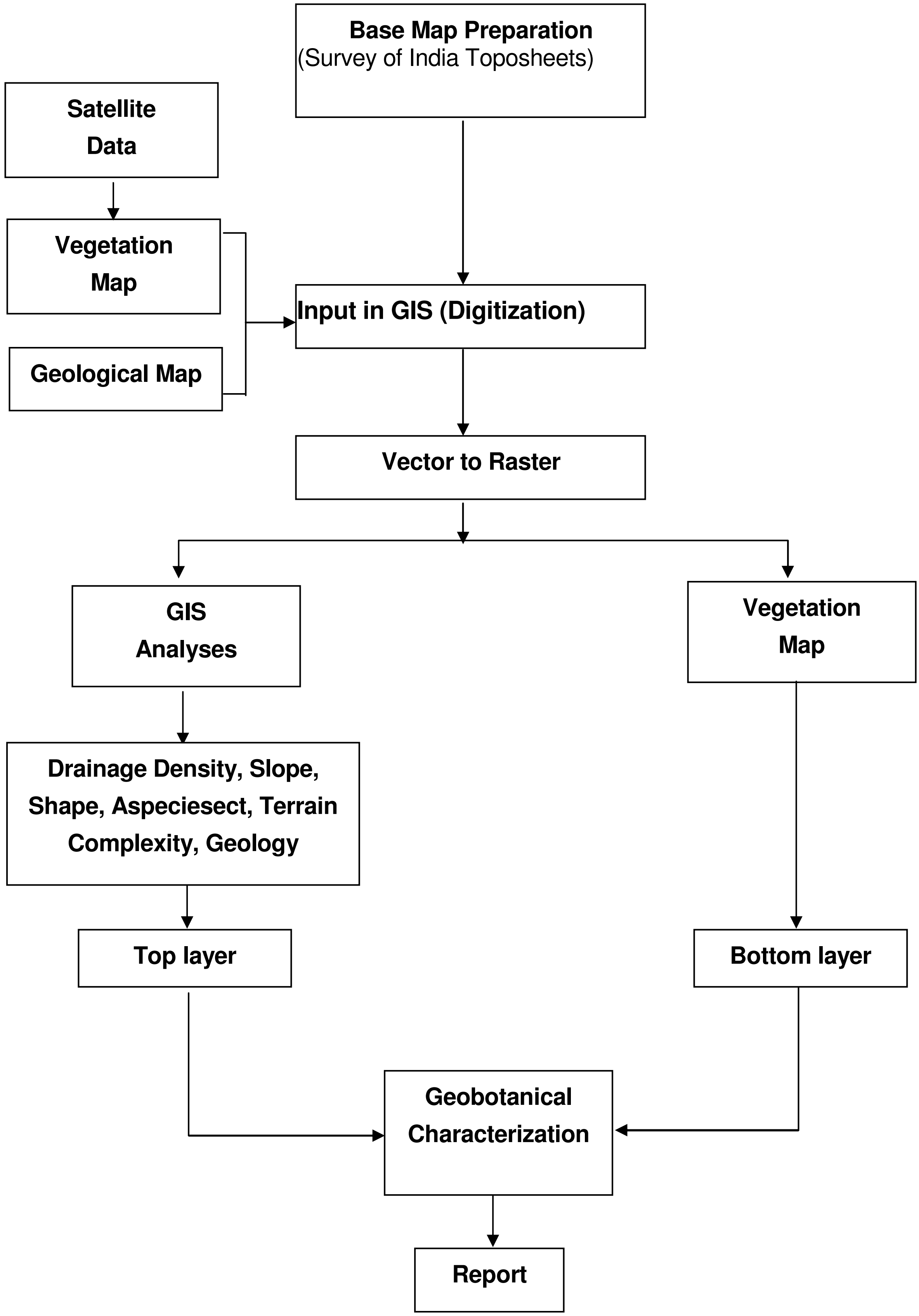
- Clinometer
- Optical pentagraph

- Simple light table
- ARC/INFO GIS Domain
- Other accessories.

4.6 GEOBOTANY

In order to establish a relationship between vegetation types and various terrain parameters i.e. vegetation, geology, and geomorphology i.e. rock types, slopes, shape, aspect, terrain complexity and drainage density, etc. were considered. These factors were correlated through overlay analysis in ERDAS software in GIS domain. The vegetation types used for overlay analysis were extracted from speciesecialized landuse/landcover maps, in which topographic data (contours) were used as per the climatic zoning (G.S. Rawat, personal communications, 1999) using GIS domain. The methodology has been depicted in Fig 4.3.

FIG 4.3 METHODOLOGY FOR GEOBOTANICAL CHARACTERIZATION



4.7 Results

4.7.1. Geomorphology:

4.7.1.1. Topographic Layers

The geomorphological map was prepared by visual interpretation and some other basic inputs through Survey of India (SOI) toposheets like water divides and speciesurs. The youthful mountains, depicting a great variation in heights of the ridges and valleys principally cover the area. Nine major units were delineated. The maximum area was covered by alpine exposed rock, which was about 149.73 sq.km whereas the minimum area was covered by Morainic islands in the eastern part of the study area, which was full of glacial forms. Besides this, other geomorphological features have been analyzed through GIS domain with basic input of contours in the study area.

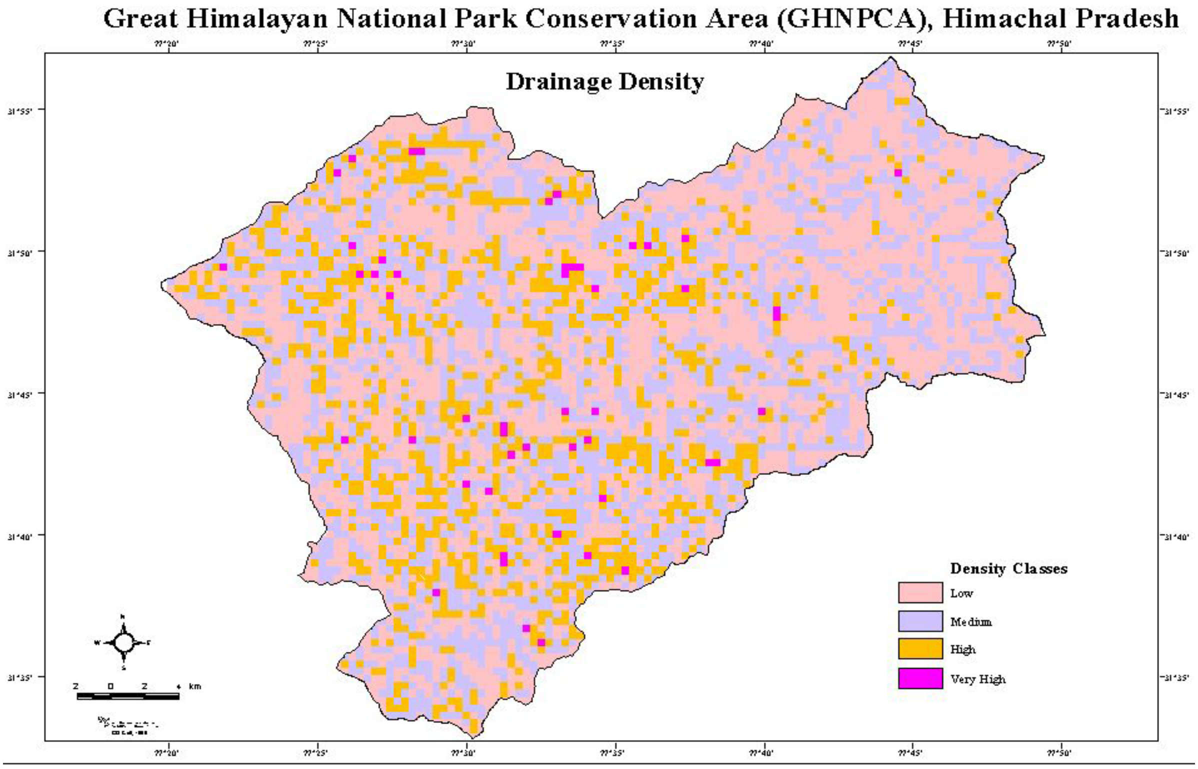
Drainage Density (D.D): The water availability in any area is an important factor for the survival of any species. The study area seems to be homogeneous, but for precise analysis the drainage density was also prepared in ARC/INFO GIS domain. It serves the purpose to understand the water availability in the study area. The drainage density was determined from the following formula-

$$\frac{\text{Total no. of stream}}{\text{Total area}}$$

The relationship between drainage density and vegetation was observed. The highest DD was found within alpine scrub. It may be because of the presence of starting point of drainage system in the form of gully and rills, whereas the lowest DD was found in riparian forests because of a single river or drainage.

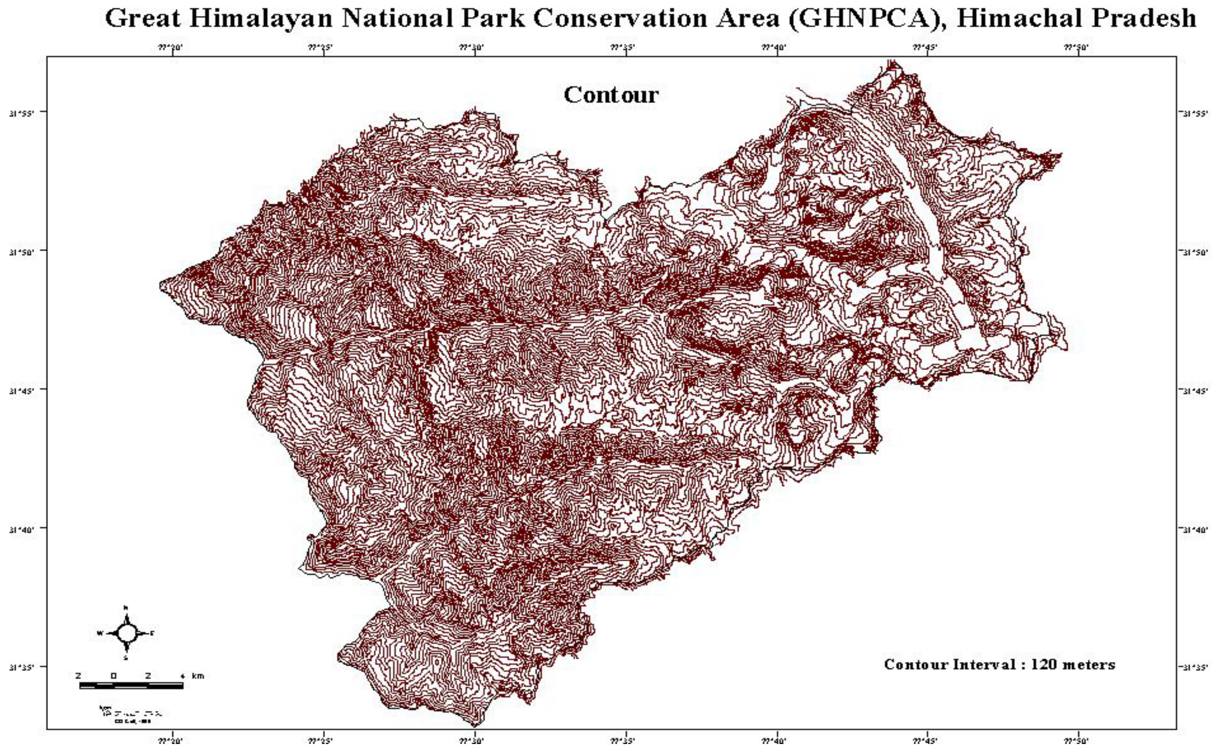
It was also observed that speciesarse vegetation was found in the high DD areas, whereas in low DD areas abundant vegetation was found and this may be due to combination of factors like slope, aspects, temperature and microclimatic conditions. The map is shown in Fig 4.4

Fig 4.4



Contour: Relief is represented on the topographic maps by the contour lines. A contour is a line drawn through points having the same altitude. The shoreline at sea level is called the contour of zero elevation. Contour has been digitized through the topographic maps in GIS domain in the form of line coverage representing elevations in the study area. The altitude in the study area varies from 1344m minimum near Seund to maximum of 6248m at a peak in the east of the study area. The contours are not only the representative of elevations but also the main source of depicting slope, aspect and DEM. The contour interval or 120m was considered because minimum mapable unit (one hectare) was taken into consideration. The map is shown in Fig.4.5.

Fig 4.5.



Aspect: Aspect is one of the important forms of land. It is a direction to which the slope faces. The effects of these are direct with other factors like temperature, and altitude reflects the density/growth of vegetation and associated wildlife abundance. The aspect map was derived initially from contours (line coverage) to slope categories and than grid image. The map was generated according to slope angles in eight different directions. Aspect categories were decided according to species Himalayan Musk Deer (*Moschus crysogaster*) and Western Tragopan (*Tragopan malanocephalus*) preferences based on the sighting data, (K. Ramesh *et al* 1999 and Vinod *et al* 1999).

The maximum area was 237.1 km^2 found in North direction whereas the minimum area 119.4 km^2 lies in the East direction. The aspect map is shown in Fig 4.6. The ASPECTSaccording to slope angles in different eight directions are given in Table 4.3. The aerial estimation of aspect is given in Table 4.4.

Fig 4.6

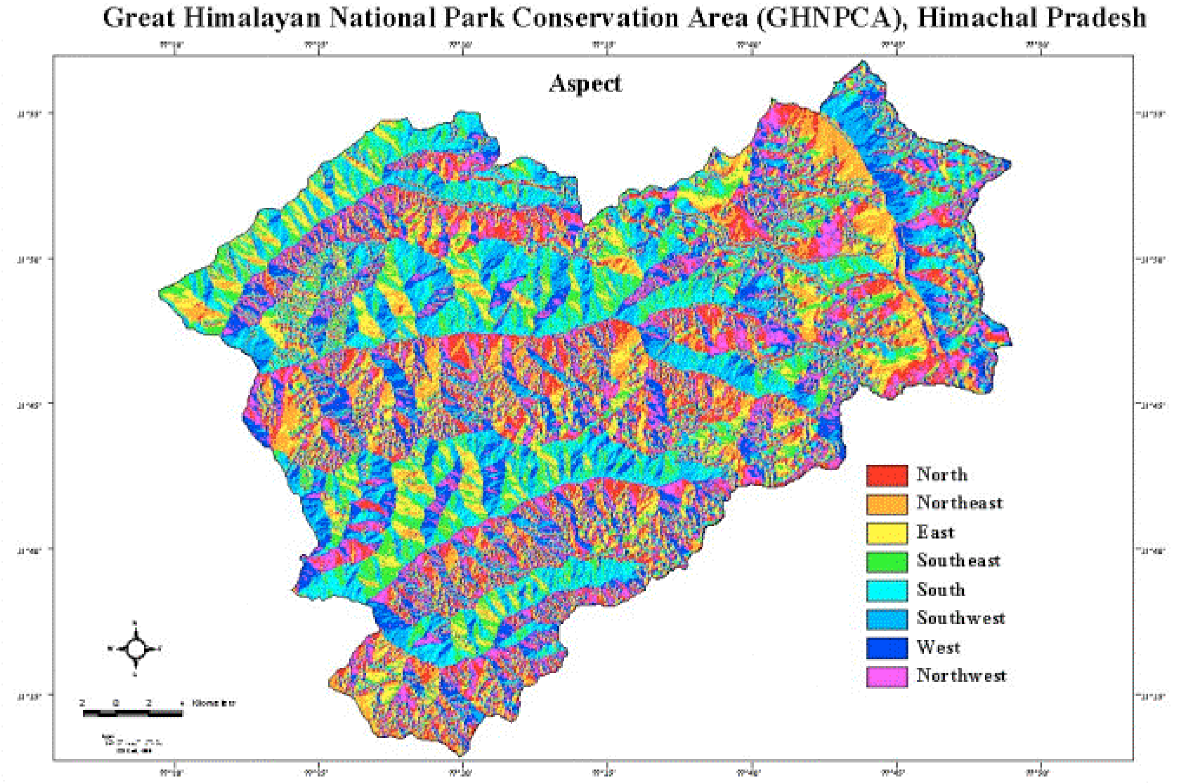


Table No.4.3 ASPECTS ACCORDING TO SLOPE ANGLES

Angle in Degrees	Directions
0-40	N
40-80	NE
80-120	E
120-160	SE
160-200	S
200-240	SW
240-280	W
280-320	NW
320-360	N

Table No.4.4 AREAL ESTIMATION OF ASPECTSIN THE STUDY AREA

Category	Area in km^2	Percentage
NORTH	237.1	20
NORTH EAST	125.2	11
EAST	119.4	10
SOUTH EAST	127.6	11
SOUTH	138.9	12
SOUTH WEST	151.7	13
WEST	141	12
NORTH WEST	130.1	11
Total	1171	100

Slope: Slope is often referred as the angle, which any part of the earth's surface makes with a horizontal datum, is another precious parameter of land. In this study, the slope map was derived from the contour map. Slope categories were decided according to species (Musk Deer and Western Tragopan) preferences based on the sighting data, (K. Ramesh *et al* 1999 and Vinod *et al* 1999). The slope and aspect map was further used for habitat analysis. The slope categories are given in Table 4.5. The aerial estimation of slopes is given in Table 4.6. The slope map is also depicted in Fig 4.7.

Table No.4.5 SLOPE CATEGORIES

In degrees

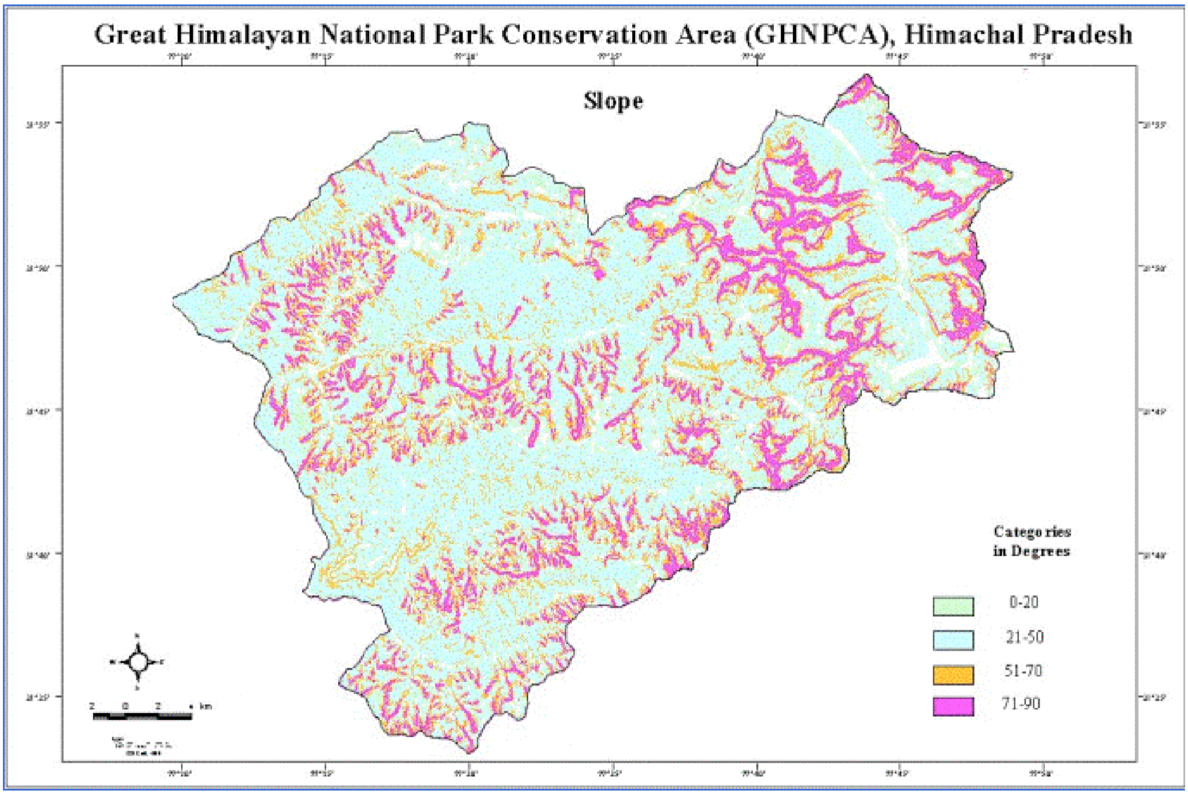
0-20	Low
21-50	Moderate
51-70	High
71-90	Very High

Table No. 4.6

AREAL ESTIMATION OF SLOPES IN THE STUDY AREA

Category	**Area in km^2**	**Percentage**
0-20	221	19
21-50	623	53
51-70	187	16
71-90	140	12
Total	1171	100

Fig 4.7



Shape: Slope may take a variety of forms. Slope may consist of several elements i.e concave, convex, straight and complex. For the characterization of topographic surfaces the methods given by Falcidieno and Speciesagnuolo, 1991 was used.

The shape was generated through Digital Elevation Model (DEM) in ARC/INFO GIS domain and categorized into three categories i.e. convex, concave and flat. The aerial estimation for the shape of study area is given in Table 4.7.

Table No. 4.7

AREAL ESTIMATION OF THE SHAPE OF THE STUDY AREA

Shape	Area In km^2	Percentage
Flat	0.04	0.003
Concave	604.61	51.63
Convex	566.35	48.36
Total	1171	100

Digital Elevation Model (DEM): To generate a DEM, a 120m contour interval was used because in higher Himalayas contours seem to be merged because of escarpments/cliffs. Survey of India toposheets also depicts the 40m interval because of same difficulty. Generally, for wildlife and forest management, the minimum mapable unit is one hectare. Accordingly, 120m contour interval was considered. In ARC/INFO domain using Topogrid module a hydrologically correct grid of elevation from line and polygon coverages was generated. In this, contour data was used to generate a generalized morphology of the surface based on the curvature of the contours and also used as a source of elevation information. Stream data was used because they are powerful ways of adding additional topographic information to the interpolation, further ensuring the quality of the output DEM. Topogrid module is an interpolation method speciesecially designed for the creation of hydrologically correct digital elevation model from well selected elevation and stream coverage's (GIS by ESRI 1994). The interpolated lower to higher values is shown in Fig 4.8. The description of visually interpreted units of geomorphology is given below; with aerial estimation in GIS shown in Fig 4.9.

Fig 4.8

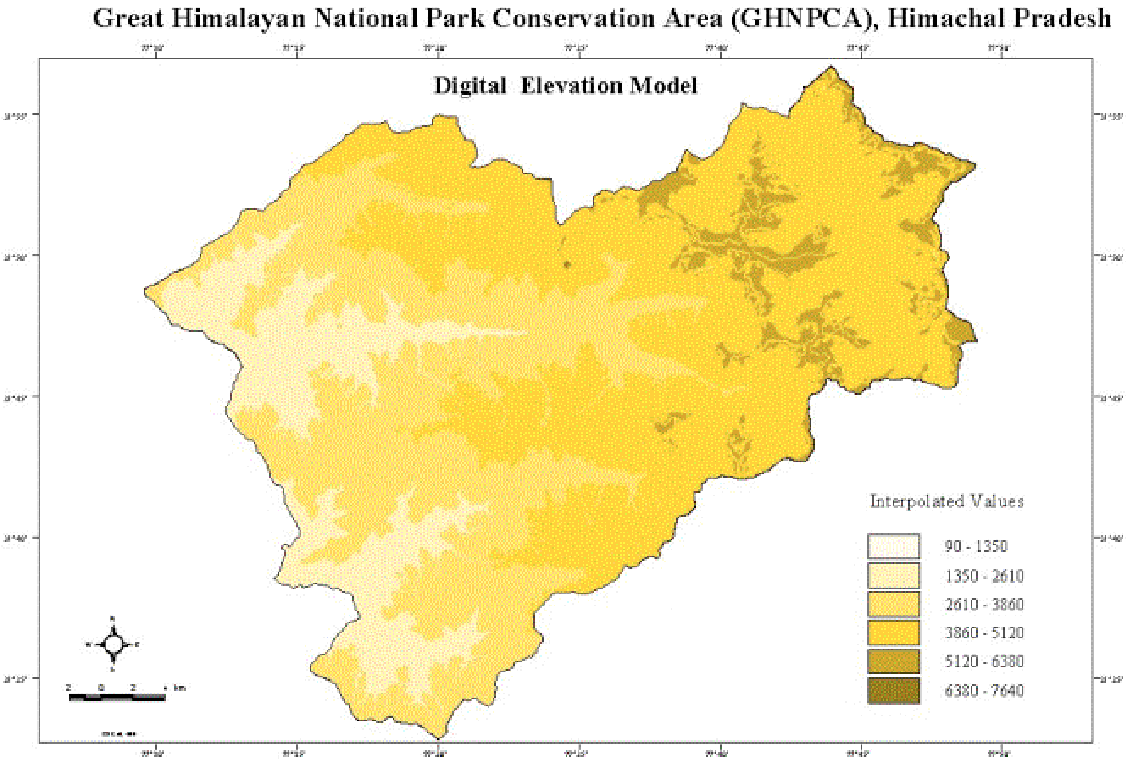
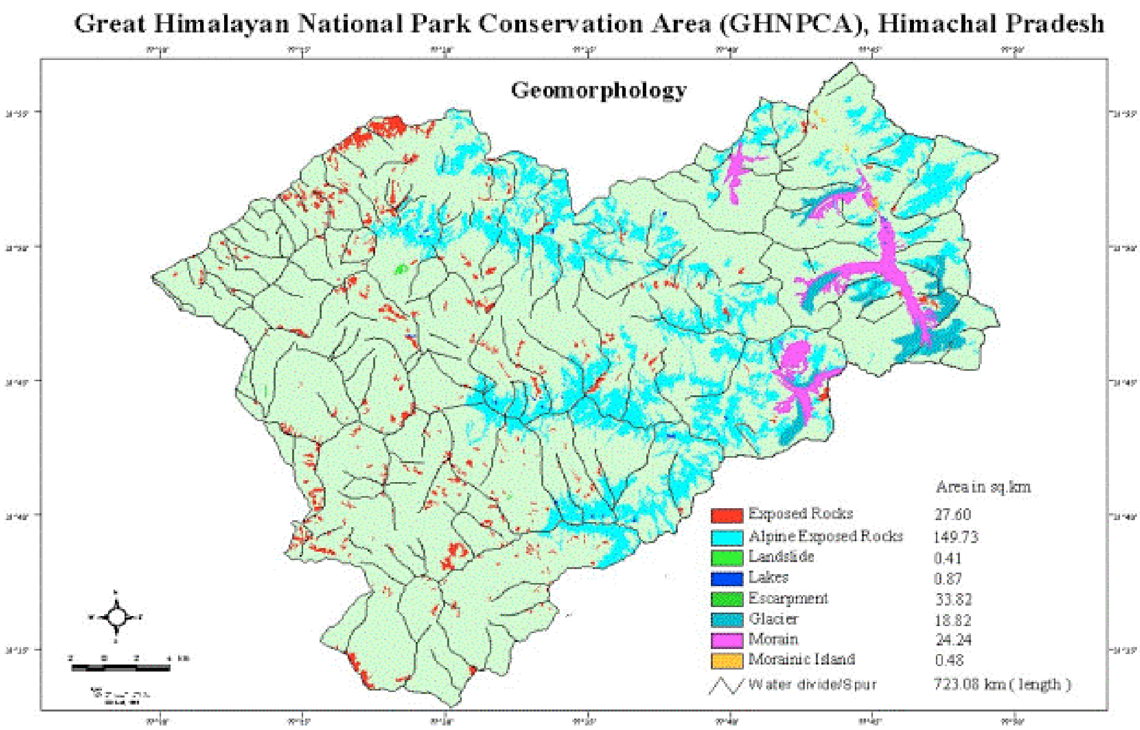

Great Himalayan National Park Conservation Area (GHNPCA), Himachal Pradesh
Digital Elevation Model
Interpolated Values
90 - 1350
1350 - 2610
2610 - 3860
3860 - 5120
5120 - 6380
6380 - 7640

Fig 4.9


Great Himalayan National Park Conservation Area (GHNPCA), Himachal Pradesh
Geomorphology
Area in sq.km
Exposed Rocks 27.60
Alpine Exposed Rocks 149.73
Landslide 0.41
Lakes 0.87
Escarpment 33.82
Glacier 18.82
Morain 24.24
Morainic Island 0.48
Water divide/Spur 723.08 km (length)

4.7.1.2. Geomorphic Units

Exposed Rocks: The rocks laying under subtropical - sub-alpine region are considered as exposed rocks. These were well distributed in all the three valleys in the study area along with few areas of Parvati valley also. The rocks are well exposed in the middle portion of the park and are maximum in lower altitude zones of the study area. They cover an area about 27.60 km^2.

Alpine Exposed Rocks: The area above 3600m to 4500m, where slope factor and mass movement was rapid was considered alpine exposed rock. The rocks were well exposed in the higher elevations up to the last limit of the park. The area was estimated to be about 149.73 km^2 in GIS domain.

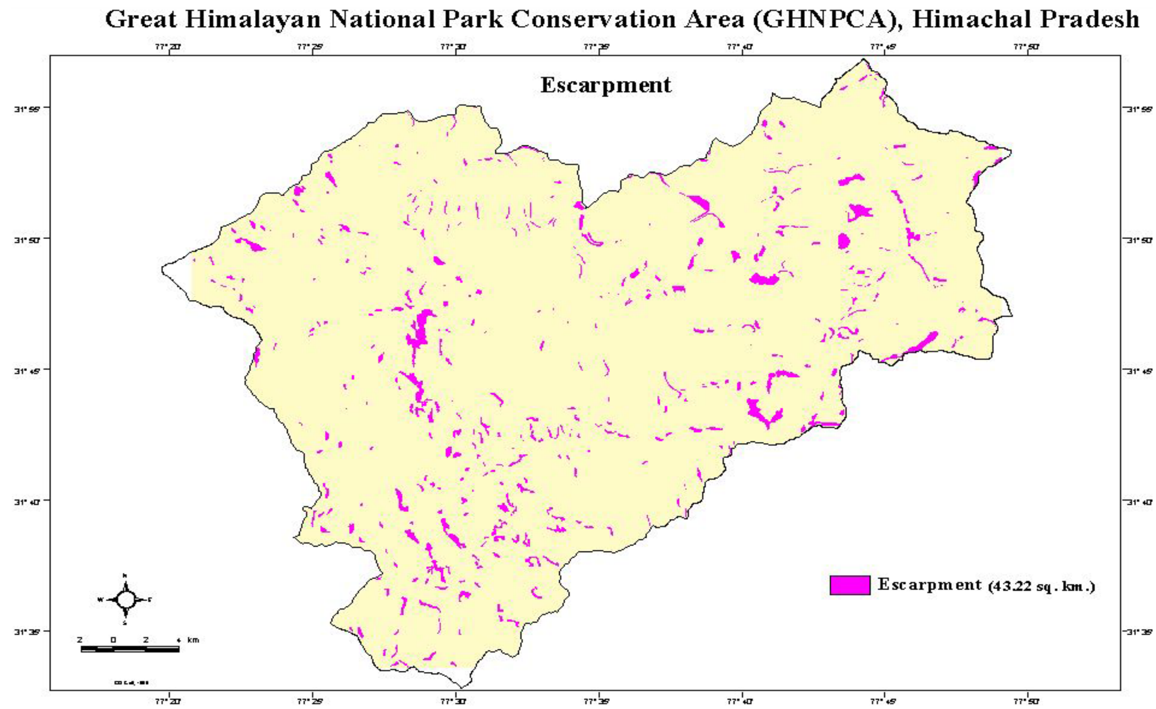
Landslides: Landslides are purely the results of slope failure, may be natural (tectonic sensitivity, gravitation, seismic) or man made (road construction, grazing, blasting, tree felling and mining). In the study area the existing landslides were mostly natural, occurring frequently in the project area especially in the rainy season. The study area was higher in elevation and receives heavy rainfall which causes widespeciesread distruction and disruption. The areal estimation of landslides in the study area was about 0.41 km^2. As far as conservation is concerned, the landslides have a negative impact because of their destructive nature.

Glacier: The glaciers are the huge solid ice mass moving or retreating along the valley floor. The glaciation of the valleys has considerably modified the original topography, which has been sculptured by subsequent fluvial action. The glaciers, moraines and fluvoglacial deposits generally occur in this zone**.** The areal estimation of glaciers was about 18.82 km^2.

Lakes: In the study area almost all the Lakes might have formed due to glacial erosion. More than 25 lakes were observed from the study area lying in the higher elevations through visual interpretation. The areal estimation of all these lakes was about 0.87 km^2.

Escarpments: Very steep faces of the rocks and particularly consolidated sediments are given such names as cliffs, scarps, escarpments, precipices etc. They usually occur on cohesive and resistant rocks with sharp crested ridges. There are high angle slope areas used by several high altitude animals as their escape terrain. The total areal estimation of escarpments in the study area was about 33.82 km^2. The areal estimation of escarpments mentioned earlier is based on visual interpretation of IRS IB LISS II FCC 1993. Layer of escarpments were also digitized through Survey of India (SOI) toposheets and the area of the map was calculated through GIS was 43.22 km^2. The percentage difference between two areas was about 12.20% (Fig 4.10).

Fig 4.10



Moraine: Ridges and irregular deposits laid down by ice are termed as moraines. Some are associated with valley glaciers and others with ice sheets. Valley glacier makes lateral, medial, terminal and recessional moraines. The interpreted moraines may be lateral or medial moraines. The areal estimation of moraine was about 24.24 km^2.

Morainic Islands: Morainic Islands are infact uplifted debris above valley floor, carried out by glacier. When the glacier melts it leaves a large part of debris in the valley. The areal estimation of these forms was about 0.48 km^2.

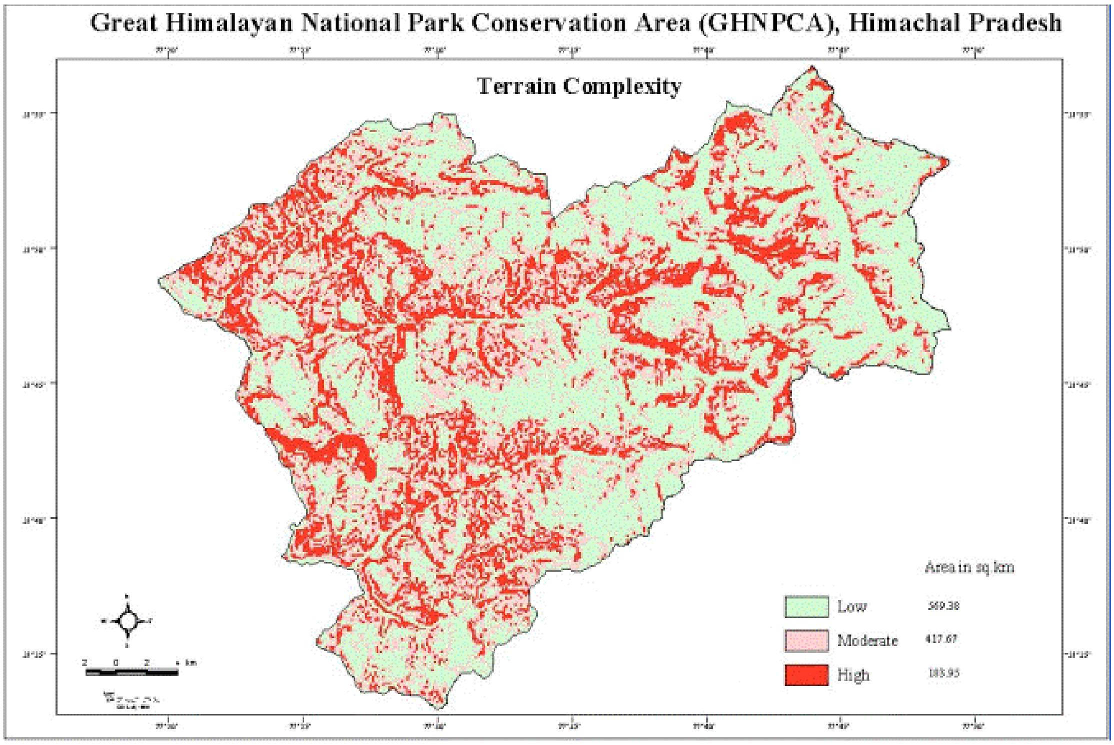
Waterdivide/ Speciesurs: In the Himalayas major ridges and valley floor impede fire movement. That is an important aspect as far as the management of grasslands is concern. The study area is having the boundaries north and north-east starting from Laru Dhar to Kasol Dhar, Drasal Dhar, Kaili Dhar, Plangcha Dhar, Rohni Dhar and Ori Dhar. In the east and south-east ridges from Pin Parwati Pass, Kokshane Peak to Gishu Pishu. South and south-west ridges from Gishu Pishu to Chakri, Sri Khand Mahadev, Dunga Thua, Mungradwari, Basleo Pass to ridges between Palachan Gad and Rohu Nal catchment along Chatri nala to Palachan gad Gushaini along Tirthan Khad to confluence of Kalwari nala and Tirthan Khad. West to north-west ridges, Thanigalo along Nuhara gad to Sainj Khad and along Sainj Khad to Seund, Bangidhar to Tiskana Thatch. Murda Thach to Laru Dhar Besides there are several other facets which form important parts of study area. The total length of the major water divides and prominent facets were calculated using GIS, was about 723.08 km^2.

Terrain Complexity: The terrain is characterised by numerous high ridges, deep gorges and precipitous cliffs, rocky crags, glaciers and narrow valleys. The terrain can be expressed in the form of slope, shape but it can also be expressed as low, medium and high complexities. The eastern part of the park is perpetually snow bound. Pleistocene glaciation has greatly influenced the topography of the region and has left extensive moraines, river terraces and hanging valleys (Gaston *et al* 1981). The terrain complexity was measured in GIS domain. This parameter was computed through DEM. For this appropriate contour interval of 120m was considered. The drainage, cliffs were also considered for better results. The whole idea was to capture variability as much as possible The Raster layer was considered for computation grid cell based variance for the entire spatial coverage. Though basic information of study area was there, but for further analysis it was vital to have some of the derived layers. The map is shown in Fig 4.11, and the areal estimation is given in the Table 4.8.

Table No.4.8 AREAL ESTIMATION OF TERRAIN COMPLEXITY IN THE STUDY AREA

Class	Area in km^2	Percentage
Less complex	565	48.24
Moderately complex	414.46	35.40
Highly complex	182.54	15.60
	1171	100

Fig 4.11



4.7.2. Geobotany

The study area reveals an interesting altitudinal pattern of vegetation types. A brief description of different types and their relationship are given in Fig 4.12 to Fig 4.17.

Pinus roxburghii **Forest:** These are found to be influenced by moderate slopes having concave form on southern and western facing aspects. They were generally observed over Rampur and Bandal formations with a low to medium drainage density, approximately 0.29% of the total area with moderate complexity.

Conifer Mixed with Broad Leaved Forest: These types occupy an area of 4.61% (33.21 km^2) of the total vegetation cover. The vegetation was growing predominantly over convex and concave forms (6.05% and 3.63%) respectively, influenced by the medium slopes. These are facing mostly east and north-eastern aspects. This vegetation is generally observed over Bandal and Rampur formations in moderately to less complexity with a medium to low drainage density covering approximately 4.61% of the total area.

Broad leaved Mixed with Conifer Forest: The vegetation was widely distributed in the study area especially on less to moderate complexity approximately 11.58% of the total area. In the study site the area of about 11.58% (83.44 km^2) of the total vegetation cover having convex and concave slopes in which they are dominantly speciesread on west and south-western aspect. This vegetation was generally observed over Rampur and Bandal formations with medium to low drainage density.

Riparian Forest: This type of vegetation was generally observed in valleys. Riparian forests were occupying an area of about 0.02% of the total area. Low slopes having concave to convex form over southern and south-western ASPECTSinfluence them. This vegetation was observed over Bandal granites with a less complexity over medium to high drainage density.

Secondary scrub: These were occupying an area of approximately 22.26 km^2 Steep slopes having concave forms on south-western and southern ASPECTSinfluence these. They were observed mostly over Bandal granite and Rampur formations with medium to low drainage density, covering approximately 3.09% of the total area, with moderate to high complexity.

Alpine scrub: This type was occupying about 16.34% of the total vegetative area. They are mostly restricted to concave and convex slopes 10.68 and 11.58 km^2 respectively. They were profound over south-western and southern ASPECTSand generally observed on Vaikrita and Jutogh group of rocks covering an area of 16.34% of the total area of vegetation with a medium to low drainage density, covering approximately 117.71 km^2 of the total area with moderate complexity.

Habitation/Agriculture/Orchard: Though this category falls under non-forest type but because of the resolution constraints in the data, the habitation could not be delineated as a separate unit. It is noticeable that the study area was having dominantly orchards with agriculture in the surroundings of habitation intermingling with natural vegetation (trees of fuel and fodder). This type was covering an area of about 3.54% of the total vegetation cover over dominant concave forms with east and northeast aspects. It was observed on Bandal granite followed by Rampur formation covering 3.54% of the total area with medium to low drainage density having less complexity.

Plantation: The vegetation type (mostly blupine) is occupying an area of about 0.02% of the total area mainly over moderate slopes with concave form in north-western aspect. Plantation was observed over Bandal granite, approximately 0.16 km^2 of the total area with less complexity and medium drainage density.

Temperate Broad Leaved Forest: In the study area the temperate broad-leaved forests were observed along valley/khadd/nalah influenced by drainage density that is why they were occupying areas with low, medium and upto the high drainage densities, approximately 10.27, 17.03 and 12.93 km^2 respectively. Moderate slopes also influence them, mostly the area is about 5.96% of the total vegetation. This type was occurring over predominantly concave form on south-western and south-eastern aspects. They were generally observed on Bandal and Rampur formations with moderate to less complexity.

Kharsu Forest: They are high altitude broad-leaved forests occupying an area of about 3.29%, and found to be restricted over concave and convex slopes covering approximately 23.7 km^2 having medium slopes on south-western and south-eastern aspects. They were observed on Rampur formation and Bandal granite approximately 16.76 and 6.39 km^2 respectively, with a medium to low drainage density approximately 3.29% of the total area with a less complexity.

Temperate Mixed Conifers Forest: This forest type is occupying an area of about 11.43% of the total area, and is influenced by moderate slopes having dominantly concave form on north-west and north-east aspect. The type was mainly observed on Rampur and Bandal formations with low to medium drainage density, covering approximately 82.39 km^2 of the total area with less complexity.

Temperate Grasslands: These grasslands were observed covering an area of about 4.40% of the total area. They were more restricted to medium slopes with concave form on south and south-eastern aspect approximately covering an area of about 31.7 km^2. They are observed over Bandal granites followed by Rampur formation with low to medium drainage densities in moderately complex areas.

Sub-alpine Mixed Conifer Forest: Occupying about 5.43% of the total area, having moderate slopes followed by lower slopes on dominantly convex forms followed by concave areas. They were observed pre-dominantly on north-western and western aspects. They were generally observed over Rampur formation followed by Bandal granite approximately covering an area of about 39.11 km^2 of the total area with low to medium drainage density in less to moderate complexity.

Sub-alpine Grasslands: These grasslands were occupying an area of about 3.09% of the total area, and were dominant over moderate slopes followed by concave form and convex form approximately the area of about 22.25 km^2. They were generally observed on south-western and southern aspects. They were observed mainly over Rampur formation followed by Bandal granite with medium to low drainage densities, and moderate complexity.

Alpine Grasslands: These are the dominant grasslands in the study area. The total area covered by this type is about 26.91% of the total area and is mainly influenced by concave form of slopes covering followed by convex form of slope approximately 139.94 and 53.95 km^2 area. The type was observed mostly on south-western aspect followed by north-eastern aspect. They were observed mainly over Rampur formation followed by Bandal granite with a low to medium drainage density and less complexity.

Slope versus Vegetation: Slopes were generally classified into four categories i.e. low, medium, steep and very steep. The slope angle and the respective areal coverages are given in Table 4.5 and 4.6. The dominance of vegetation over particular slope categories was observed and it was found that in lower slope category the maximum area covered by alpine grasslands was 32.40% followed by alpine scrub (14.48%), temperate mixed conifer (11.45%) and broad-leaved mixed with conifer (9.30%). On the moderate slope, alpine grasslands (26.19%) covered maximum area whereas riparian forests covered minimum area. Likewise in steep slopes again alpine grasslands were dominated (20.48%) and the plantation was minimum (0.01%). In the same way broad-leaved with conifers (31.70%) were found dominant on very steep slopes whereas riparian forest were found minimum (0.67%) on these slopes. Overall maximum area lying under moderate slopes was approximately 444.45 km^2, whereas the minimum area observed on lower slope category was approximately 181.67 km^2. As the lower slopes covering vegetation about 19% of the total area (1171 km^2) within the total vegetation (721km^2). The landuse/landcover covered by lower slopes is 25%. In the same way maximum area over moderate slope cover was 38% of the total area, of which 62% was covered by vegetation and landuse type out of the total vegetation area. On the other hand under very steep category is only 0.38% of the total area in which only 0.62% was covered by vegetation out of the total vegetation cover i.e. (721sq km^2).

Shape (form) versus Vegetation: It was observed that the maximum area covered by vegetation falls under concave form of slope i.e. by alpine grasslands (approximately 31.62%) followed by alpine scrub (15.09%) and temperate mixed conifer (13.84%). On the convex form, maximum area was covered by alpine grasslands (18.53%) followed by dry alpine scrub and broad-leaved mixed with conifer (14.62%). As a whole the minimum area covered by the riparian forest was 0.01% on the convex form. Likewise, in flat category only sub-alpine mixed conifer forests were found covering an area of about 0.04 km^2 which is 100% within the flat form of slope. Overall maximum area lies in concave category covering vegetation approximately (38%) within the total area in which 60% of vegetation has been covered by the slopes out of the total vegetative cover i.e. 721 km^2 whereas the minimum area found under flat category was approximately 0.4 km^2.

Aspect versus Vegetation: Aspect was categorized into eight categories/ directions. The maximum vegetation type was influenced by south-western aspect covering approximately 119.16 km^2, whereas the minimum area covered by the vegetation i.e. *Pinus roxburghii* (0.3%) on northern aspect. The overall minimum area was found under total vegetation in north aspect (3%) approximately 32.2 km^2. The maximum area covered by alpine grassland was (30%) followed by alpine scrub in SW aspect. On the eastern aspect maximum vegetation found on alpine grassland followed by broad-leaved mixed with conifer and temperate mixed with conifer whereas on south-eastern aspect, maximum area was covered by alpine grassland followed by dry alpine scrub. On southern aspect the alpine grasslands were dominant. On western aspect the same alpine grassland were dominating followed by alpine scrub. The northwest aspect was dominated by temperate mixed conifer (24.49%) followed by alpine grassland (19.50%).

Drainage density versus vegetation: Drainage density was classified into four categories i.e. low, moderate, high and very high. The dominance of vegetation type was observed in each category. On lower density the maximum area was covered by alpine grassland (approx. 29.91%) followed by the alpine scrub and temperate mixed conifer. The minimum area was covered by the *Pinus roxburghii* (0.38%). Under the moderate drainage density, the maximum area was covered by the alpine scrub (25.54%) followed by the alpine scrub (15.70%), whereas the minimum area was covered by the vegetation in this category is riparian (0.03%). On the higher drainage density the maximum area was covered by alpine grassland (25%) followed by the alpine scrub (20%), whereas the minimum was covered by riparian (0.02%). Under the very high category the alpine scrub (28%) were dominated followed by the alpine grassland (25%). The minimum area covered by riparian forest was 0.12%. The correlation between vegetation and drainage density indicated that the alpine scrub has highest drainage density (27%) and riparian forest (0.02%) had the lowest drainage density. Generally the maximum area covered by the vegetation found over lower drainage density i.e. approximately 277.76 km^2, which is 38% of the total vegetation i.e. (721 km^2) whereas the minimum area lies in the riparian forest (0.12%).

Terrain complexity versus vegetation: The study area was divided into three categories for the study of complexity, namely low, moderate and highly complex terrain. In the less complex terrain the maximum area of vegetation (41%), of which alpine grassland are (32%) followed by alpine scrub and temperate mixed conifer. The minimum area of vegetation was found in highly complex areas (19%) in which riparian was (0.01%). Under the moderate complex zone, the maximum area was of alpine grasslands (25.79%), whereas the minimum area of vegetation found in riparian forest (0.01%). The alpine grassland (25.41%) followed by the alpine scrub (16.14%) dominates the highly complex zone. Overall Maximum area found under less complex zone i.e. (approximately 41%) of the total vegetation cover and 25% of the total area i.e. 1171 km^2), whereas minimum area observed in highly complex zone i.e. (19% of the total vegetation cover).

Geology versus vegetation: The study area is consisting of mainly following fomations/groups, which were exposed on the study sites viz. Rampur formation, Bandal Granite, Chail Group, Jutogh Group, Vaikrita Group and Haimanta Group. Rampur formation has maximum exposers and covers the most of the area by vegetation, which was about 312.61 km^2. The maximum area under the vegetation on this formation was alpine grasslands (27.39%) followed by the broad-leafed mixed with conifer. The Bandal granites were the second largest formation covering most of the vegetation. The maximum vegetation in this was covered by broad-leafed mixed with conifer approximately 18.96% followed by the temperate mixed conifer. The riparian forest (approx. 0.07%) covered the minimum area. On Chail group the maximum area found under alpine grassland was 49.47% followed by the alpine scrub (36.48%). The minimum area covered by the vegetation in this group was temperate broad-leaved forest (0.07%). Under the Jutogh group the maximum area covered by alpine grassland was 57.98% and the minimum area covered by the subalpine grasslands, whereas under Vaikrita group. Alpine grassland were covering most of the area and minimum area covered by the alpine scrub. The Haimanta group found above 5000m altitude that is why no vegetation was observed in this Group. The maximum area of vegetation found in Rampur formation, whereas minimum area of vegetation found under Vaikrita Group.

Fig 4.12

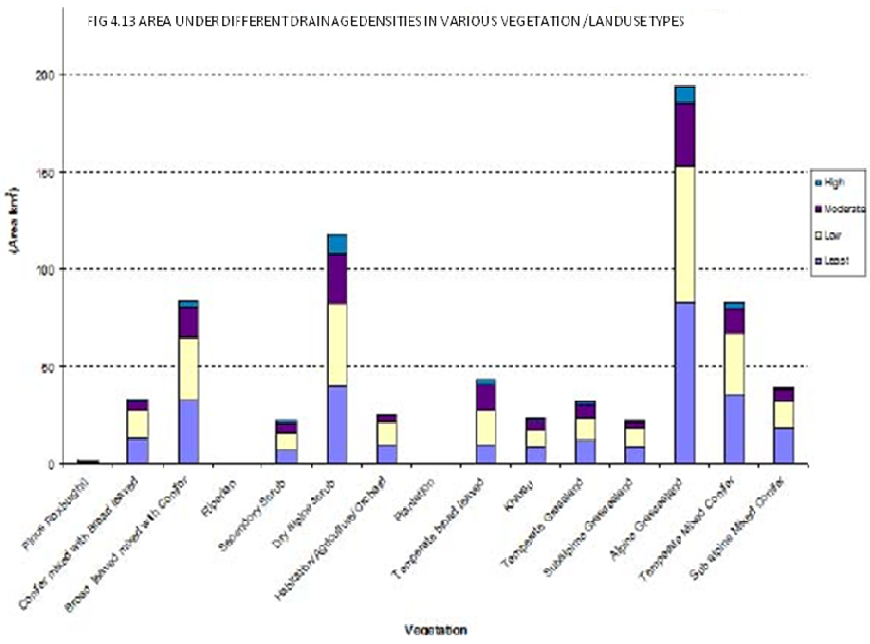


Fig 4.13

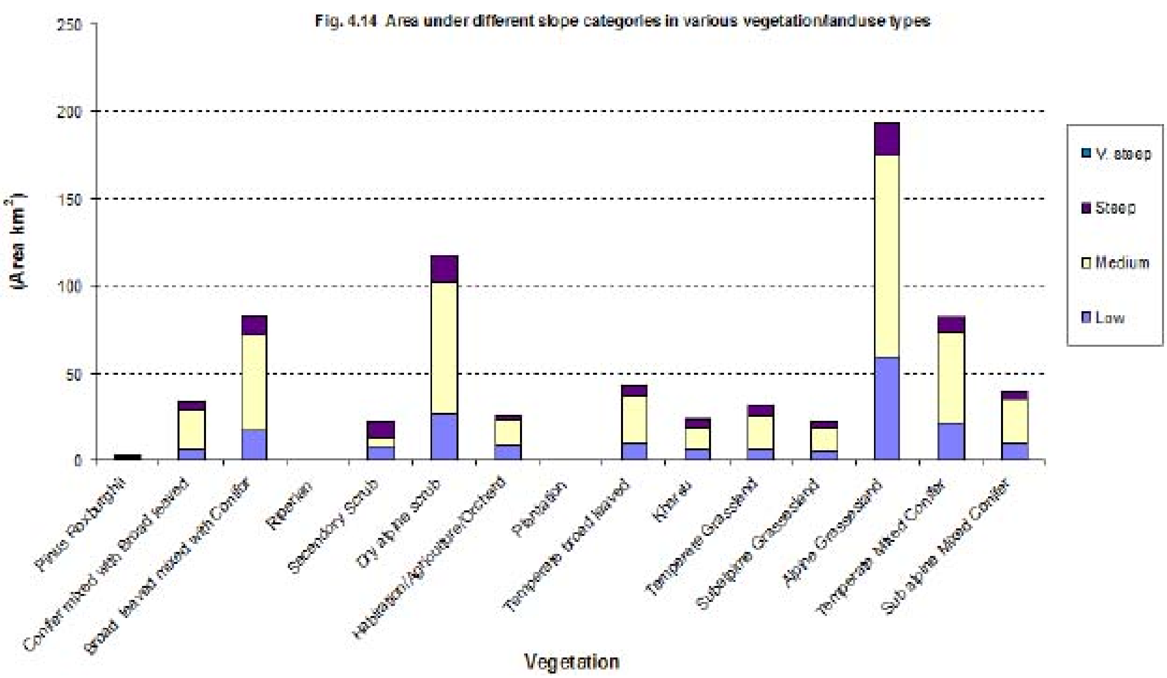


Fig. 4.14

AREA UNDER DIFFERENT SHAPE CATEGORIES IN VARIOUS VEGTATION/LANDUSE TYPES

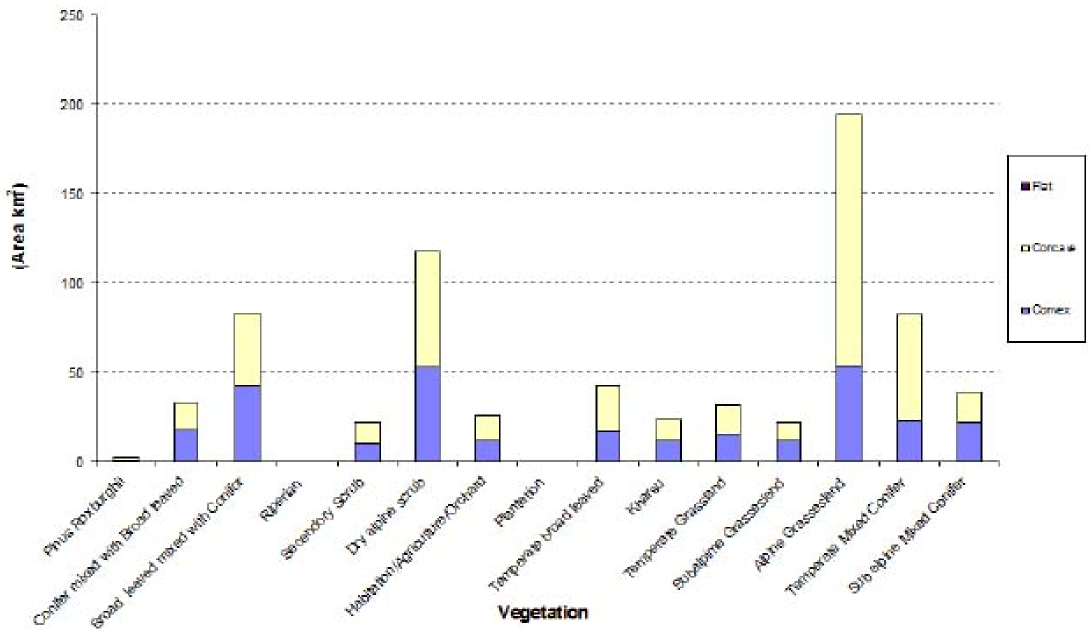


Fig 4.15

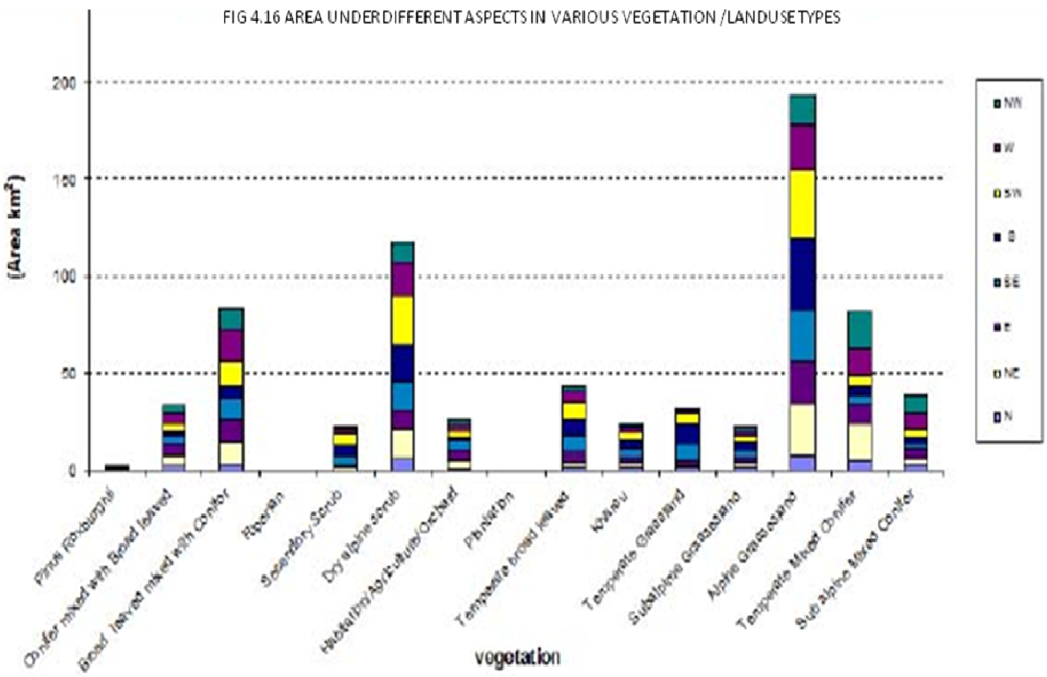


Fig 4.16

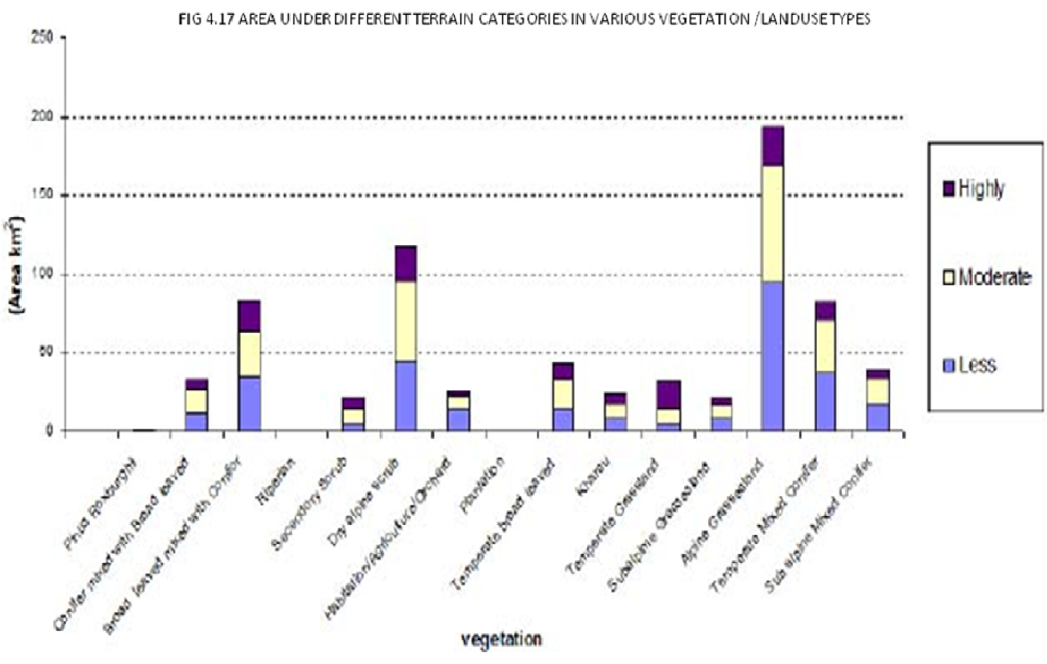
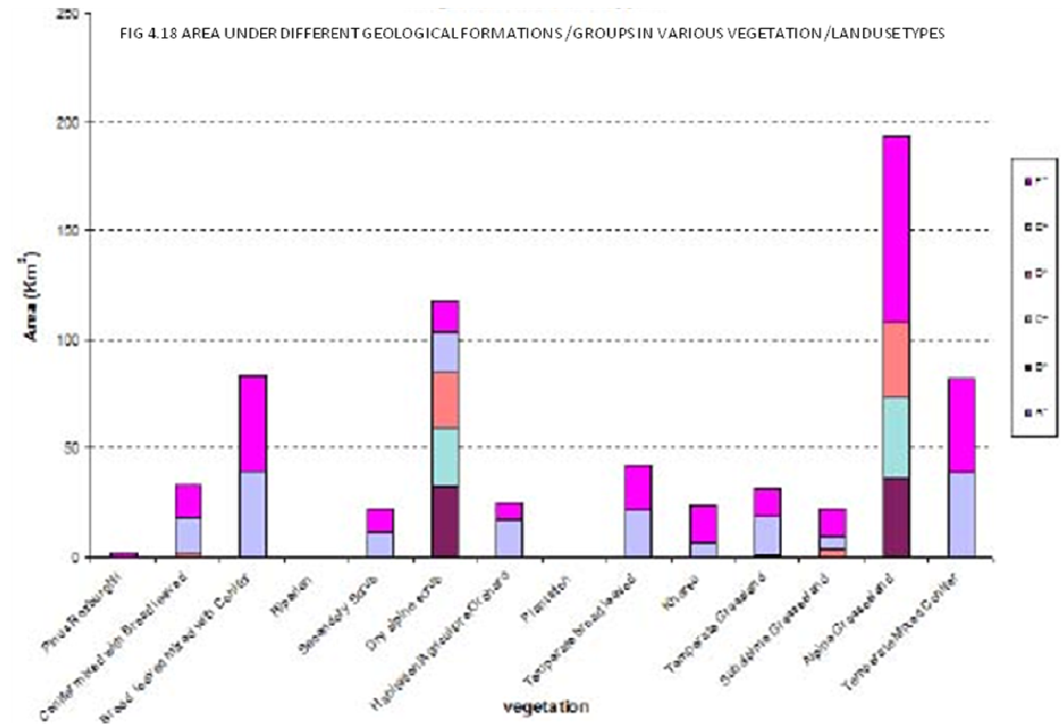


Fig 4.17



4.8 DISCUSSION

4.8.1. Geomorphology

Much of the observations in this study are based on visual interpretation with convergence of evidences. It also includes the opinions of experts. In the park the exposed rocks may be result of changing topography (Himalaya is tectonically sensitive) and may be because of mass movements from the area because of slope effect. They are infact good habitat for prey and predator species. The alpine exposed rocks are seasonally full of alpine grasses and are used as grasslands by many Himalayan animal species along with domestic sheep and goat. The study area faces an acute problem of erosion including glacial erosion. In the Sainj valley, Negi, (1996) reported that during heavy rains in 1995 between Shakti and Maror the turbulent Sainj Khad river caused toe cutting at numerous places on the banks resulting in occurrences of several landslides. The escarpments found in the park are faulting form/ fault cliff, some of which are erosional, because of weathering, abrasion and both. Escarpments were also formed on movement of ice in the past, which greatly steepened the valley walls. The presence of visually interpreted escarpment and digitized escarpment, through toposheets reflects the tectonic and the ecological sensitivities of the area. Vegetation and wildlife losses due to these phenomena are aggravated through natural causes i.e. snow avalanches, high rainfall, faulting etc, and the man made activities like, construction, overgrazing, tree felling etc.

The water divides and speciesurs distinguish the major and minor watersheds. Some watersheds are confined within the landform whereas several landforms also can be included in a large watershed. The total length of water divide/speciesur depicts the combination of several landforms within the park. The speciesur/divide control the microclimate of the area, with combination of altitude, temperature, slope, solar radiation received by the site, for vegetation growth. It was observed that southern parts are warmer then northern parts, which may also influence the intensity of disturbances because of different slope conditions. The water divides and speciesurs usually act as fire breaks / fire lines at any site. Hemstrom (1982) in Pacific North- West USA has also reported, that major ridges and valley bottoms impede fire movements. In the study area grasslands was observed to be maximum (37.76%) of the total vegetation (excluding habitation/agriculture/orchards). It means the grazing land/ pastures would be affected most if any change occurs in landscape topography due to of avalanches, natural phenomena or even by manmade interventions.

As far as the terrain complexity is concerned, although it is derived layer through DEM but this conveys a meaningful pattern, especially where the areas are highly complex like GHNP, which combine several landscape units. This method is being used in several RS based studies. The total glaciated zone and landforms within it, covers more than 16% of area. In the north-east portion, especially the upper reaches of Khandadhar in Jiwanal, Saketi in Sainj and Tirth from Tirthan valley, the topography is round to sub – round because of glacial action.

The process of glaciation, which starts with accumulation of snow on valley heads which gradually coalesce. Mostly valley glaciers were delineated through interpretation because they seem to be following the paths of a single stream. It was observed by the Dyson (1962), that a valley glacier may be a single ice stream or it may consist of a main stream and several tributaries similar to a river system. In the study area the modified landform by glaciers, have been visually observed viz. glacial lakes, moraines, U shaped valleys, hanging valleys etc. Moraines were observed in the study area particularly from the Parvati valley, whereas U shaped and hanging valleys were observed during ground truth from all the valleys in the study area. A hanging valley is a tributary to a main valley, which is deeply scoured by the glacial ice, leaving the tributary valley hanging above the main valley. In Sainj valley between Bah to Maror on the opposite side of river the best examples can be seen. The valleys made by glaciers were characterized by U shaped Profile, broadly carved rock walls, polished and grooved by ice abrasion. Tributary valleys usually enter at levels considerably above the main valley floor. All these features were vary well developed in all the valleys of national park. The glacial lakes were also interpreted in GHNPCA, especially at higher reaches, which depicts their origin is related to the former presence of the glacier. In the study area rounded to sub rounded topography depict the presence of glaciations in the past, and now the cirques, which usually give birth to the glacial lakes. The selective erosion of the softer horizons causes these formations. Through interpretation few lakes seem to originate by the moraine dammed basins (product of glacial retreat) (Campbell, 1914), Kettle lakes (Ogilvie 1902) are swampy depressions within the ground moraines. These areas may be the good habitat zones for high altitude species and of-course may be the suitable areas for migratory birds.

Moraines were interpreted and observed in north-east especially from the Parvati valley area. These glacial forms can be interpreted and observed by their size, shape, orientation and extension at the valley floor. Moraines may be of different kinds concentrated on certain lines (Small, 1970). When two valley glaciers meet together they form a large one (Medial moraine). In the study area the mixing of two valley glaciers, can also be observed through satellite imageries, which depict the presence of lateral and medial moraines. Beside this, at the margin of the glaciers the localized deposition of rock debris might be end moraine, but all these units cannot be interpreted separately. Therefore the entire unit was interpreted as moraine. According to Flint, (1957) the wide speciesread distribution of moraine indicates general glaciation. Actually the limits of moraines indicate the approximate extent of the glaciated area. These may form important sites for high altitude species especially for migratory birds, depending upon their suitability. It is a fact that the units interpreted in the glaciated zone lie in the inaccessible areas of higher reaches of Parvati valley. On the basis of visual interpretation of shape, size, and orientation of the forms, it is assumed that characteristics of forms resemble with drumlins/eskers. According to Lougee (1956) when ice recedes, the delta is left standing as a sinuous ridge in the middle of the valley called esker. On the other hand by Small

(1970), eskers can be long, narrow ice contact ridges sometime divided into branches, are best developed in low relief areas along valley courses. All these characteristics are more or less matched with interpreted form *viz.* Moranic Island.

For integrated studies the geomorphology can be treated as one of the parameters, because various landforms are the result of intersecting causes. Wildlife species make use of several habitats; many species have wide range of topography and vegetation. That is why under landscape it is important to study the landform with vegetation for proper understanding of wildlife distribution and management.

4.8.2. Geobotany

In geobotanical studies the relation between lithology and vegetation was observed through overlay analysis and it was found that the minimum vegetation growth was over Jutogh formation. It is noticeable that overlay analysis considers the spatial extant and areal estimation within the overlays. The minimum percentage of vegetation was in sub alpine about (0.28%) on jutogh group. The group was composed of garnet-biotite, schist and gneisses along with quartzite**.** Whereas, the maximum vegetation cover was found on the Rampur formation composed of quartzite and metavolcanics i.e. alpine grasslands cover about 27.39% of the total area. It was observed that the maximum percentage of Chirpine was found in the Rampur formation with influence of southern aspect and lower altitudes. Other studies have also reported these observations. For example, Dhar and Jha (1978) found chirpine on terraces/piedmont deposits derived from sandstone and shale, while studying geology and distribution of plant communities in Dharamsala area of Himachal Pradesh. The importance of geology in the study of forest vegetation in India was recognized as early as 1921 by Troup who recorded that the effect of geological formations in determining the local distribution of the blue pine on mica schist and chirpine on quartzite, below Bandal in the Tirthan valley.

In this study the Khasu forest and subalpine mixed conifer (fir and speciesruce) was found maximum in the upper reaches of the Rampur and Bandai formations composed of Quartzite with metavolcanics and Granites. Here soil was fertile with higher humus. While studying in Dhuladhar range Dhar and Jha (1978) observed, that this range was composed of gneissose granite in maximum altitude, on weathering because of kaolinisation of the orthoclase, the rock becomes soft, deep fertile with high humus soil which supports the Kharsu oak, speciesruce and fir. Riparian forest was also found especially distributed only on the Bandai granite but certainly it is not only influenced by the lithology but also because of drainage and transpeciesorted material. Non-forest class i.e. habitation/agriculture/orchards were considered for analysis because of intermingling of the vegetal cover with the habitation. Though habitation was not directly related to the litho units, but slope, aspect, drainage and shape might play important role in distribution of this non-forest category. Though no marked relationship was observed while correlating geology with vegetation, but through this study it was realized that there are also other factors controlling the vegetation growth in the forms of topographic features (slope, aspect, shape, drainage density, terrain complexity etc.). This fact was observed by the earlier studies by Warner *et al*, (1991) while analyzing remote sensing geobotanical trends in Quctico Provincial Park, Ontario, Canada, using Digital Elevation Data. They found an increase in the deciduous species growing on mafic lithologies. They also found that north facing, cool sites underlain by mafic lithologies have the highest conifer components. The mafic lithologies were found to support vegetation similar to that growing over granite for north facing slopes steeper than three degrees. They also observed that aspect, drainage and the lithology; all influence the forest cover in Quantico. Aspect was an important parameter, while determining the geobotanical relationship.

Mohan and Puri (1956) established the relation between development and succession of vegetation with geological and soil features. He observed the striking habitat difference on scarp and dip slopes. The *Pinus roxburghii* is found stable over scarp slopes, which are steep and precipitous while on the dip slopes, the other conifers with broad-leaved communities were found, which are gentle and topographically stable sites. This relation may be understood in the context of aspect. In the study area although the rocks have many folds and are tectonically aligned but the general alignment of the ranges is NW-SE (Puri 1950). It was observed in field that maximum percentage of *Pinus roxburghii* was in the southern and western aspect along with maximum percentage of temperate, sub alpine and alpine grasslands. It may be because the sun illuminates the scarp slope portion, as the rocks of the study area generally dip towards ENE/NE. The NE & E aspect had the maximum vegetation composed of conifer and broad leaved forest vegetation possessed. The growth of vegetation on NW aspect may be because all the river systems are flowing from NE/E to SE/S direction except Parvati (which flows initially towards north then turns towards west and afterwards south). Generally, they are making NW aspect with combination of north, north-east by erosion in the valley portions in the study area, which may further be influenced by the microclimatic factors as far as vegetation growth is concerned. In the study area moderate slopes were observed on the most preferable sites for the vegetation growth with concave shape and its forms. Most of the flat areas were under snow and the absence of vegetation. This also indirectly reflects that the flat/rounded/subrounded topography might be under glaciation.

Slope studies are generally quantitative (Savigear, 1956 and Young, 1964). So to define the slope in the form of concavity, convexity and flat areas now software is available in GIS domain for characterizing the topographic surfaces. This has also been reported by the Falcidieno *et al* (1990) and Lin and Perry, (1982). While seeking relation between drainage density and vegetation, it was observed that the alpine scrub were on higher drainage density (DD), which may be because of the nature of catchment area and lower DD was found in the riparian forest. The moderate slopes (21^0-50^0) were having the maximum vegetation followed by lower angle slopes, while correlating with vegetation. In the less complex areas, alpine grasslands were dominant which may be due to modification in topography during glaciation. Wherever in the study area on lower altitude, terrain was found less complex it was realized that the area was covered with forest. On the other hand, there was less vegetation on highly complex convex form, as far as the spatial distribution of vegetation is concerned. In geobotanical studies soil play important roles (Puri, 1950a and Mohan and Puri, 1955). In the Himalayas soils are *in-situ* in nature, wherever the landform elements are covered by the secondary soil as stated by (Puri, 1955), their physical and chemical nature varies greatly with original rock material and nitrogen. It was observed in the study area, wherever the soils were sandy the succession of chirpine and blue pine community were observed. On more fertile soils over little higher ridges, the Blue pine, Deodar, Abies with *Piecia smithiana* communities were present. On fresh alluvium, there were riparian paches of *Alnus nitida* at Bathad, which grow up to 50 meters along nalas because of the same fresh alluvium. Near Shakti, patches of *Hippophae* species and *Myicaris* species were found comparatively at higher altitudes may be because of climatic variations with altitude and different soil materials deposited by the river.

The chirpine was found on the rock scree in the study area near Sairopa in Tirthan valley and near Seund in Sainj valley. Through visual interpretation of satellite images, it was observed that the alpine scrub was widespeciesread in the Parvati valley along stream on the both sides (Rawat, 1999 personal communication). In the study area, the conifers are also related to altitudinal zones. This fact is also supported by Puri (1950a) that *Pinus roxburghii* occurs at low altitude zone and on upper limits the silver fir is found, and in the intermediate altitude *Cedrus deodara*, *Abies pindro*, *Picea smithiana* accur, supported by data of foliar ash and CaO (Calcium Oxide) of tree species. The study reveals that in the case of Himalayas the vegetation is not only dependent on geology and landform with soil but is also controlled by the climate and altitude. The overlay analysis of land use /land cover with integration of remote sensing data (Geo-units) is useful.

5. HABITAT CHARACTERIZATION OF ENDANGERED SPECIES

5.1 INTRODUCTION

Habitat has been defined by Odum (1971), as a combination of landscape elements often characterized by vegetation, landform and hydrology. It is a place occupied by specific population within the community of populations. This includes wide range of components *viz.* soil, topography, water availability and cover characteristics (Smith, 1974). Theoretically, it has also been defined as the location that supports a population including speciesace, food, cover and other animals (Giles, 1978). According to Morrison *et al* (1992) habitat denotes the physical and biological environment, in which a species is usually found. Habitat forms crucial component for any living organism and any negative impact on the habitat generally affects the survival of the species. Hence, it becomes imperative to both characterize and monitor the habitat suitability for a species. Besides, being a central concept in ecology, the habitat plays an important role in wildlife management as it forms the basic link between the organism and its external environment (Mathur and Mukherjee, 1992).

What constitute a good habitat for a species is of fundamental importance to both wildlife ecologist and manager (Mathur, 1991). Every organism is dependent on its habitat for food, cover and other resources. Ironically, knowledge on the habitat requirement for the conservation and management of species particularly the endemic/endangered species, found in the Himalayan region is very limited. In order to fill the gaps in this direction, this study was conducted to determine the habitat suitability of two endangered species *viz.* faunas namely Western Tragopan (*Tragopan melanocephalus*) and Himalayan Musk Deer (*Moscus chrysogaster*). Western Tragopan occurs in low density and inhabits understorey forest in temperate region (McGowan and Garson, 1995). Muskdeer is a crepuscular or nocturnal animal of subalpine and alpine scrub areas, it is listed in Schedule 1 of Indian Wildlife (Protection) Act, 1972 (Anon. 1992). Although few ecological studies have been undertaken in the recent past on Western Tragopan (Islam 1982, Duke 1990 and Ramesh *et al* 1999) and Musk Deer (Green, 1985; Kattel, 1990; Harris *et al* 1993; Sathyakumar, 1994 and Vinod and Sathyakumar, 1999), there is still inadequate information available on these species, for developing species conservation plans. Moreover with the exception of Prasad (1993), who has mapped the potential habitat zones of Western Tragopan using remote sensing all other studies were based on ground methods that have limitations due to vast rugged terrain and limited resources.

With the advent of remote sensing and GIS (Geographical Information System), the ecological studies in recent past have began to use this tools not only for mapping the vegetation and distribution of animals, but also to predict the habitat suitability of species of interest (Roller, 1978; Mead, 1981; Worah *et al* 1989; Russell *et al* 1993; Roy *et al* 1995 Pabla, 1998; Dubey, 1999).

The habitat suitability/ quality refer to the ability of the environment to provide conditions appropriate for survival, reproduction and population persistance (Block and Brennan, 1993). The macro and micro habitat variables, which control the distribution and survival of species, form the determinants of the suitability for any species. Use of remote sensing to map vegetation and geomorphology for habitat analysis, is already in practice in India (Roy *et al* 1986, Unni *et al* 1986). Porwal and Roy (1991b) have attempted to gather understorey information using large scale aerial photographs and integrate it with ground data and terrain details. Spatial analysis of habitat of mountain Goral (*Nemorhaedus goral*) was carried out for Dhaulkhand range in Rajaji National Park (Roy *et al* 1995).

However, similar study based on Remote Sensing and GIS on Himalayan Musk Deer and Western Tragopan do not exist. This study aims to generate the Habitat Suitability Index for Himalayan Musk Deer and Western Tragopan.

5.2 HABITAT CHARACTERIZATION

The contribution of ecological components in habitat characterization strongly influences the overall decision making and natural resource utilization. Integration of spatial and field based information is an important process in habitat characterization. GIS technology, on account of its ability to compile and analyze spatially related data is a powerful tool for habitat management (Mayer, 1984, Hodgson *et al* 1988).

The Great Himalayan National Park Conservation Area (GHNPCA) supports a viable population of endangered species, especially Western Tragopan and Himalayan Musk Deer. Considering the conservation importance of these species their habitat characterization has been attempted in this study. Ramesh *et al* (1999) and Vinod and

Sathyakumar (1999) collected extensive data on Western Tragopan and Musk Deer respectively as part of the WII project and their sighting data has been used for habitat characterization.

5.2.1. Habitat of Western Tragopan (*Tragopan melanocephalus*)

In the Great Himalayan National Park Conservation Area (GHNPCA), a multidisciplinary survey was conducted in 1979-80 with particular emphasis on wildlife and the impact of human disturbance and livestock on the structure and composition of the vegetation (Gaston *et al* 1981). As a part of another multidisciplinary research project a study was conducted in Great Himalayan National Park, which concluded that GHNP is one of the two national parks in the world that supports a substantial population of endangered Western Tragopan (Collor and Andrew, 1988). This bird is locally known as "Jujurana" (King of Birds). It is endemic to North western Himalaya with a narrow range from Hazara in north Pakistan through Jammu & Kashmir to Garhwal in India, (McGowan in del Hoyo, *et al* 1994). It is been considered to be as a range restricted species (ICBP 1992). Very few studies have been conducted so far on Western Tragopan (Islam 1982, Duke 1990 and Ramesh 1999). Few surveys have been conducted for collecting the baseline information on status and distribution of this species (Islam, 1982; Ali & Ripley, 1983; Duke, 1990; Gaston, *et al* 1993; Prasad, 1993; Pandey, 1993; Ramesh *et al* 1999). According to Islam, (1982) these are distributed in temperate coniferous forest having sufficient understorey. These pheasants are generally observed to select specific habitat conditions. During winter, when the habitat is snow bound with little resource availability they move to lower elevations. This is the period when they face competition for food and other resources from other pheasants and are also affected by poaching incidences. Habitat requirement for Western Tragopan as described by workers are as follows:

- It inhabits speciesruce (*Picea smithiana)*, deodar (*Cedrus deodara*) and brown oak (*Quercus semicarpifolia*) forests at the upper edge of the treeline between 2500-3000 m in summer (Islam, 1982).
- In winter, it occupies the dense coniferous forest of northern aspect at 2000-2800m (Islam, 1982).
- It inhabits the dense vegetative cover (canopy cover) (Prasad, 1993).

- Western Tragopan was observed to use only three habitats; showing maximum use in mixed conifer and broad-leaved forest with Arundinaria undergrowth and sub-alpine Oak Forest in speciesring season (Ramesh *et al* 1999).

5.2.1.1. Field Observations

The inventory data, for Western Tragopan for the month of April to July 1997-1999 was used for the analysis. The territory of the bird was worked out to be about 500 m (Ramesh, 1999). On the basis of sighting evidences the minimum and maximum elevation has been determined to be between 2750m and 2890m. Likewise slope condition range has been considered as Min. 25^0 and Max. 45^0. Aspect use range was found Min. SE and Max. NW. Vegetation map was used determining habitat preferences.

5.2.2. Habitat of Musk Deer (*Moschus chrysogaster*)

Musk Deer is small, solitary forest ruminant, which occurs in relatively low densities. Isolation depends on the relief of the area. Families are prone to seasonal transformation, caused by reproductive strategy of the species, representing a continual series with gradual complication of their structure (Green, 1985). According to Green (1985) and Sathyakumar (1994) the Himalayan Musk Deer is threatened due to two major pressures namely:

- Large scale poaching for musk and
- Extensive habitat degradation.

Several studies on the habitat use by ungulates in the Himalayas have been carried out and information on altitude, aspect, slope, escape terrain, escapes cover, food availability, abundance and quality have been worked out. (Schaller,1977; Wilson, 1981; Green, 1985; Geist, 1985; Kattel, 1990; Chundawat, 1992; Sathyakumar, 1994).

Musk Deer is a crepuscular or nocturnal animal of the subalpine and alpine scrub. It inhabits between elevations 2500 m to treeline, approximately 3800 m in western Himalayas (Sathyakumar *et al* 1993). It rests all day in dense undergrowth of subalpine to alpine scrub. The biotic pressures in the treeline area affect its abundance and habitat.

The habitat, in which Musk Deer are found are summarized below, based on field observations and literature survey:

- They prefer non-exploited part of forest and tend to use *Abies/Betula* forest and avoid grasslands (Buffa *et al* in press).
- Musk Deer need dense shrub cover or undergrowth for shelter and food (Green, 1985).
- It was observed that Musk Deer are very selective feeders utilizing mostly easily digestible tree (birch & rhododendron) and shrub (dwarf rhododendron), flower and inflorescence and forbs during summer. They feed lichens in winter (Kattel, 1992).
- Musk Deer needs dense shrub cover or undergrowth for its shelter and food (Green, 1985).
- They feed on high cliff and rocky terrain especially in evening and night hours (Green, 1985).
- The most preferable vegetation types on the basis of sighting data were found in subalpine oak, fir, maple, subalpine scattered tree scrub, temperate scattered tree scrub and alpine scrub (Sathyakumar, 1994).

5.2.2.2. Field Observations

The data used in this study was collected during April and June from 1997 to 1999. According to Kattel (1992) during the study in Sagarmatha National Park Nepal, it was found that the average home range for males and females were 14 and 13 ha respectively. Harris *et al* (1993) observed on Tibet-Quinghai Plateau the home range of Musk Deer to be 17.6 ha in November. The Musk Deer was radio collared and locations were mapped using Global Positioning System (GPS). Green (1985) estimated winter home range for Musk Deer based on tracks on known individuals and found that it ranged from 15.0 to 31.6 ha. On the basis of above studies the average home range was calculated around 23 ha. The inventory data for Musk Deer for the month of April to June 1997-1999 was used for analysis (Vinod & Sathyakumar, 1999). On the basis of sighting evidences the minimum and maximum elevation were considered 3300m and 3760m. Slope condition range was considered as Min. 30^0 and Max. 55^0. The range of aspect was found Min. NE and Max. SW. Vegetation map (speciesecialized categories) were used for the habitat analysis i.e. interspersion and juxtaposition.

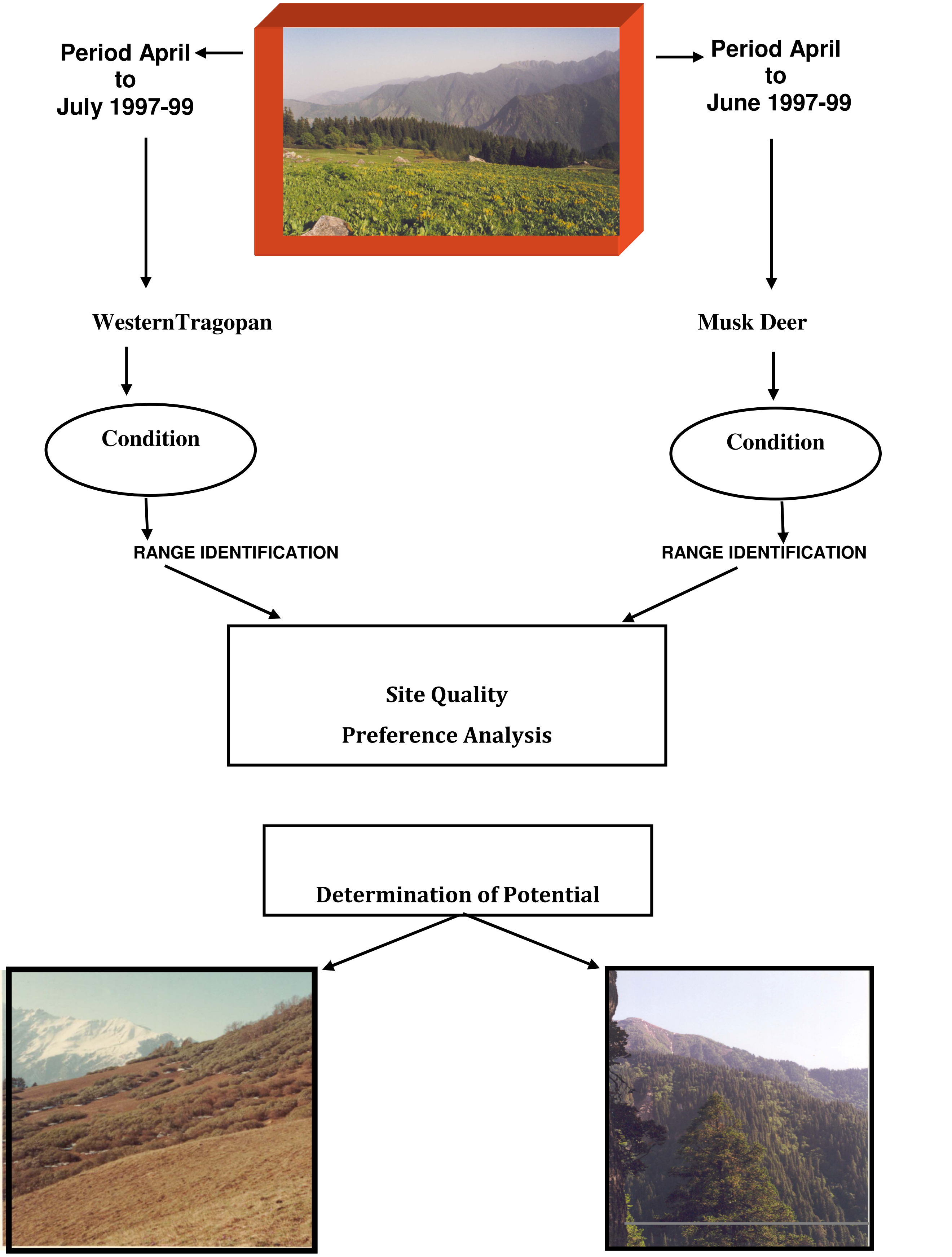
5.3 METHODOLOGY

Visual interpretation of IRS IB LISS II (with ground resolution of 36.25m) data was carried out for landuse/cover mapping. Ground truthing was done for preparing interpretation key as well as evolving a classification scheme for vegetation mapping. Other ground data and restrictive factors for animal species were incorporated based on inventory data. Contours were digitized and interpolated to develop a Digital Elevation Model (DEM) and a slope map was derived. Analysis of landscape by measuring interspersion and juxtaposition with restrictive factors was carried out using software routines developed in database management system interfaced with ARC/INFO software. Spatial modeling was done to determine the habitat suitability of Western Tragopan and Musk Deer. The overlay analysis of each parameter using buffer function was done. The calculation of the number of pixels of a particular value of a parameter (interspersion, juxtaposition, and buffer) was carried out. On this basis contributing % for each index was calculated.

5.3.1. Habitat Range Identification

The range identification map for Western Tragopan and Musk Deer have been developed using ground-sighting data along with slope, elevation and aspect values. In addition to this, weightages were assigned to various parameters, used for habitat characterization through overlay analysis (Refer Fig. 5.1).

Fig.5.1 DELINEATION OF SIGHTING AREAS FOR MUSK DEER AND WESTERN TRAGOPAN



5.3.2. Habitat Analysis

Geographic Information Systems (GIS) technology is playing an increasingly important role in conservation biology and wildlife management because it provides an efficient means for modeling potential distributions of species and habitats (Davis *et al* 1990 and Roy *et al* 1996*)*. GIS modeling of species-habitat associations is one form of land suitability analysis. The deductive approach extrapolates known habitat requirements to the spatial distributions of habitat factors. A habitat suitability index can also be calculated from the spatial configuration of a single data layer (Mead *et al* 1981).

Some end users of GIS analysis accept that the output products should be critically evaluated with respect to accuracy. The usefulness of GIS technology is now limited more by data availability and quality than by anything else.

5.4 Results

The results of the analysis of vegetation to determine habitat interspersion and juxtaposition are discussed below:

5.4.1. Interspersion

The interspersion is a measure of spatial intermixing of habitat/landuse and is calculated in a non species-specific manner. A window is panned over vegetation map and an interspersion value is assigned to the central grid to prepare the interspersion map. Interspersion of central cells is calculated as number of surrounding cells, differing from the central cell. For example Interspersion of central cell is calculated as a number of surrounding grid cells that differ from the central cell. The interspersion of a given **window** is 7 (see example). The maximum limit of interspersion is 8. As raster data is more appropriate for this operation; grid GIS has been used for parameter derivation. Grid size can be changed as per the required level of details. Considering the territory/home range size of Western Tragopan and Musk Deer grid size of 500m by 500m were used. Interspersion values provide an indication of an area in terms of homogeneity and heterogeneity. (Refer Tables 5.1 & 5.2).

Window:

5	**2**	**1**
1	**5**	**1**
3	**4**	**2**

⇩

Interspersion Index = 7

The dispeciesersal ability of species depends on spatial organization of landscape. Certain fragile/rare species occur only in highly connected landscape mosaic. From this point of view, calculation of interspersion gives the zoomed view of resistance, the central pixel or central class has with respect to its surrounding. Higher value of interspersion means the dispeciesersal ability of central class will be low or in other words the influence of the resistance by neighbors will be much which may lead to the obliteration of the central class.

Table 5.1 Interspersion values for Western Tragopan (Grid size 500 m x 500 m)

	Area in km^2	**Percentage**
Homogeneous	209.96	17.93
	143.24	12.23
	152.35	13.01
	172.94	14.77
to	164.43	14.04
	137.27	11.72
	103.97	8.88
	67.99	5.81
Heterogeneous	18.85	1.61
Total	1171	100

Table 5.2 Interspersion for Musk Deer (Grid size500 m x 500 m)

	Area in Km^2	**Percentage**
Homogeneous	209.96	17.93
	143.24	12.23
	152.35	13.01
	172.94	14.77
to	164.43	14.04
	137.27	11.72
	103.97	8.88
	67.99	5.81
Heterogeneous	18.85	1.61
Total	1171	100

5.4.2. Juxtaposition

The juxtaposition is a measure of proximity or adjacency of vegetation type, accomplished by defining the grid, which has been placed on forest type map based on the field observation of the habitat size. For example, Grid wise juxtaposition of the central cell is calculated by comparing the class of the central cell with an adjacent cell as per the weighted preferences of the species on use of the habitat. Juxtaposition map has two components.

1. Spatial adjacency weightage definition (Matrix 1).
2. Class / Type adjacency weightage definition (Matrix 2)

Matrix 1.

1	2	1
2	x	2
1	2	1

The diagonal or horizontal/vertical neighbourhoodness is considered as a spatially influencing element, and hence given the weightages 1 or 2 respectively.

Under second component, as per the field observations over the requirement of the species, Western Tragopan and Musk Deer neccesary vegetation type combination, which are suitable for the species have been given the weightages, for example the Musk Deer prefers subalpine forest and the adjacent areas, so in terms of GIS, if subalpine forest is central pixel and adjacent pixel is also subalpine category then it will be given maximum weifgtage, if subalpine forest is adjacent to temperate forest then weightage will be lower.

Forest Type

Subalpine Broad leaved	Subalpine Broad leaved	Temperate Broad leaved
Subalpine Broad leaved	Subalpine Broad leaved	Temperate Broad leaved
Subalpine Broad leaved	Subalpine Broad leaved	Temperate Broad leaved

Musk Deer

0.9	0.9	0.5
0.9	x	0.5
0.9	0.9	0.5

Matrix 3

Western Tragopan

1	1	0.9
1	x	0.9
1	1	0.9

Matrix 2

For Western Tragopan, juxtaposition measure is Σ Matrix 1 * Matrix 2

Σ

1	2	1
2	X	2
1	2	1

*

1	1	0.9
1	x	0.9
1	1	0.9

1*1+2*1+1*0.9+2*1+2*0.9+1*1+2*1+1*0.9 = 11.6

This is juxtaposition measure for Western Tragopan

For Musk Deer juxtaposition measure is Matrix 1 * Matrix 3

Σ

1	2	1
2	X	2
1	2	1

*

0.9	0.9	0.5
0.9	x	0.5
0.9	0.9	0.5

1*0.9+2*0.9+1*0.5+2*0.9+2*0.5+1*0.9+2*0.9+1*0.5 = 9.2

This is juxtaposition measure for Musk Deer

The above spatial type adjacency is converted into weightages (Refer Table 5.3 & 5.4). Grid wise Interspersion and juxtaposition was calculated in GIS domain for habitat characterization.

Table 5.3a Juxtaposition Weightages Matrix: Western Tragopan

	Pinus roxburghii	Temp. mixed conifer	Subalpine M-conifer	Conifer & broad leaved mixed	Broad leaved & conifer mixed	Sobtropical broad leaved	Temp. broad leaved	Subalpine broad leaved	Riperian	Secondary scrub	Dryalpine scrub	Subtropical grassland	Temperate grassland	Subalpine grassland
Conifer *(Pinus roxburghii)*	0	0.1	0.4	0.3	0.2	0	0	0	0	0	0	0	0	0
Temp. mixed conifer	0.3	1.0	0.6	0.8	0.6	0.2	0.8	0.6	0.3	0.2	0.1	0	0.5	0.5
Subalpine M-conifer	0	0.6	0.3	0.4	0.1	0	0.1	0.7	0.1	0.1	0	0	0	0
Conifer & broad leaved mixed	0.2	0.5	0.7	0.5	0.1	0.3	0.4	0.6	0.5	0.4	0.3	0	0.8	0.5
Broad leaved & conifer mixed	0.2	0.5	0.3	0.6	0.2	0.3	0.6	0.5	0.4	0.3	0.2	0	0.3	0.6
Subtropical broad leaved	0	0.5	0.3	0.3	0.3	0	0.6	0	0	0	0	0	0.1	0
Temp. broad leaved	0.1	0.7	0.4	0.4	0.5	0	0.5	0.8	0.2	0.1	0.1	0.1	0.1	0.1
Subalpine broad leaved	0	0.7	0.8	0.5	0.7	0	0.9	1.0	0	0.1	0.7	0	0.4	0.6
Riperian	0	0.3	0.1	0.5	0.4	0	0.2	0.2	0	0	0	0	0	0
Secondary scrub	0	0.2	0.1	0.4	0.3	0	0.1	0.1	0	0	0	0	0	0
Dryalpine scrub	0	0	0	0	0	0	0.1	0.7	0	0	0	0	0	0
Subtropical grassland	0.1	0	0.3	0	0	0	0	0	0	0	0	0	0	0
Temperate grassland	0	0.5	0.1	0.3	0.2	0	0.3	0	0	0	0	0	0	0
Subalpine grassland	0	0.1	0.3	0.4	0.2	0	0.4	0.8	0	0	0	0	0	0
Alpine grassland	0	0	0.1	0	0	0	0	0.1	0	0	0	0	0	0
Habilation/Agri/Orchard	0	0.4	0.2	0.3	0.2	0	0.1	0.2	0	0	0	0	0	0
Cliffs	0	0.7	0.5	0.2	0.3	0	0.3	0.5	0	0	0	0	0	0
Exposed rock with slope grassess	0	0.7	0.5	0.4	0.2	0	0.2	0.8	0	0	0	0	0	0
Alpine exposed rocks with grasses	0	0	0	0.1	0.1	0	0	0	0	0	0	0	0	0
Landslide	0	0	0	0	0	0	0	0	0	0	0	0	0	0
River	0	0.8	0.5	0.7	0.2	0	0.5	0.7	0	0	0	0	0	0
Sand bar	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lakes	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Morain	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Morainic island	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glacier	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Permanent snow	0.2	0.2	0.1	0	0	0	0	0.4	0	0	0	0	0	0
Plantation	0	0.2	0	0.5	0.3	0	0	0.1	0	0	0	0	0	0

Table 5.3b Juxtaposition Weightages Matrix: Western Tragopan

	Alpine grassland	Habilation/Agri/Orchard	Cliffs	Exposed rock with slope grassess	Alpine exposed rocks with grasses	Landslide	River	Sand bar	Lakes	Morain	Morainic island	Glacier	Permanent snow	Plantation
Conifer *(Pinus roxburghii)*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Temp. mixed conifer	0.2	0.1	0.7	0.5	0	0	0.8	0	0	0	0	0	0	0.2
Subalpine M-conifer	0	0	0.3	0.7	0	0	0.5	0	0	0	0	0	0.1	0
Conifer & broad leaved mixed	0.1	0.1	0.2	0.2	0.1	0	0.7	0	0	0	0	0	0	0.5
Broad leaved & conifer mixed	0.3	0.1	0.3	0.3	0	0	0.2	0	0	0	0	0	0	0.3
Subtropical broad leaved	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Temp. broad leaved	0	0	0.5	0.7	0	0	0.5	0	0	0	0	0	0	0
Subalpine broad leaved	0.1	0	0.5	0.6	0.1	0	0.7	0	0.4	0	0	0	0.4	0.1
Riperian	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Secondary scrub	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dryalpine scrub	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Subtropical grassland	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Temperate grassland	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Subalpine grassland	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alpine grassland	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Habilation/Agri/Orchard	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cliffs	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Exposed rock with slope grassess	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alpine exposed rocks with grasses	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Landslide	0	0	0	0	0	0	0	0	0	0	0	0	0	0
River	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sand bar	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lakes	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Morain	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Morainic island	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glacier	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Permanent snow	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plantation	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table No 5.4a Juxtaposition weightages Matrix: Musk Deer

	Pinus roxburghii	Temp. mixed conifer	Subalpine M-conifer	Conifer & broad leaved mixed	Broad leaved & conifer mixed	Sobtropical broad leaved	Temp. broad leaved	Subalpine broad leaved	Riperian	Secondary scrub	Dryalpine scrub	Subtropical grassland	Temperate grassland	Subalpine grassland
Conifer *(Pinus roxburghii)*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Temp. mixed conifer	0	0	0.3	0.1	0.1	0	0	0.3	0	0	0.4	0	0	0.3
Subalpine M-conifer	0	0.3	0.7	0.4	0.4	0	0.1	1	0	0.1	1	0	0.2	0.6
Conifer & broad leaved mixed	0	0.1	0.4	0.3	0.3	0	0.1	0.4	0	0	0.5	0	0	0.6
Broad leaved & conifer mixed	0	0.1	0.4	0.3	0.3	0	0.1	0.4	0	0	0.5	0	0	0.6
Sobtropical broad leaved	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Temp. broad leaved	0	0	0.1	0.1	0.1	0	0	0.5	0	0	0	0	0	0.1
Subalpine broad leaved	0	0.3	1	0.4	0.4	0	0.5	0.9	0	0.1	1	0	0.2	0.5
Riperian	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Secondary scrub	0	0	0.1	0	0	0	0	0.1	0	0	0	0	0	0
Dryalpine scrub	0	0.4	1	0.5	0.5	0	0	1	0	0	1	0	0.4	0.8
Subtropical grassland	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Temperate grassland	0	0	0.2	0	0	0	0	0.2	0	0	0.4	0	0	0.1
Subalpine grassland	0	0.3	0.6	0.6	0.6	0	0.1	0.6	0	0	0.8	0	0.1	0.3
Alpine grassland	0	0.2	0.4	0.3	0.3	0	0	0.4	0	0	0.6	0	0.1	0.2
Habitation/Agri/Orchard	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cliffs	0	0.1	0.2	0.1	0.1	0	0	0.2	0	0	0	0	0	0.2
Exposed rock with slope grassess	0	0.1	0.2	0.1	0.1	0	0	0.2	0	0	0	0	0	0.1
Alpine exposed rocks with grasses	0	0.0	0.2	0.1	0.1	0	0	0.2	0	0	0	0	0	0.1
Landslide	0	0	0	0	0	0	0	0	0	0	0	0	0	0
River	0	0	0.1	0	0	0	0	0	0	0	0	0	0	0.1
Sand bar	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lakes	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Morain	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Morainic island	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glacier	0	0	0.6	0.2	0.2	0	0.4	0	0	0	0.2	0	0	0.2
Permanent snow	0	0	0.6	0.2	0.2	0	0.4	0	0	0	0.2	0	0	0.2
Plantation	0	0.2	0.2	0.2	0.2	0	0.1	0.1	0	0	0	0	0	0

Table No 5.4 b Juxtaposition weightages Matrix: Musk Deer

	Alpine grassland	Habitation/Agri/Orchard	Cliffs	Exposed rock with slope grassess	Alpine exposed rocks with grasses	Landslide	River	Sand bar	Lakes	Morain	Morainic island	Glacier	Permanent snow	Plantation
Conifer *(Pinus roxburghii)*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Temp. mixed conifer	0.2	0	0.1	0.1	0	0	0	0	0	0	0	0	0	0.2
Subalpine M-conifer	0.4	0	0.2	0.2	0.2	0	0.1	0	0	0	0	0.6	0.6	0.2
Conifer & broad leaved mixed	0.3	0	0.1	0.1	0.1	0	0	0	0	0	0	0.2	0.2	0.2
Broad leaved & conifer mixed	0.3	0	0.1	0.1	0.1	0	0	0	0	0	0	0.2	0.2	0.2
Sobtropical broad leaved	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Temp. broad leaved	0	0	0	0	0	0	0	0	0	0	0	0.4	0.8	0.1
Subalpine broad leaved	0.4	0	0.2	0.2	0.2	0	0	0	0	0	0	0	0	0.1
Riperian	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Secondary scrub	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dryalpine scrub	0.6	0	0	0	0	0	0	0	0	0	0	0.2	0.8	0
Subtropical grassland	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Temperate grassland	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0
Subalpine grassland	0.2	0	0.2	0.2	0.1	0	0.1	0	0	0	0	0.2	0.2	0
Alpine grassland	0.2	0.0	0.2	0.2	0.1	0	0	0	0	0	0	0.1	0.1	0
Habitation/Agri/Orchard	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cliffs	0.2	0	0.6	0.2	0.3	0	0	0	0	0	0	0.1	0.1	0
Exposed rock with slope grassess	0.1	0	0.3	0.2	0.2	0	0	0	0	0	0	0.1	0.1	0
Alpine exposed rocks with grasses	0.1	0	0.3	0.2	0.1	0	0	0	0	0	0	0	0	0
Landslide	0	0	0	0	0	0	0	0	0	0	0	0	0	0
River	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sand bar	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lakes	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Morain	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Morainic island	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glacier	0.1	0	0.1	0.1	0	0	0	0	0	0	0	0	0	0
Permanent snow	0.1	0	0.1	0.1	0	0	0	0	0	0	0	0	0	0
Plantation	0	0	0	0	0	0	0	0	0	0	0	0	0	0

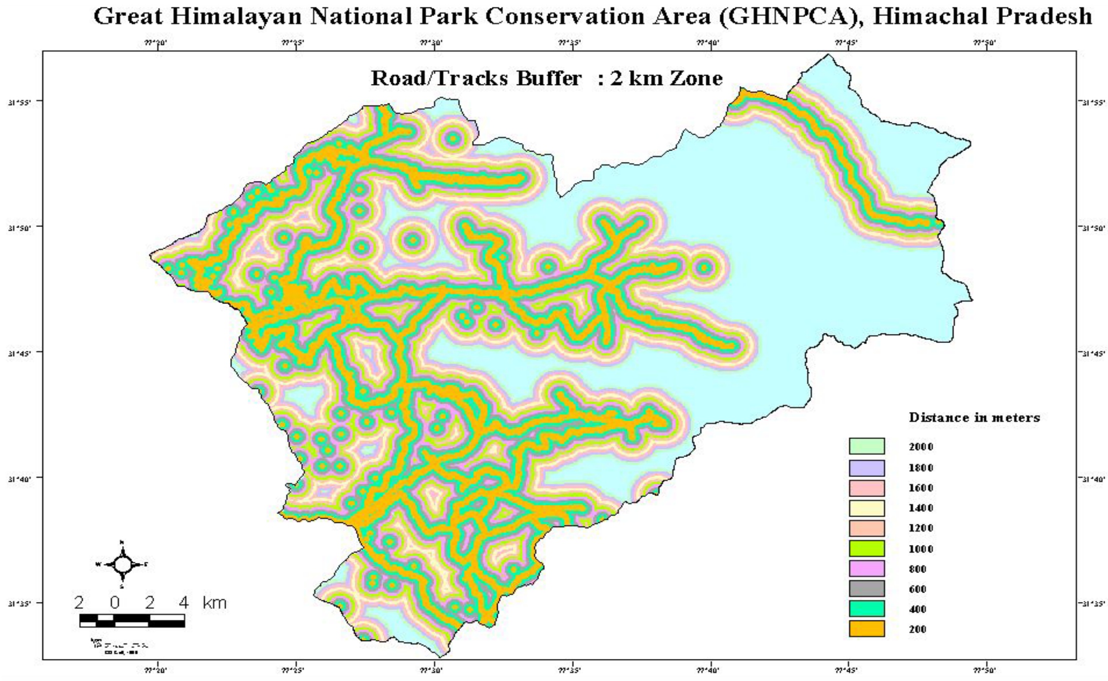
5.4.3. Ground Sighting Condition

The ground sighting condition-extracted map has been discussed earlier. It has been used to assign weightages.

5.4.4. Road/Track Buffer

It has been considered as a restrictive factor. Roads/Tracks are considered as a potential habitat disturbance factor. This map was also prepared by generating a distance buffer around roads. The contributing weightages have been given for each zone i.e. 200m based on animal sighting data. The buffer map is shown in Fig 5.2.

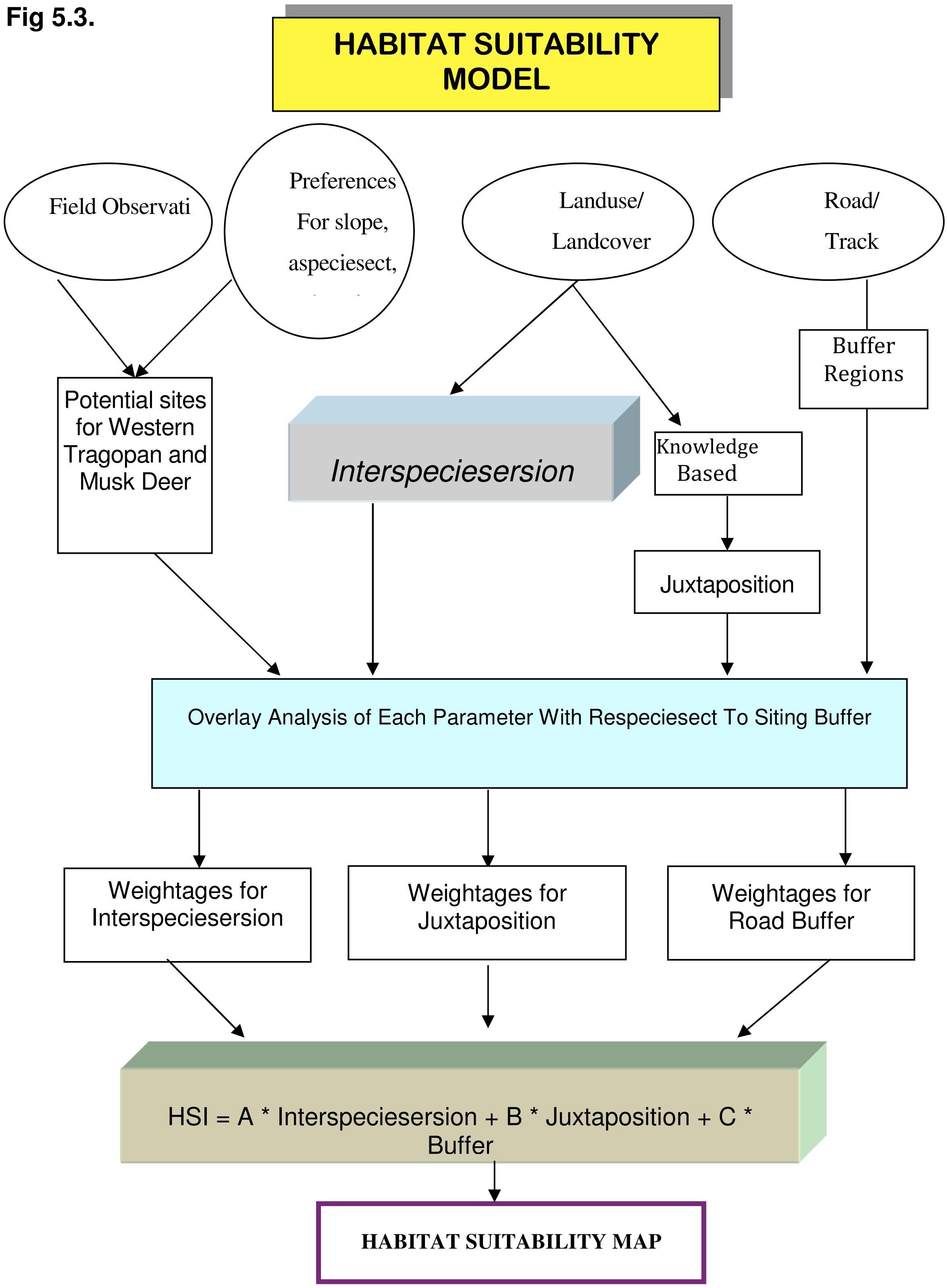
Fig 5.2



5.5 HABITAT MODEL

For modeling, the sighting based statistical evidential weightages have been assigned for Musk Deer and Western Tragopan for the period April –July from 1997 to 1999 respectively. Likewise, the same approach has been used for the buffer map. All these contributing weightages has been crossed with ground sighting map within that the Landuse / Landcover parameters have already been considered. All these value have been used for habitat suitability analysis. These assigned values are depicted in the Tables 5.5, 5.6, 5.7, 5.8, 5.9 to 5.12. The approach for habitat suitability analysis is shown in Fig 5.3.

Fig 5.3.



(Where A = 0.2, B = 0.6, C = 0.2)

Fig. 5.3: Flow chart showing process involved in developing Habitat Suitability Model

Step1.

$$\text{Class carrying capacity index} = \frac{\text{Area of a class coming under sighting}}{\text{Total area of the class}}$$

This can be done by crossing vegetation map with sighting map or interspersion with sighting or juxtaposition with sighting.

Step2.

$$\text{Class contributing index or Class evidential index} = \frac{\text{class carrying capacity index}}{\text{sum of all the classes' carrying capacity index}}$$

The weightages are depicted in Table 5.5, 5.6, 5.7, 5.8, 5.9 to 5.12.

Table 5.5 JUXTAPOSITION WEIGHTAGES FOR WESTERN TRAGOPAN

Value	Weightage
0	0.01
1	0.07
2	0.10
3	0.08
4	0.07
5	0.09
6	0.10
7	0.12
8	0.09
9	0.07
10	0.06
11	0.07
12	0.07
Total	1.00

TABLE 5.6 JUXTAPOSITION WEIGHTAGES FOR MUSK DEER

Value	weightage
0	0.01
1	0.02
2	0.03
3	0.04
4	0.07
5	0.07
6	0.10
7	0.09
8	0.10
9	0.10
10	0.10
11	0.14
12	0.14
Total	1.00

Table 5.7 CONTRIBUTING WEIGHTAGES FOR BUFFER OF MUSK DEER

(2km=10 zone, one zone= 200m)

Value	Weightage
0	0.01
2000m or 2km	0.04
1800m	0.06
1600m	0.07
1400m	0.08
1200m	0.09
1000m or 1km	0.11
800m	0.13
600m	0.14
400m	0.14
200m	0.14
Total	1.00

TABLE 5.8 CONTRIBUTING WEIGHTAGES FOR BUFFER OF WESTERN TRAGOPAN (2KM=10 ZONE, ONE ZONE= 200M)

VALUE	Weightage
0	0.00
2000m or 2km	0.02
1800m	0.04
1600m	0.06
1400m	0.10
1200m	0.12
1000m or 1km	0.14
800m	0.14
600m	0.14
400m	0.13
200m	0.11
Total	1.00

TABLE 5.9 INTERSPERSION WEIGHTAGES FOR MUSK DEER

Value	Weightage
0	0.02
1	0.06
2	0.09
3	0.10
4	0.12
5	0.13
6	0.15
7	0.15
8	0.17
Total	1.00

Table 5.10 INTERSPERSION WEIGHTAGES FOR WESTERN TRAGOPAN

Value	Weightage
0	0.02
1	0.05
2	0.08
3	0.09
4	0.12
5	0.15
6	0.16
7	0.16
8	0.16
Total	1.00

TABLE 5.11 CONTRIBUTING WEIGHTAGES FOR LANDUSE/ LANDCOVER MAP FOR MUSK DEER (BASED ON SIGHTING DATA)

Forest type	Weightage
Pinus roxburghii	0.00
Temp. conifer & broad leaved mixed	0.08
Temp. broad leaved & conifer mixed	0.06
Reparian	0.00
Temp. secondary scrub	0.03
Alpine scrub	0.19
Exp. Rocks with slope grasses	0.06
Escarpment	0.03
Alpine exp. Rocks with slope grasses	0.00
Landslides	0.00
Lakes	0.00
River	0.05
Parmanent snow	0.00
Habitation/Agriculture/ Orchards	0.00
Glacier	0.00
Morain	0.00
Plantation	0.00
Morainic Islands	0.00
Temp. broad leaved	0.04
Kharsu forest	0.14
Temp. grassland	0.03
Sub alpine grassland	0.13
Alpine grassland	0.03
Temp. mixed conifer	0.02
Subalpine fir	0.10
Total	1.00

Table 5.12 CONTRIBUTING WEIGHTAGES FOR LANDUSE/ LANDCOVER MAP FOR WESTERN TRAGOPAN (based on sighting data)

Forest type	Weightage
Pinus roxburghii	0.00
Temp. conifer & broad leaved mixed	0.13
Temp. broad leaved & conifer mixed	0.12
Reparian	0.04
Temp. secondary scrub	0.12
Alpine scrub	0.00
Exp. Rocks with slope grasses	0.04
Escarpment	0.01
Alpine exp. Rocks with slope grasses	0.00
Landslides	0.13
Lakes	0.00
River	0.08
Permanent snow	0.00
Habitation/Agriculture/ Orchards	0.05
Glacier	0.00
Morain	0.00
Plantation	0.00
Morainic Islands	0.00
Temp. broad leaved	0.13
Kharsu forest	0.11
Temp. grassland	0.08
Sub alpine grassland	0.03
Alpine grassland	0.00
Temp. mixed conifer	0.05
Subalpine fir	0.01
Total	1.00

5.6 Habitat suitability index

Habitat Suitability Index (HSI) for Western Tragopan and Musk Deer have been developed by assigning appropriate weightages to each parameter, i.e., Landuse/Landcover, interspersion, juxtaposition and restrictive factors. The equation for habitat suitability index is as follows:

$$HSI = \sum W_I * P_{wi}$$

Where W_I = Importance weightage

P_{wi} = Parameter contributing weightage for i^{th} class

Here parameters are interspersion (Is), juxtaposition (Jx) and restrictive factor (Rf) so,

Habitat Index = (0.2*Is) + (0.6* Jx) + (0.2* Restrictive factor)

Each cell was assigned a habitat suitability index ranging from 0 to 1.

5.7 Comparison of model with field realities

An extensive literature search has revealed that models using remote sensing and GIS have not been developed for Western Tragopan and Musks Deer. Hence, no real comparison could be performed. The locations of Western Tragopan and Musk Deer have also been mapped in ARC/INFO GIS domain during the fieldwork from 1997-99. Thus the influence of field observations is already taken into account in terms of the contributing weightages by overlaying the field sighting buffer with ground layers *viz.* like vegetation, slope, aspect, interspersion and juxtaposition. The sighting of Western Tragopan and Musk Deer can also be cross checked by overlaying field sighting maps; Fig. 5.4 and Fig. 5.6 with Habitat suitability maps *i.e.* Fig 5.5 and Fig. 5.7. It is apparent from Table 5.13 that a substantial area (67%) is under low suitability class for the Western Tragopan and only about 10% of GHNPCA provides a good habitat for this species. Similarly, for the Musk Deer (see Table 5.14) about 61% of the area is having a low suitability class whereas about 25% area has high and very high suitability and 28% area is not suitable for Musk Deer habitat. By overlaying Climatic Zone on the Habitat Suitability map for Musk Deer it is observed that within the alpine zone (314 $km^{2)}$ 132 km^2 (42%) comes under low suitability; 48 km^2 (15%) comes under medium suitability and 133 km^2 (42%) comes under high suitability and only 1 km^2 (0.3%) comes under very high suitability. similarly, for the Western Tragopan under alpine zone 305 km^2 (97%) comes under low suitability; 8km^2 (2%) comes under medium suitability and 1 km^2 (0.3%) comes under high suitability class. The suitable area under alpine zone is possibly the ecotone areas between subalpine and alpine zones. The alpine zone in Parvati Valley is around 3 % (40 km^2) and is perpetually snowbound and therefore does not provide suitable habitat for the Western Tragopan.

Fig 5.4 Distribution of Western Tragopan, Based on sighting in GHNPCA

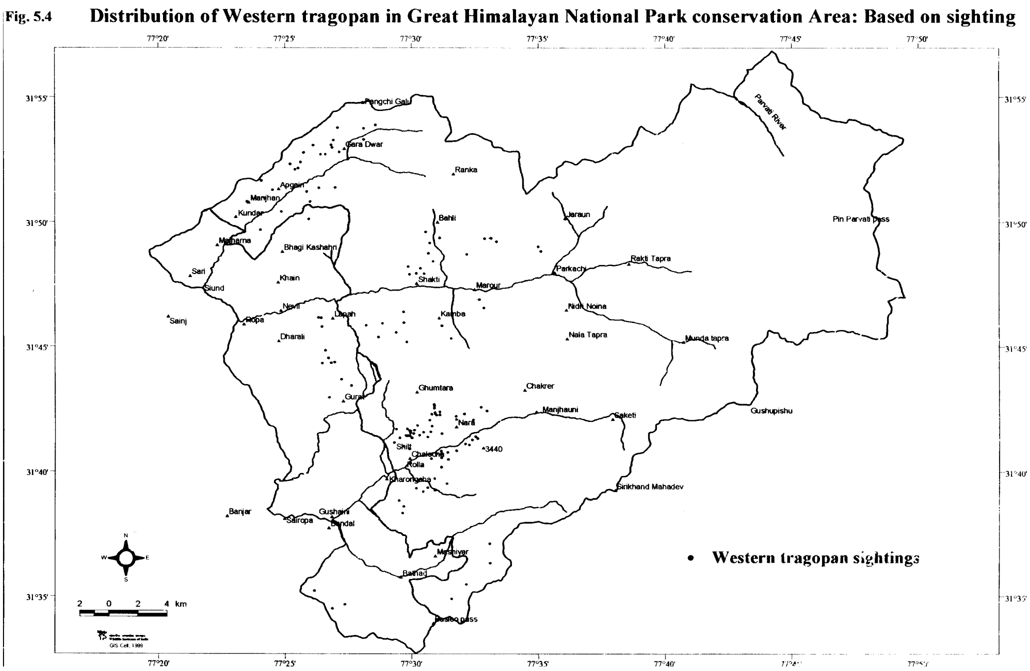


Fig. 5.5

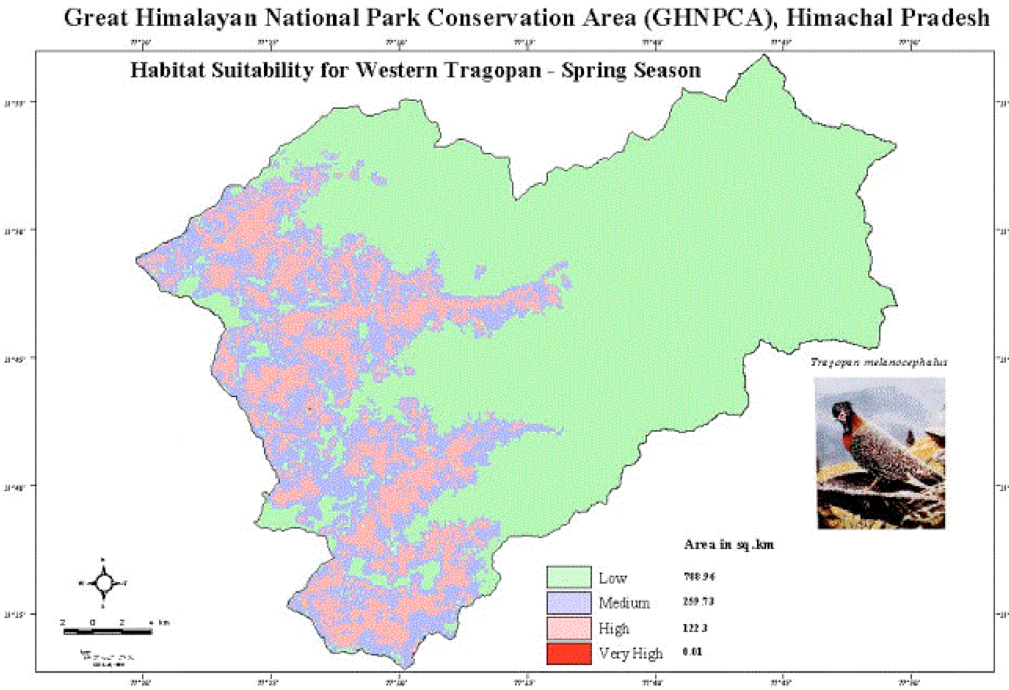


Fig 5.6 Distribution of Musk Deer, Based on sighting in GHNPCA

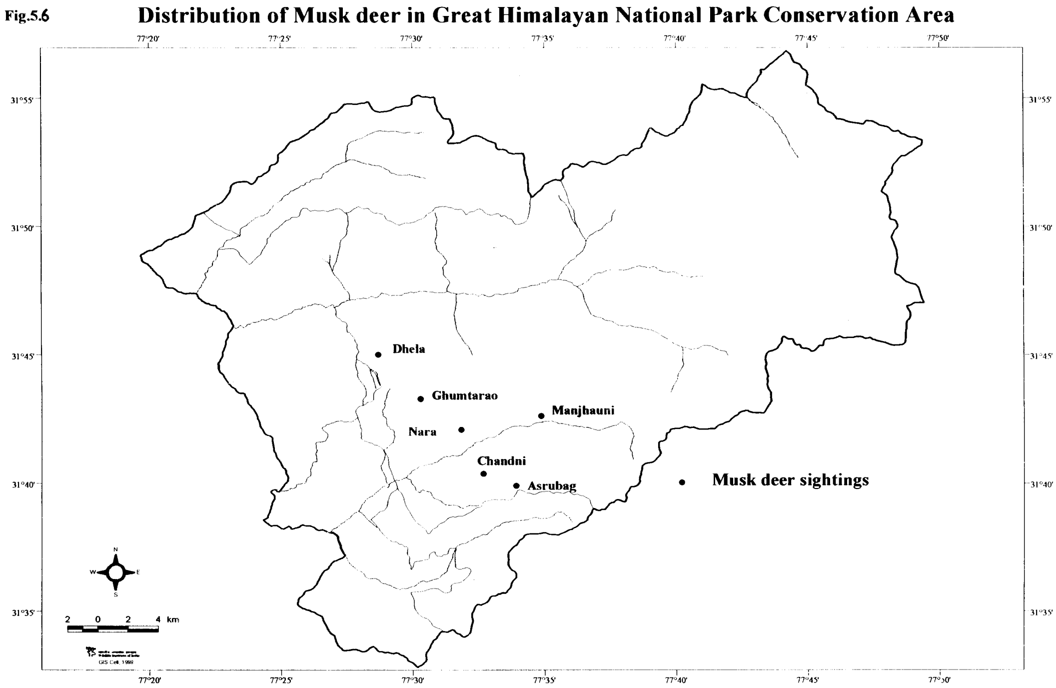


Fig 5.7

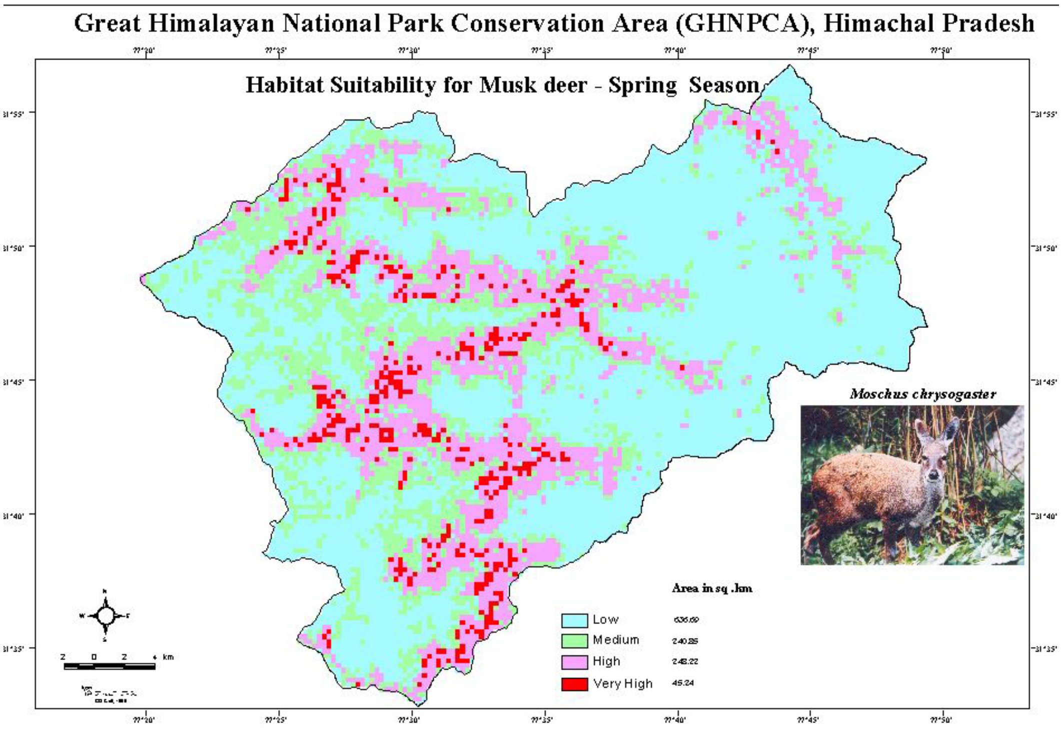


Table 5.13 AREAS UNDER EACH HABITAT SUITABILITY CLASS FOR WESTERN TRAGOPAN

Habitat Suitability Class	Area (km^2)	%
Low	788.96	67.37
Medium	259.73	22.18
High	122.3	10.44
Very High	0.01	0.00
TOTAL	1171	100.00

Table 5.14 AREA UNDER EACH HABITAT SUITABILITY CLASS For MUSK DEER

Habitat Suitability Class	Area (km^2)	%
Low	719.06	61.40
Medium	149.5	12.77
High	268.04	22.89
Very High	34.40	2.94
TOTAL	1171	100.00

5.8 DISCUSSION

Developing Habitat Suitability Index (HSI) for the indicator species is a well-accepted practice for characterization of habitats. The Western Tragopan and Musk Deer both are highly endangered species and are indicators of habitat quality.

In the present study an attempt has been made to determine the habitat suitability and availability of potential habitats of Western Tragopan and Musk Deer, based on several ground based parameters as well as using spatial analytical techniques.

Mead *et al* (1981), Lyon (1983) and Roy *et al* (1995) have earlier discussed the conceptual framework on the use of parameters (interspersion, juxtaposition and restrictive factors). The habitat suitability analysis of goral (*Nemorhaedus goral*) in Rajaji National Park U.P., has been attempted by Roy *et al* (1995). In this study interspersion, juxtaposition and restrictive factors have been used for habitat suitability analysis. The same concept has been applied in the present study except for the difference in the method of assigning weightages to the parameters. The weightages are based on sighting data. In the model the habitat parameters used for Western Tragopan and Musk Deer were observed by Ramesh *et al* (1999), Vinod and Sathyakumar (1999) respectively.

For Himalayan Musk Deer the ground based habitat suitability index has been developed (Rawat, 1994). The model has been developed throughout the range of Himalayan Musk Deer in Pakistan, Nepal and India. Rawat, 1994 used the habitat variables, life requisites and cover types without applying remote sensing but suggested that remote sensing could be used in habitat evaluation.

As far as the habitat analysis of Western Tragopan is concerned, no other habitat models for these were found in literature. Western Tragopan is highly endangered pheasant with localized distribution in Western Himalayas of Pakistan and India. A survey report of the potential areas of Western Tragopan has been prepared by Prasad (1993). This study was conducted for finding habitat contiguity and presence of pheasant's population in parts of Uttarkashi District U.P. Remote sensing and Digital Image Processing was used to identify the potential habitat. The study provided information about the habitat contiguity of Western Tragopan in Himachal Pradesh and in Western parts of U.P. Himalayas. During the Study "Ecology and Conservation Status of the Pheasants of Great Himalayan National Park, Western Himalayas", Ramesh *et al* (1999) prepared the distribution map of Western Tragopan on the basis of ground sighting data using GIS. However, no work on habitat suitability analysis was done.

According to Vinod and Sathyakumar 1999 the mean density of Musk Deer in Gumtrao is $3.33+0.29/km^2$ and in Dhela is $0.72+0.49/km^2$ using silent drive counts. Infact the habitat of Musk Deer in Dhela is larger than Gumtrao. But the lower density in Dhela may be because of higher rate of disturbance and poaching compared to Gumtarao. Dhela is easily accessible when compared to Gumtrao from local villages when compared to Gumtrao.

This study has appropriately demonstrated the potential of using remote sensing technology in conjunction with GIS and ground data for determining the habitat suitability for two endangered species. Based on the available information appropriate management interventions are now needed to ensure long term conservation of these species in their habitat range. In order to further refine the predictive ability of the models for determining the habitat suitability for Western Tragopan and Musk Deer seasonal variations in species distribution and abundance will have to be taken into account. Similarly, studies must be undertaken for developing HSI models for other species in the GHNPCA for ensuring their effective conservation.

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