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Development of a Spatial Database of the Great Himalayan National Park Conservation Area (GHNPCA) in GIS Domain

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EXECUTIVE SUMMARY

1. *A comprehensive spatial database in GIS domain has been developed for the Great Himalayan National Park Conservation Area (GHNPCA), Himachal Pradesh under this task. This database has thematic layers covering the physical, floral, faunal and socio-economic attributes. Additionally, spatial database for the 4 management entities of GHNPCA viz. Great Himalayan National Park (754.40 km^2); Sainj Wildlife Sanctuary (90 km^2); Tirthan Wildlife Sanctuary (61 km^2) and Ecodevelopment Area (265.60 km^2) has also been developed. In all, the database has 52 thematic layers.*

2. *Vegetation is a very important component in both forest and wildlife management. In this study a very detailed vegetation map has been developed using remotely sensed data and ground truthing. A total of 22 classes, 11 in forest area and 11 in non-forest area have been mapped. Area under different landuse/landcover categories have been determined. Grasslands (19%), Mixed conifers (11%) and Alpine scrubs cover about 10% area. Nearly 16% of the GHNPCA is under permanent snow while the Alpine exposed rocks cover 13% area.*

3. *The Ecodevelopment Area (EDA) is one of the important subunits of GHNPCA. It is the main habitation zone (265 km^2) and it forms about 22% of the GHNPCA. There are 13 revenue villages, 123 hamlets in EDA having 2465 households and a population of 11715 as per the 1991 census. Nearly 10% area of EDA is under Habitation/Agriculture/Orchard category and its proportion has increased over the years. As per the 'Change Detection Analysis' carried out under this task in the EDA, the fuelwood/fodder consumption has increased nearly 78% in the period between 1961 and 1993. There has been an increase of about 9 km^2 area under Habitation/Agriculture/Orchard category with a corresponding decline of about 4 km^2 forest area between 1961 and 1993.*

4. *Habitat suitability modelling for two species viz. Western Tragopan (**Tragopan melanocephalus**) and Musk Deer (**Moschus Chrysogaster**) has been undertaken in this task using spatial analytical procedures and field data analysis of landscape, by measuring interspersion and juxtaposition values with restrictive factors. The*

analysis has been carried out using software routines developed in database management system interfaced with GIS software – ARC/INFO. Developing Habitat Suitability Indices (HSI) for indicator species is a well accepted practice for characterization of habitats. Results indicate that about 67% of GHNPCA 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 also about 54% of the area has a low suitability whereas about 21% area has a high suitability. Appropriate management interventions would have to be employed to increase the habitat suitability for these species in the GHNPCA. However, the HSI modeling undertaken in the study is based on a very small dataset and would have to be refined in order to take into account the influence of seasonal variations on species abundance and other associated parameters in order to arrive at definite conclusions.

5. *It is stated that GHNPCA has one the most comprehensive spatial database and the best and immediate use of this database would be in preparing the Management Plan of GHNPCA, which is now a critical necessity.*

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CHAPTER 1 : TASK BACKGROUND

1.0 BACKGROUND

The Department of Forest Farming and Conservation, Government of Himachal Pradesh accepted funding from the International Development Association for the Conservation of Biodiversity through ecodevelopment approach in the Great Himalayan National Park (GHNP) Area. The project was designated as " Forestry Research, Education and Extension Project (FREEP) ". The FREE project has three main components (i) Improvement of PA Management; (ii) Reduction of people's dependencies on PA through village ecodevelopment and (iii) Research, Monitoring and Education programme to support PA management. The research and monitoring component was assigned to the Wildlife Institute of India (WII). A multi-disciplinary team of Faculty, Researchers and Consultants was put together by WII to work on the research and monitoring component for a five year period from 1995 to 1999 . The state of Himachal Pradesh has 33 Protected Areas (2 National Parks and 31 Wildlife Sanctuaries) covering an area of 6232.87 km^2 , which represents 11.20% of the geographical area of the state (Fig. 1.1).

1.1 TERMS OF REFERENCE

The original Terms of Reference (ToR) for this task underwent several modifications during the project duration in response to the felt need expressed by the PA management and a consensus was reached to develop a spatial database in GIS domain. The following were specific components of this task:

1. Develop spatial database in GIS domain on select attributes of Great Himalayan National Park Conservation Area (GHNPCA) including Great Himalayan National Park; Sainj Wildlife Sanctuary; Tirthan Wildlife Sanctuary and Ecodevelopment area.

2. Map vegetation communities using remotely sensed data.

3. Develop habitat suitability models of select animal species correlating habitat components with species distribution and abundance.

The outputs from this task have therefore become more comprehensive and of immediate relevance to the PA management for planning management and monitoring of the resources. Further, the spatial database has been designed and developed in such manner that its outputs can be directly used in the preparation of GHNPCA Management Plan, which has now become a critical necessity.

1.2 LINKAGES WITH OTHER TASKS

As per the approach adopted for the implementation of the 'Research and monitoring Component' of the FREE Project , the Institute developed a series of tasks and sub – tasks and a multidisplinary team of WII faculty members, researchers, technical staff , consultants, both national and international, were involved in carrying out the study. As thematic map layers form an integral part of all studies this task has linkages with all other tasks and output maps generated through this study have been used by the team members in abundant measure. In order to provide specialized inputs in use of remotely sensed data for mapping vegetation communities, Dr. Sarnam Singh, Indian Institute of Remote Sensing, Dehradun was engaged as a consultant and the field visit component of this study was jointly organised with him.

1.3 REMOTE SENSING AND GEOGRAPHICAL INFORMATION SYSTEM

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 spectrum from various objects. The remotely sensed data provides an opportunity to monitor and manage the natural resources within a stipulated time frame. Noteworthy developments in sensors with respect to spectral and spatial resolutions viz. Landsat - TM (USA), SPOT - I (France) and IRS IA, IB and IC (India) have enhanced the utility of remote sensing. The spectral resolution offered by narrow swath sensors enables suitable delineation of vegetation patterns at spatial level.

The appearance of a range of satellites on the scene has given tremendous boost to resource monitoring programmes (Curran, 1988; Lillesand and Kiefer, 1994). "Space" is now being increasingly used as a medium to seek information of the earth. Remote sensing with its unique synoptic perspective 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 spectral 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 have led towards developing various methods for vegetation mapping. The two commonly used methods are (i) manual i.e., visual interpretation and (ii) machine based i.e., digital analysis. Digitally acquired data can also be interpreted through computer. In both cases ground truth data is required for developing interpretation key or training sets.

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

For 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 and this tool is the Geographical Information System (Burrough, 1986). This technology provides techniques to capture, store, manipulate, analyze and display geographically referenced data. GIS systems are being used in natural resource management and several other multidisciplinary fields. The use of Remote Sensing technology in conjunction with Geographic Information System technology has considerably enhanced its application in natural resource conservation. This study demonstrates the value of these technologies in understanding the patterns and processes in a and inaccessible terrain in the Himalayas landscape.

1.4 LITERATURE REVIEW

Most of the ecological studies of Himalayan vegetation pertain to Kumaun 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, Northwestern Himalaya have 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 aspects of western Himalaya. More recent studies on the flora and vegetation of high altitude areas of western Himalaya include (Chaudhry *et al*., 1984; Rawat *et al*., 1986; Pangtey *et al*., 1988; Adhikari *et al*., 1991; Singh *et al*., 1992; Singh *et al*., 1994; Rawat *et al*., 1993; Aswal *et al*., 1994;Rawat, 1994; Rawat *et al*., 1996 Kala *et al*., 1997). With the advent of satellite remote sensing and its ever increasing popularity because of its repetitive coverage, mapping of inaccessible and large area within short time, the true picture of area specially 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). Several workers have done visual interpretation of IRS data for developing landuse/landcover map. Satellite data has been 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).

In India, studies have also been carried out in the field of wildlife habitat evaluation (Dutt *et al*., 1986; Roy *et al*., 1986; Unni *et al*., 1986 and Porwal and Roy, 1991b). In relation to geology and forest vegetation Puri (1950 & 1960) and Champion and Seth (1968) have carried out work. As far as the habitat of musk deer is concerned the conservation status of musk deer has been studied by Green (1985), Sathyakumar *et al*., (1991, 1992) Sathyakumar (1994) in Kedarnath Wildlife Sanctuary and Hari Dang (1968).

CHAPTER 2 : SPATIAL DATABASE OF GREAT HIMALAYAN NATIONAL PARK CONSERVATION AREA (GHNPCA)

2.0 INTRODUCTION

As per the Terms of Reference of this study a spatial database in GIS domain has been developed for the Great Himalayan National Park Conservation Area. The GHNPCA comprises of the following entities (Table 2.1 and Fig 2.1).

Table 2.1 : Entities of Great Himalayan National Park Conservation Area (GHNPCA)

S. No.	Name of the entity	Area in km^2	% of GHNPCA
1	Great Himalayan National Park (GHNP)	754.40	65
2	Sainj Wildlife Sanctuary (SWS)	90	8
3	Tirthan Wildlife sanctuary (TWS)	61	5
4	Ecodevelopment Area (EDA)	265.60	22
	Total	1171	100

The GHNPCA is bounded by Rupi Baba Wildlife Sanctuary in the east, Pin Valley National Park in the north-east and Kanawar Wildlife Sanctuary in the north- west. In the south- west portion habitation, cultivation and orchards occur. The GHNPCA forms a large , relatively undisturbed area in the Himalaya and has a range of biological diversity.

The GHNPCA also forms the catchment of Jiwanal, Sainj, Parvati and Tirthan rivers which are tributaries of river Beas (Fig 2.2). Tirthan and Sainj rivers flow in the east-west direction and they cris cross the steep gorges. The unique feature of GHNPCA is that nearly all the sub-watersheds are snow bound and therefore all the rivers flowing from the area are perennial . Nearly 50% of the GHNPCA area lies above 4000 m and is usually snowbound. The main access to the area is from westward direction in the Kullu district i.e from Mandi-Aut-Larji-Banjar/Sainj.

2.1 SPATIAL DATABASE LAYERS

The GHNPCA spatial database has 17 layers of which 10 are Primary layers and 7 are Derived layers. Several sources viz. Survey of India (SOI) Topographical Sheets, Remotely Sensed Data, Geographical Information System technology coupled with field surveys and ground truthing have been used in developing the spatial database.

The spatial database layers of GHNPCA are shown in Table 2.2.

Table 2.2 : Spatial database layers of Great Himalayan National Park Conservation Area (GHNPCA)

S. No.	Name	Primary/Derived	Source
1	GHNPCA: Base Map	Primary	SOI Toposheet
2	GHNPCA: Physical Features	Primary	SOI Toposheet
3	GHNPCA: Drainage	Primary	SOI Toposheet
4	GHNPCA: Drainage Density	Derived	GIS
5	GHNPCA: Contour	Primary	SOI Toposheet
6	GHNPCA: Aspect	Derived	GIS
7	GHNPCA: Slope	Derived	GIS
8	GHNPCA: DEM	Derived	GIS
9	GHNPCA: Road /Track Buffer	Primary	SOI Toposheet & GIS
10	GHNPCA: Geology	Primary	Field Survey & GIS
11	GHNPCA: Geomorphology	Primary	Field Survey & GIS
12	GHNPCA: Escarpment	Primary	SOI Toposheet
13	GHNPCA: Terrain Complexity	Derived	GIS
14	GHNPCA: Landuse/landcover	Primary	RS, GIS and Field Survey
15	GHNPCA: Landuse/landcover (Specialized Categories)	Derived	GIS
16	GHNPCA: 3D	Derived	GIS
17	GHNPCA: Main Trekking Routes	Primary	SOI Topsheet

SOI - Survey of India
RS - Remotely Sensed Data
GIS – Geographical Information System

2.1.1 GHNPCA: Drainage

The major tributaries of Beas river such as Tirthan, Sainj, Jiwa and Parvati drain the GHNP. Most of the area has dendritic and trellis pattern (Fig.2.3). In dendritic pattern, controlling factors are homogeneous with equal resistance and have compact and hard rocks. In trellis pattern, sub tributaries are perpendicular to main stream developed along strike and the dip direction 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 the water of the project area into Beas River. Around 50% of the area lies above 4000m, which is usually snowbound and acts as a source for the perennial river system. The largest river system is the Sainj watershed. Snow and glaciers cover around 17% of area and high altitude lakes cover nearly 1% area.

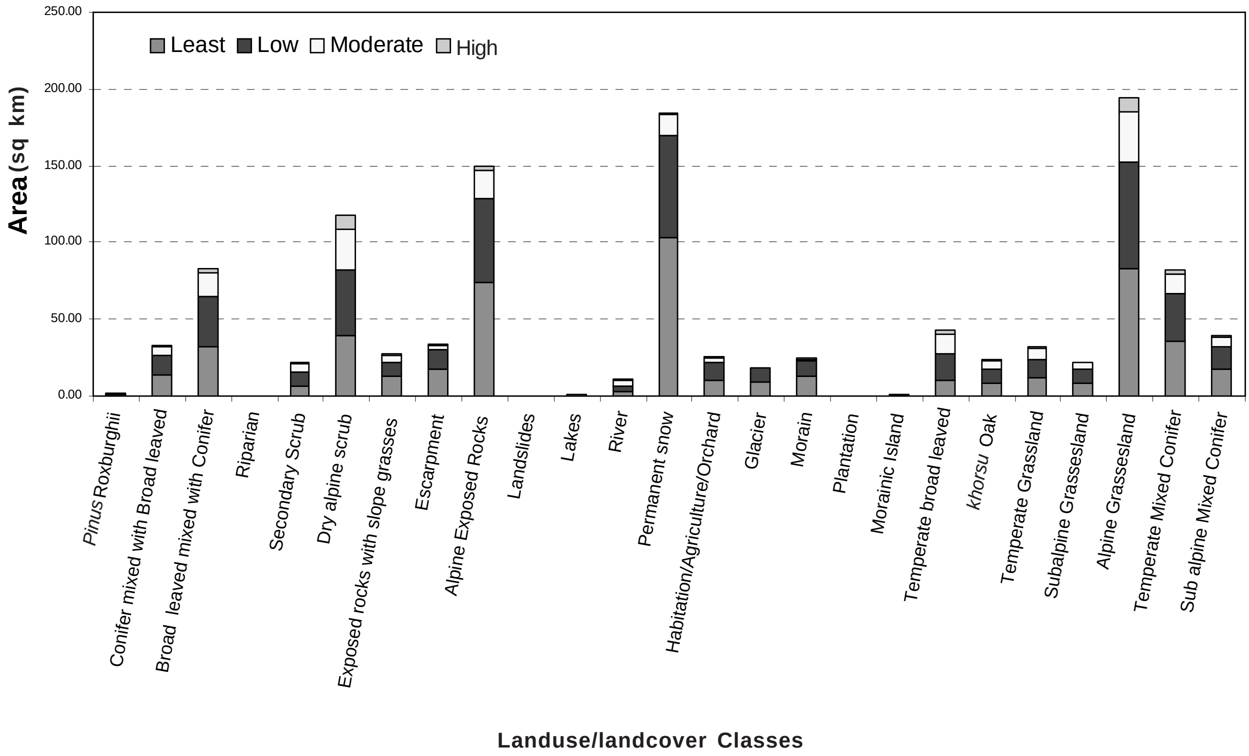
2.1.2 GHNPCA: Drainage Density

The water availability in any area is an important factor for survival of any species. The study area appears to be homogeneous in terms of water availability but for precise analysis a drainage density map was derived from line coverage using GIS functionality (Fig 2.4). The drainage density is derived using the following formula -

$$\text{Drainage Density} = \frac{\text{Total no. of Streams}}{\text{Total Area}}$$

A relationship between drainage density and vegetation has also been observed (Fig 2.5). The highest drainage density is found within alpine scrub. It may be because it is starting point of drainage system whereas the lowest drainage density is found in riparian forest.

Fig. 2.5 : Area under different drainage density classes in different landuse/landcover classes.



2.1.3 GHNPCA: Contour

Contours have been generated in GIS domain in the form of line coverage representing different elevations of the study area. The altitude of the study area varies 1344m minimum near Seund to a maximum of 6248m at an unnamed peak in the east of the study area (Fig. 2.6). In the GIS domain contours are not only the representative of elevations but also the main source of building slope, aspect and Digital Terrain Model (DEM). The contour interval has been kept at 120m.

2.1.4 GHNPCA: Aspect

Aspect has an important role to play in the utilisation of the habitat in the Himalayan landscape. The aspect map has been derived from the contour map (Fig. 2.7). The area coverage under different aspect categories is given in Table 2.3. The maximum area is found in North direction i.e. 237.1 sq.km. whereas the minimum area lies in the East direction i.e 119.4 sq.km.

Table 2.3 : Area coverage under different aspect categories

Category	Area in sq.km	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

2.1.5 GHNPCA : Slope

Slope is an important parameter for habitat characterisation. The slope map has also been derived from the contour map using GIS functionality (Fig. 2.8). The slope categories have been decided on the basis of species sighting data in respect of musk deer and western tragopan (Table 2.4).

Table 2.4 : Area coverage under different slope categories

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

2.1.6 GHNPCA : Digital Elevation Model (DEM)

In order to have a better visualisation of the terrain and topography of the study area a Digital Elevation Model (DEM) has been generated from the contour map using GIS functionality (Fig. 2.9).

2.1.7 GHNPCA : Road/Track Buffer

Although the GHNPCA is having not many metalled roads roads but because of the collection of useful herbs and edible mushrooms and grazing of sheep and goat and for collection of fodder, fuel wood, minor forest products, a number of tracks have come into existence. The total length of the roads/tracks as estimated in GIS domain is 394 km. The roads/tracks are generally considered as a disturbance factor and the disturbance has been observed upto 2000m from the center of the road, in a declining manner. Using a buffer functionality in GIS domain a road/track buffer map has been created, which visually depicts the area under disturbance in GHNPCA due to roads/tracks (Fig. 2.10).

2.1.8 GHNPCA : Geology

The study area forms a part of Inner Himalayas. A number of workers have made attempt to understand the geological complexity of the region (Sharma 1977, Sinha 1977, Valdia 1980, Mishra 1993). However, (Sharma 1977) first time tried to establish a complete geological account of this Kullu Rampur belt of about 2500 sq. km area. This work has been referred by many workers including (Mishra 1993, Wadia Institute of Himalayan Geology). As per the geological map the major rock types in the study area are Quartzite, Phyllite, Slates and Phyllite, Schist and Gneiss along with Granite having a regional trend NW-SE with a varying amount of dip due NE. These rocks have been folded, faulted and thrusted as a consequence of different tectonic episodes.

For preparing the geological map of the study area, the geological map of Satluj and Bias valley (Mishra, 1993) has been taken as a secondary data. The area of interest has been digitised in ARC/INFO GIS domain (Fig. 2.11). The description of tectinostratigraphic succession is given in Table 2.5 and has been described by (Mishra, 1993) as follows:

Rampur Formation: The major rocktypes in this formation are metavolcanics and quartzite, these have been intruded by bandal granite suppose to be 1800 million years old, roughly extending from bandal to north of Manihar (Frank, 1974). The rocks are forming an antyformal structure. These also show the sedimentary structure like cross bedding, ripple marks and bedding cleavages. This formation extant approximately from Rampur to Manikaran area. The Rampur formation is older then bandal granite. Age is around 2500 million years.

Central Crystalline Complex of Higher Himalayan: This zone is situated between two Great thrust, viz., the Main Central Thrust in the south and Tethyan Thrust in the north. This zone is comprises of Chail group, Jutogh group, Vaikrita group 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, Phylite, Quartzite, and Carboniferous slate and Mylonised gneiss. The Chail group shows three generation of folds. The rocks were developed as nappe and moved southwards along the thrust sheet, a band of mylonite augan gneiss is throughout extensively developed showing pronounced crumpling, crushing and shearing. Here mylonite means compact laminated rocks which show intense penetrative deformation. According to Mishra, the Larji Rampur window is formed on all sides by the low grade metamorphosis of the Chail group. This group extent in the west around Nirth pandow and Kullu upto Malana and south upto Jhakri in Satluj valley. The age is around 1200-1400 million years.

Jutogh Group: The low grade metamorphics of the Chail group is tectonically overlaid by the medium grade metamorphic of jutogh group along jutogh thrust. A persistent band of garnetiferous Chlorite- biotite, Phyllite, Phillonite and Carboniferous Schist follows the plain of thrust throughout the belt. The Karchham quartzite is sandwiched between the interbedded sequence of garnet-biotite schist, banded gneiss and carboniferous schist of the jutogh group. The age is estimated around 1800-2000 million years.

Vaikrita Group: The Vaikrita thrust demarcates the plain of abrupt change in grade of metamorphism and composition of the lithology. The Vaikrita consist of high-grade central crystalline. Mainly coarse grained Kynite Silimanite schist and gneiss. The rocks of Vaikrita and Jutogh group together show three phase of deformation. In Vaikrita the folds are isoclinal, recumbent to open to light along with asymmetrical and cross fold plunging in all three phases of deformation. The age of the has been estimated around Pre –Cambrian to Lower Palaeozoic.

Haimanta Group: This overlies the Central crystalline (Vaikrita Group) along a tectonic contact (Thethyan Thrust). These are low-grade metasediments, in the vicinity of the thrust zone the Sericite-Chlorite schist of the Haimanta group showing pronounced crumpling, crushing and even shearing. The Tethyan thrust is marked by break in metamorphism. Vaikrita shows Kynite, Silimanite metamorphism whereas Biotite grades metamorphism found in Haimanta group. The age is estimated around Late Precambrian. The areas under different geological formations is given in Table 2.6.

Table 2.5. Tectonostratigraphic succession in Great Himalayan National Park, Himachal Pradesh (Mishra, Wadia Institute of Himalayan Geology, 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-feldspathic 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 2.6 : Area under different geological formations in the study area

Formation	Area in sq.km	Percentage
Haimanta group	449.5	38.42
Vaikrita group	205.31	17.53
Jutogh group	211.71	18.08
Chail group	187.71	16.03
Bandle granite	2.86	0.25
Rampur formation	113.91	9.73
	1171	100

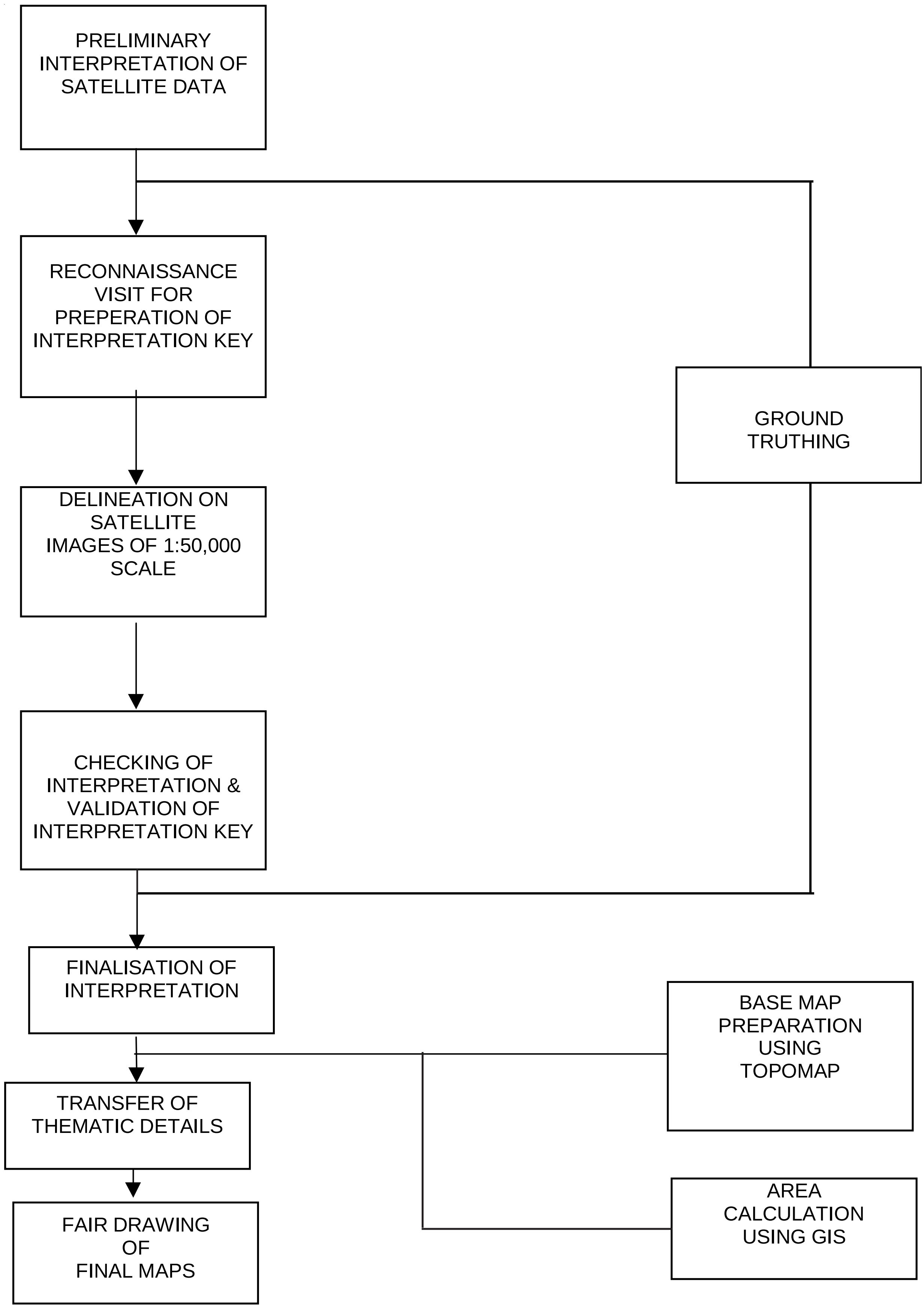
2.1.9 GHNPCA : Geo-morphology

Geomorphology is considered as “the science of land form”. James Hotton (1726-1997) stated that “the present is the key of past”. It is important to understand the geomorphology on the basis of lithology, stratigraphy, climatic variation and regional basis in the development of landforms. The increasing application of geomorphic interpretation through aerial photographs and satellite data provides an understanding of the relationship between landforms and vegetation.

Landforms effect conservation areas in many ways for example the slope, gradient, elevation and aspect affect the quantity of solar energy, water, nutrients and other materials. Slope also is the deciding factor in the intensity of disturbance, such as fire and wind, which are strongly influenced by the presence of vegetation (Swanson *et al*., 1988)

The geomorphologic map of GHNPCA has been prepared mainly through visual interpretation of IRS IB LISS II 1993-94 satellite data on 1:50,000 scale (Fig. 2.12). Some physiographic details were also transferred from toposheets (waterdivide/spurs) to base map along with interpreted units (Fig. 2.13). Nine major units have been delineated. Maximum area is covered by alpine exposed rock about 149.73 sq.km. where the minimum area is covered by Morainic islands lying in the eastern part of the study area.

Fig. 2.13 Flow chart showing steps in geomorphological mapping



Exposed Rocks: The rocks lying within subtropical to subalpine region are considered as exposed rocks. They are having an area about 27.60 sq.km. They may have been formed as a result of chaining topography (Himalaya is tectonically sensitive) and may be because of mass flow from the area because of slope affect. They are infact good habitat for prey and predator species

Alpine Exposed Rocks: This area has been considered above 3600m to 4500m where slope factor and mass movement is rapid in action. The area is about 149.73 sq.km. 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 goats.

Landslide: Landslides are purely the net result of slope failure and may be natural (Tectonic sensitivity, Gravitation, Seismic) or man made (Road construction, Grazing, Blasting, Tree felling and Mining). In the study area the landslides are natural, accruing frequently in the project area especially in the rainy season. The project area is having an acute problem of Sheet erosion, Gully erosion, Bank erosion and Glacial erosion. The areal estimation of landslides shows the figure of about 0.41 sq.km. Landslides have a negative impact because of their destructive nature.

Glacier: The Glaciers are huge solid ice mass moving or retreating in the valley floor. The glaciation of the valley has considerably modified the original topography, which has been sculptured by subsequent fluvial action. The Glaciers, Moraines and Fluvoglacial deposits generally occur in the field. The areal estimation of glaciers is about 18.82 sq.km.

Lakes: In the study area almost all the lakes have been formed by glacial erosion. These are high altitude lakes. More than 25 lakes have been observed from the project area through visual interpretation. The aerial estimation of these lakes is about 0.87 sq.km. These areas may be good habitat zones for high altitude species and may also be suitable areas for migratory birds.

Escarpments: Too vertical or very steep faces of the rock and particularly consolidated sediments are given such names as cliffs, scarps, escarpments, precipices, bluffs atc. They usually occur on hard and resistant rocks with sharp crested ridges. These are high angle slope areas used by several high altitude animals as their escape terrain. The total areal estimation of escarpment is about 33.82 sq.km

Moraine: Ridges and irregular deposits laid down by ice are spoken as Moraines. Some are associated with valley glaciers and others with ice sheets. Lateral, Medial, Valley glaciers make terminal and recessional Moraines. The interpreted Moraines may be the Lateral Moraines because they give an impression as embankments on either side of the valley. The areal estimation of moraine is about 24.24 sq.km.

Morainic Islands: Morainic Islands are in fact uplifted debris above valley floor, carried up by glacier. When the glacier melts it leaves a large part of debris in the valley. These forms may form an important site for high altitudes species especially for migratory birds, depending upon their stability. The areal estimation of these forms is about 48 sq km.

Waterdivide/ Spurs: In the Himalayas major ridges and valley floor impede free movement. The study area is having water divide/spurs starting from Laru Dhar to Kasol Dhar,Drasal Dhar,Kaili Dhar, Plangcha Dhar, Rohni Dhar and Ori Dhar. In the E and SE ridges from Pin Parwati Pass to Kokshane Peak to Gishu Pishu. SE. South and SW 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. W to NW ridges Thanigalo along Nuhara gad to Sainj Khad and along Sainj Khad to Seund , Bangidhar to Tiskana Thatch. Murda Thach to Laru Dhar. The total length of the major water divides and prominent facets has been calculated using GIS to be 723.08 km.

2.1.10 GHNPCA : Escarpment

The escarpments have already described in the section on geomorphology and are shown in Fig. 2.14.

2.1.11 GHNPCA : Terrain Complexity

The terrain of GHNPCA is characterised by numerous high ridges, deep gorges, precipitous cliffs, rocky craggs, glaciers and narrow valleys. The terrain can be expressed in the form of slope, shape but it can also be expressed in the form of 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 & Garson 1981). The terrain complexity has been measured in GIS domain. This parameter have been computed through DEM. For this appropriate contour interval of (120 m) has been considered (Fig. 2.15 and Table 2.7).

Table 2.7 : Area under different categories of Terrain Complexity

Class	Area in sq km	Percentage
Less complex	565	48.24
Moderately complex	414.46	35.40
High	182.54	15.60
	1171	100

2.1.12. GHNPCA : Landuse/Landcover

Landuse/landcover is the single most important parameter for evaluation and conservation of biodiversity (Singh, 1999). Therefore, qualitative and quantitative status of the vegetation are basic requirements for strategy formulation and future monitoring. Aero-space 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 users requirement or objectives. These images contain enormous information and to obtain these one needs to know the ground realities. In this particular exercise vegetation mapping has been carried out using remotely sensed images of September /October data of 1993. In western Himalayas these months 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.

2.1.12.1 Material and methods

Vegetation mapping has been done based in conjunction with Dr. Sarnam Singh of Indian Institute of Remote Sensning, 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:

2.1.12.2 Materials

2.1.12.2.1 Satellite Data

False Colour Composites (FCC) of IRS –1B LISS II sensor of September/ October of 1993 have been used. LISS II sensor has spatial resolution of 23.5m. One scene covers nearly 148km 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 is covered in 6 scenes of geocoded data on 1:50,000.

2.1.12.2.2 Ancillary Data

Mapping needs accurate ground truth. Survey of India topo maps have been used during the field and interpretation. Other equipment used during field work were 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 were of immense use and were used for correct recognition of vegetation types.

2.1.12.3 Methods

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.

2.1.12.3.1. 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.

2.1.12.3.2 Reconnaissance Survey

First reconnaissance survey of a short duration was carried out in the 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 key was tested and rectified wherever necessary.

2.1.12.3.3 Ground Truthing

The Earth features on an satellite data appear in different tones and textures. For correct identification it is extremely important to correlate 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.

During these trips information on vegetation types specially in shadow areas were taken and incorporated in the mapping. Almost every vegetation types has been covered during these surveys. Every time interpretation was tested and improved.

2.1.12.3.4 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 were then transferred to base map on 1: 50,000 scale.

2.1.12.3.5 Ground Checking

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. About 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.

2.1.12.3.6 Classification Scheme

The classification scheme has been designed to meet the project objectives and should be used directly by other researcher at present and future. Therefore, 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. This was done after discussion with other participants or users of this data and keeping mainly their requirements. 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%

2.1.12.3.7 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 was finalized after proper annotations on 1:50,000 scale.

2.1.12.4 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. The map was available for the other researchers for their use.

2.1.12.4.1 Mapping

The GHNPCA was visited by the team for ground truth collection in various seasons. First reconnaissance survey was conducted to familiarize with ground features and terrain. 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 2.8, and 2.9 and Landuse/Landcover map of the GHNPCA is given in Fig. 2.16.

The GHNPCA has mountains of greater Himalayas, therefore, lot of area 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.).

Mapping of vegetation has been done keeping the project requirements in mind. 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 has also been given keeping again the requirement of the project for wildlife management/conservation. Eleven features have been delineated for this purpose.

2.1.12.4.2 Area Analysis

The GHNPCA has very good forests in Tirthan and Sainj Valleys. 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 aspects having higher moisture contents harbour very rich unique flora. The area has varied land cover and land use. Ecodevelopment Zone has agricultural fields and orchards as the main landuse. 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 GHNPCA is given in Table 2.10.

Table 2.8: Interpretation Key for (a) Forests Classes for visual interpretation

S. N.	Class (Mapping)	Tone	Texture	Physiography	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	Broadleaf 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* sp. *Quercus semecarpifolia*
3	Broadleaf mixed with conifer	Various shades of red to brownish red	Medium to coarse	Gentle to medium slopes, spurs with good soil	1500-3000	Himalayan Moist Temperate Forest	*Acer sp., 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 broadleaf	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 sp., Agrostis sp., and other herbaceous plants like Primula sp., Gentiana sp., Aster sp., 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 sp., Myricaria sp.
11	Plantation	Redish brown	Fine to medium	Medium to higher slopes	1500-3300	Temperate zone plantation	Pinus wallichiana, with Abies, Acer sp.

Table 2.9: Interpretation key for (b) Non-Forest Classes

S N.	Class (Mapping)	Tone	Texture	Physiography	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	Escarp-ment	Dark cyan to dirty blackish	Medium to coarse	Very steep slopes	1500-2500	Temperate zone	Exposed Cliffs with scattered grasses
15	Lpine 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, Scrophulariaceae
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 2.10: Area Analysis of GHNPCA under different Landuse/Landcover classes

S.No.	Land Cover/Land Use Category	Area km^2	Area in %
	Forests		
1	Conifer Forest (Chir Pine)	2.08	0.178
2	Broadleaf (Ban & Kharsu Oak)	66.62	5.689
3	Broadleaf mixed with conifer	83.36	7.119
4	Mixed conifers	127.98	10.929
5	Conifer mixed with broadleaf	33.16	2.83
6	Secondary Scrub	22.28	1.902
7	Alpine Scrub	117.62	10.044
8	Slope Grasses	25.92	2.213
9	Grasslands	221.8	18.941
10	Riverain	0.14	0.011
11	Plantations	0.16	0.014
	Non-Forest		
12	Habitation/ Agriculture / Orchard	25.55	2.182
13	Exposed Rocks with slope grasses	27.6	2.357
14	Escarpments	33.82	2.888
15	Alpine Exposed Rocks with slope grasses	149.73	12.786
16	Landslides	0.41	0.035
17	Moraine Islands	0.48	0.041
18	Glaciers	18.82	1.607
19	Moraine	24.24	2.070
20	Permanent Snow	184.01	15.713
21	Lakes	0.87	0.074
22	Rivers	4.35	0.371
	Total	**1171**	**100**

2.1.12.4.3 Discussion

Subtropical forests of Chir Pine (*Pinus roxburghii*) occur mainly in the Ecodevelopment Area (EDA) and cover about 0.178% of the total area. And good patches of forest can be seen in the lower reaches amidst orchards and agricultural fields. Under storey flora is less and is put to frequent fires. These forests have tremendous biotic pressure and at some places tree density is very low. Chir Pine forest are occurring around Rolla and Sainj and Nevli. Towards Sangah from Sainj and Nevli very good forest of Chir Pine can be seen.

Most of the area is under temperate conditions and therefore, temperate broadleaf and conifer forests occupy majority of the forested land cover. Broadleaf forests in lower and upper temperate areas have been shown together and cover about 5.6% of the total area. Oaks are predominant species of these forests along with *Acer* sp. *Juglens regia, Rhododendron* sp. 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 is 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 have extensive forests of Kharsu Oak specially along drainage. Kharsu forests do not have very good ground flora. Moist broadleaf forests have high potential of minor forest produce. Gregarious formations of various tree species like, Kharsu oak is found around Shilt, upper reaches of Tung, Shakti, Hemkhudi thatch and towards Basleo Pass. Moru oak forest near Shangad, Kharongcha, above Bathad is heavily lopped. Formations of different sizes of *Acer* sp. near Lappa and above Rolla can be seen. *Rhododendron arboreum* formations grow around Kharongcha. Trees are mature and quite old.

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 more dense. Broadleaf species like *Aesculus indica, Quercus smecarpifolia, Acer* sp., *Prunus cornuta, Juglens regia* etc. and coniferous species like *Picea smithiana, Pinus wallichii, Cedrus deodara, Abies pindrew* etc.

Coniferous forest cover maximum portion of GHNPCA and form about 10.9% of the total area. Conifer forest have 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 along with varying inter-mixing of broadleaf plants as well. Broadleaf trees like *Prunus* sp., *Betula*, sp., *Quercus* sp. 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 forest near Lappa and towards Basleo Pass. Conifer forest towards Tirthan are very dense and phytodiversity is also very rich.

Coniferous forest also have 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, Celtis sp*. and also patches of bamboo 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 is associated with human activities. These are the areas subjected to overgrazing or cultivation and then abandoned. Extensive scrub of *Berberis aristata* occur on the southern slope from Nevli to Tung. In Palachan Gad around Bathad, Mashiyar, Galiyar and Chipni. *Lonicera* sp. and *Indigofera* sp. 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 form about 10% of the total area. It is 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 occur in pure patches on northern aspects near 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 aspects on 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 Thatch, Dhela Thatch, Gumtarao thatch, Manoni Thatch etc. Grasslands of subtropical, temperate and alpine zone have been maped put 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* sp., *Chrysopogon echinulatus, Oplismensus compositius, Paspalum* sp.etc.

Riverain forest occur 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* sp. and *Pyrus* sp., *Girardinia* sp. and *Berberis* sp. Temperate riverain scrub of *Hippophae* occur before and after Shakti towards Maror. These grow gregariously on flat raised riverbeds and along streams. The main species are *Hippophae salicifolia, Sorberia tomentosa* and *Rosa webbiana*. An interesting patch of Viburnum sp. 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 EDA.

A large extent of the GHNPCA is without vegetation, which is 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.

EDA has a very complex landuse. 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.

2.1.13 GHNPCA : Landuse/Landcover (Specialised Categories)

Although the data has been visually interpreted and eleven forest and eleven non forest classes have been delineated but for habitat characterization analysis of the species preferences (Western Tragopan and 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 in GIS domain using ARC/INFO software. The basis of extraction was latitudinal 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 landuse / landcover map and area of forest types and grasslands along with extracted classes through GIS is given in Fig 2.17. and the area details are given in Table 2.11.

Table 2.11 : Area under specialized categories of landuse/landcover

Class	Area in sq. km	Percentage
Pinus roxburghi	2.1	0.179
Temp Mixed conifer	82.39	7.036
Subalpine Fir	39.11	3.340
Temp. conifer and broad leaved Mix	33.21	2.836
Temp. Broad leaved and conifer mixed	83.44	7.126
Temp. Broad leaved forest	42.95	3.668
Kharsu forest	23.7	2.024
Temp. Grassland	31.7	2.707
Subalpine grassland	22.25	1.900
Alpine grassland	193.89	16.558
Riparian	0.14	0.012
Temperate secondary scrub	22.26	1.901
Alpine scrub	117.71	10.052
Plantation	0.16	0.014
Nonforest:		
Habitation/Orchard Agriculture	25.53	2.180
Escarpments	33.69	2.877
Exposed rocks with slope grasses	27.54	2.352
Alpine exposed Rocks with slope grasses	149.89	12.800
Land slides	0.42	0.036
River	10.78	0.921
Morrain	24.25	2.071
Lakes	0.86	0.073
Moranic island	0.48	0.041
Glacier	18.68	1.595
Snow	183.87	15.702
	1171	100

2.1.14 GHNPCA : 3-Dimensional Visualisation of Landuse/Landcover

The 3-Dimensional visualisation of GHNPCA landuse/landcover is given in Fig. 2.18.

2.1.15 GHNPCA : Main Trekking Routes

The main trekking routes of GHNPCA are mostly along the river valleys (Fig. 2.19). 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 sheeps and goats for grazing in appropriate season. As most of GHNPCA is inaccessible, trekking is the only option for movement. The trekking map has been generated to facilitate the development of ecotourism in the area.

CHAPTER 3 : SPATIAL DATABASE OF GREAT HIMALAYAN NATIONAL PARK (GHNP)

3.1 INTRODUCTION

The Great Himalayan National Park (GHNP) forms an integral and substantial part of the GHNPCA. The GHNP encompasses an area of nearly 1171 sq km and lies between 31° 38' 28" N to 31° 54' 58" N latitude and 77° 20' 11" E to 77° 45' 00" E longitude (Fig. 3.1). It is located at the junction of great faunal realms i.e. Palearctic and Oriental (Mackinnon *et al*, 1986). According to the Biogeographic Classification of India by Rodgers and Panwar, 1988, GHNP falls under North-Western Himalayan Biotic Province - 2A. The GHNP is well known for its rich biological 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 which support a population of endangered western tragopan and a large number of rare and threatened plant species, many of which are of medicinal values (Gaston and Garson, 1993).

3.2 SPATIAL DATABASE LAYERS OF GHNP

From the master database of GHNPCA seven database layers have been extracted for GHNP, of which 4 are primary layers and 3 are derived layers (Table 3.1).

Table 3.1 : Layers of Great Himalayan National Park

S.No.	Name	Primary/Derived	Source
1	GHNP: Base Map	Primary	SOI* Toposheet
2	GHNP: Drainage	Primary	SOI * Toposheet
3	GHNP: Contour	Primary	SOI * Toposheet
4	GHNP: Aspect	Derived	GIS
5	GHNP: Slope	Derived	GIS
6	GHNP: DEM	Derived	GIS
7	GHNP: Landuse/landcover	Primary	RS, GIS and Field Survey

SOI * - Survey of India
RS = Remotely Sensed Data
GIS = Geographical Information System

3.2.1 GHNP: Drainage

The major tributaries of Beas river such as Tirthan, Sainj, Jiwa and Parvati drain the GHNP. Most of the area has dendritic and trellis pattern (Fig. 3.2). In dendritic pattern, controlling factors are homogeneous with equal resistance and have compact and hard rocks. In trellis pattern, sub tributaries are perpendicular to main stream developed along strike and the dip direction reflects the structural controls.

3.2.2 GHNP: Contour

Contours have been generated in GIS domain in the form of line coverage representing different elevations of the study area. The altitude of the study area varies 1344m minimum near Seund to maximum of 6248m at an unnamed peak in the east of the study area (Fig. 3.3). In the GIS domain contours are not only the representative of elevations but also the main source of building slope, aspect and Digital Terrain Model (DEM). The contour interval has been kept at 120m.

3.2.3 GHNP: Aspect

Aspect has an important role to play in the utilisation of the habitat in the Himalayan landscape. The aspect map has been derived from the contour map (Fig. 3.4). The area coverage under different aspect categories is given in Table 3.2. The maximum area is found in North-East direction i.e. 144.7 sq.km. whereas the minimum area lies in the South-East direction i.e 62.8 sq.km.

Table 3.2 : Area under different aspect categories

Aspects	Area in sq. km	Percentage
North	92.4	12
North East	144.7	19
East	99.8	13
South East	62.8	8
South	66.7	9
South West	88.1	12
West	99.1	13
North West	101	14
Total	754.6	100

3.2.4 GHNP : Slope

Slope is an important parameter for habitat characterisation. The slope map has also been derived from the contour map using GIS functionality (Fig. 3.5). The slope categories have been decided on the basis of species sighting data in respect of musk deer and western tragopan (Table 3.3).

Table 3.3 : Area under different slope categories

Category	Area in sq.km	Percentage
0-20	45.6	17
21-50	149.3	56
51-70	45.1	17
71-90	25.5	10
Total	265.6	100

3.2.5 GHNP : Digital Elevation Model (DEM)

In order to have a better visualisation of the terrain and topography of the study area a Digital Elevation Model (DEM) has been generated from the contour map using GIS functionality (Fig. 3.6).

3.2.6 GHNP : Landuse/Landcover

The complete details of the landuse/landcover mapping of the study area have already been discussed in section 2.1.12. The landuse/landcover map of GHNP is given in Fig. 3.7 and the area estimation under different categories have been provided in Table 3.4.

Table 3.4 : Area estimation under different landuse/landcover classes

S.No.	Type	Area in sq. km.
1	Mixed conifer	34.68
2	Conifer and Broad Leaved Mixed	13.44
3	Broad Leaved	22.42
4	Broad Leaved and Conifer Mixed	25.35
5	Slope Grasses	25.92
6	Grasslands/ Blanks (Temp. sub Alpine & Alpine)	170.05
7	Secondary Scrub	4.13
8	Alpine Scrub	85.27
9	Habitation/Agriculture/Orchards	0.03
10	Exp.Rocks with Slope Grasses	16.03
11	Alpine Exp. Rocks with Slope Grasses	128.71
12	River	3.46
13	Lakes	0.85
14	Escarpments	29.87
15	Landslide	0.03
16	Snow	176.43
17	Morian	23.87
18	Morainic Islands	0.45
19	Glaciers	18.54
	Total	754.4

CHAPTER 4 : SPATIAL DATABASE OF SAINJ WILDLIFE SANCTUARY (SWS)

4.1 INTRODUCTION

The Sainj Wildlife Sanctuary (SWS) covers an area of 90 sq km and forms about 8% of the GHNPCA (Fig. 4.1). The SWS is surrounded by the GHNP in the North, East and South and by the Ecodevelopment Area (EDA) in the West.

4.2 SPATIAL DATABASE LAYERS OF SWS

From the master database of GHNPCA seven database layers have been extracted for SWS, of which 4 are primary layers and 3 are derived layers (Table 4.1).

Table 4.1 : Spatial Database Layers of Sainj Wildlife Sanctuary

S.No.	Name	Primary/Derived	Source
1	SWS: Base Map	Primary	SOI* Toposheet
2	SWS: Drainage	Primary	SOI * Toposheet
3	SWS: Contour	Primary	SOI * Toposheet
4	SWS: Aspect	Derived	GIS
5	SWS: Slope	Derived	GIS
6	SWS: DEM	Derived	GIS
7	SWS: Landuse/landcover	Primary	RS, GIS and Field Survey

SOI * - Survey of India
RS = Remotely Sensed Data
GIS = Geographical Information System

4.2.1 SWS : Drainage

The major tributaries of Beas river such as Tirthan, Sainj, Jiwa and Parvati drain the GHNP. Most of the area has dendritic and trellis pattern (Fig. 4.2). In dendritic pattern, controlling factors are homogeneous with equal resistance and have compact and hard rocks. In trellis pattern, sub tributaries are perpendicular to main stream developed along strike and the dip direction reflects the structural controls.

4.2.2 SWS : Contour

Contours have been generated in GIS domain in the form of line coverage representing different elevations of the study area. The altitude of the study area varies 1344m minimum near Seund to maximum of 6248m at an unnamed peak in the east of the study area (Fig. 4.3). In the GIS domain contours are not only the representative of elevations but also the main source of building slope, aspect and Digital Terrain Model (DEM). The contour interval has been kept at 120m.

4.2.3 SWS : Aspect

Aspect has an important role to play in the utilisation of the habitat in the Himalayan landscape. The aspect map has been derived from the contour map (Fig. 4.4). The area coverage under different aspect categories is given in Table 4.2. The maximum area is found in South and South-West direction i.e. 22.3 sq.km each whereas the minimum area lies in the North direction i.e 1.1 sq.km.

Table 4.2 : Area estimation under different aspect categories

Category	Area in sq. km	Percentage
North	1.1	1
North East	4.4	5
East	10.5	12
South East	20.0	21
South	22.3	25
South West	22.3	25
West	7.2	8
North West	2	3
Total	90	100

4.2.4 SWS : Slope

Slope is an important parameter for habitat characterisation. The slope map has also been derived from the contour map using GIS functionality (Fig. 4.5). The slope categories have been decided on the basis of species sighting data in respect of musk deer and western tragopan (Table 4.3).

Table 4.3 : Area estimation under different slope categories

Category	Area in sq.km	Percentage
0-20	12.1	14
21-50	67.8	75
51-70	8.0	9
71-90	2.1	2
Total	90	100

4.2.5 SWS : Digital Elevation Model (DEM)

In order to have a better visualisation of the terrain and topography of the study area a Digital Eleveation Model (DEM) has been generated from the contour map using GIS functionality (Fig. 4.6).

4.2.6 SWS : Landuse/Landcover

The complete details of the landuse/landcover mapping of the study area have already been discussed in section 2.1.12. The landuse/landcover map of SWS is given in Fig. 4.7 and the area estimation under different categories have been provided in Table 4.4.

Table 4.4 : Area estimation under different landuse/landcover categories

S.No.	Type	Area in Sq km
1	Mixed conifer	3.49
2	Conifer and Broad Leaved Mixed	1.11
3	Broad Leaved	7.61
4	Broad Leaved and Conifer Mixed	5.65
5	Grasslands/ Blanks (Temp. sub Alpine & Alpine)	32.57
6	Secondary Scrub	22.21
7	Alpine Scrub	15.67
8	Habitation/Agriculture/Orchards	0.37
9	Exposed Rocks with Slope Grasses	2.07
10	Alpine Exp. Rocks with Slope Grasses	13.62
11	River	0.16
12	Escarpments	1.00
13	Landslide	0.30
14	Snow	4.10
	Total	90

CHAPTER 5 : SPATIAL DATABASE OF TIRTHAN WILDLIFE SANCTUARY (TWS)

5.1 INTRODUCTION

The Tirthan Wildlife Sanctuary (TWS) covers and area of 61 sq km and forms about 5% of the GHNPCA (Fig. 5.1). The TWS has GHNP in the North and Ecodevelopment Area (EDA) in the West.

5.2 SPATIAL DATABASE LAYERS OF TWS

From the master database of GHNPCA seven database layers have been extracted forTWS of which 4 are primary layers and 3 are derived layers (Table 5.1).

Table 5.1 : Spatial Database Layers of Tirthan Wildlife Sanctuary

SN.	Name	Primary/Derived	Source
1	Tirthan: Base Map	Primary	SOI* Toposheet
2	Tirthan : Drainage	Primary	SOI * Toposheet
3	Tirthan : Contour	Primary	SOI * Toposheet
4	Tirthan : Aspect	Derived	GIS
5	Tirthan : Slope	Derived	GIS
6	Tirthan : DEM	Derived	GIS
7	Tirthan : Landuse/landcover	Primary	RS, GIS and Field Survey

SOI * - Survey of India
RS = Remotely Sensed Data
GIS = Geographical Information System

5.2.1 TWS : Drainage

The major tributaries of Beas river such as Tirthan, Sainj, Jiwa and Parvati drain the GHNP. Most of the area has dendritic and trellis pattern (Fig. 5.2). In dendritic pattern, controlling factors are homogeneous with equal resistance and have compact and hard rocks. In trellis pattern, sub tributaries are perpendicular to main stream developed along strike and the dip direction reflects the structural controls.

5.2.2 TWS : Contour

Contours have been generated in GIS domain in the form of line coverage representing different elevations of the study area. The altitude of the study area varies 1344m minimum near Seund to maximum of 6248m at an unnamed peak in the east of the study area (Fig. 5.3). In the GIS domain contours are not only the representative of elevations but also the main source of building slope, aspect and Digital Terrain Model (DEM). The contour interval has been kept at 120m.

5.2.3 TWS : Aspect

Aspect has an important role to play in the utilisation of the habitat in the Himalayan landscape. The aspect map has been derived from the contour map (Fig. 5.4). The area coverage under different aspect categories is given in Table 5.2. The maximum area is found in North-West direction i.e. 11.3 sq.km whereas the minimum area lies in the East direction i.e 3 sq.km.

Table 5.2 : Area estimation under different aspect categories

Category	Area in sq. km	Percentage
North	8.8	14
North East	5.3	9
East	3.0	5
South East	5.2	8
South	9.1	15
South West	8.8	14
West	9.6	16
North West	11.3	18
TOTAL	**61**	**100**

5.2.4 TWS : Slope

Slope is an important parameter for habitat characterisation. The slope map has also been derived from the contour map using GIS functionality (Fig. 5.5). The slope categories have been decided on the basis of species sighting data in respect of musk deer and western tragopan (Table 5.3).

Table 5.3 : Area estimation under different slope categories

Category	Area in sq. km	Percentage
0-20	10	16
21-50	34	55
51-70	11	18
71-90	6	11
Total	61	100

5.2.5 TWS : Digital Elevation Model (DEM)

In order to have a better visualisation of the terrain and topography of the study area a Digital Elevation Model (DEM) has been generated from the contour map using GIS functionality (Fig. 5.6).

5.2.6 TWS : Landuse/Landcover

The complete details of the landuse/landcover mapping of the study area have already been discussed in section 2.1.12. The landuse/landcover map of TWS is given in Fig. 5.7 and the area estimation under different categories have been provided in Table 5.4.

Table 5.4 : Area estimation under different landuse/landcover categories

S.No.	Type	Area in sq km
1	Mixed conifer	18.38
2	Conifer and Broad Leaved Mixed	5.51
3	Broad Leaved	4.66
4	Broad Leaved and Conifer Mixed	5.69
5	Grasslands/ Blanks (Temp. sub Alpine & Alpine)	8.71
6	Secondary Scrub	0.01
7	Alpine Scrub	9.16
8	Habitation/Agriculture/Orchards	0.09
9	Exposed Rocks with Slope Grasses	1.29
10	Alpine Exp. Rocks with Slope Grasses	5.45
11	Escarpments	1.18
12	Snow	0.80
	Total	61

CHAPTER 6 : SPATIAL DATA BASE OF ECODEVELOPMENT AREA (EDA)

6.1 INTRODUCTION

Ecodevelopment Area (EDA) is one of the important sub units of Great Himalayan National Park Conservation Area (Fig. 6.1). This is the main habitation zone having an area of 265 sq km and it forms about 22% of the GHNPCA. The EDA lies to the east of GHNPCA and the three main rivers namely Jiwa, Sainj and Tirthan drain this area. The western boundary of EDA lies in Kullu district while the Anni Tehsil lies in the south. The Kanawar Wildlife Sanctuary lies in the North-East direction. The accessibility to this area is from the western side i.e. from Mandi-Aut-Sainj/Banjar.

6.2 SPATIAL DATABASE LAYERS

From the master database of GHNPCA seven database layers have been extracted for EDA of which 4 are primary layers and 3 are derived layers (Table 6.1). In addition to this, data layers on human habitation and habitat change detection analysis have also been derived.

Table 6.1 : Spatial Database Layers of Ecodevelopment Area

S.No.	Name	Primary/Derived	Source
1	EDA: Base Map	Primary	SOI Toposheet
2	EDA : Human Habitation	Secondary	Negi (1996)
3	EDA : Drainage	Primary	SOI Toposheet
4	EDA : Contour	Primary	SOI Toposheet
5	EDA : Aspect	Derived	GIS
6	EDA : Slope	Derived	GIS
7	EDA : DEM	Derived	GIS
8	EDA : Landuse/landcover	Primary	RS, GIS and Field Survey
9	EDA : Habitation/Agriculture./Orchard (1961)	Derived	GIS
10	EDA Habitation/Agriculture./Orchard (1993)	Derived	GIS
11	EDA : Change Detection between 1961 –1993	Derived	GIS

SOI - Survey of India

RS = Remotely Sensed Data

GIS = Geographical Information System

6.2.1 EDA : Landuse and People of the Area

There are 13 revenue villages, 123 hamlets in EDA having 2465 households and a population of 11715 (Table 6.2 and Fig. 6.2).

Table 6.2 : Population and Number of Hamlets in the Revenue Villages of EDA

Tehsils / Waziri	Kothi	Phanti/Revenue village	No. of Major Hamlets	No. of Households	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	1. Shili	4	137	812
Sainj/Inner Seraj	Banogi	1. 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	1. Railla	19	512	512
Total	**8**	**13**	**123**	**2465**	**11715**

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

The population growth statistics for the period 1981, 1991 and projections for the year 2001 are given in Table 6.3.

Table 6.3 : Population growth statistics of EDA

Name of villages	1981	Total Population (1991)	Total Projected Pop. 2001
1. Chipni	1187	1537	1982
2. Mashyar	948	1280	1728
3. Pekhri	841	1098	1427
4. Tinder	541	677	846
5. Srikot	339	417	513
6. Kalwari	978	1132	1313
7. Shili	618	812	1064
8. Suchen	914	1212	1600
9. Shangurh	462	618	822
10. Lapah	173	222	284
11. Sainshar	1183	1606	2184
12. Garaparli	490	592	716
13. Raila	426	512	614
Total	9100	11715	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.

Table 6.4 : Social structure of the population in EDA

Name of Village	Total Popu-lation	Males	Females	Sex Ratio	Total SC Popu-lation	SC Males	SC Females	% of SC to Total Pop.	Total ST Popu-lation	Total Literates	Male Literates	Female Literates	% of Literate to Total Pop.
Chipni	1537	793	744	938	536	247	262	35	0	490	352	138	32
Mashyar	1280	647	633	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 practised 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 1997).

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* spp., *Corylus jaeguemontli*, and some shrubs like *Indigofera spp.*, *Desmodium* spp. *Thalmnocalamus spathiflora* 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* spp. and the alpine *Juniperus* spp. and *Rhododendron* spp.

6.2.2 EDA : Drainage

The major tributaries of Beas river such as Tirthan, Sainj, Jiwa and Parvati drain the GHNP. Most of the area has dendritic and trellis pattern (Fig. 6.3). In dendritic pattern, controlling factors are homogeneous with equal resistance and have compact and hard rocks. In trellis pattern, sub tributaries are perpendicular to main stream developed along strike and the dip direction reflects the structural controls.

6.2.3 EDA : Contour

Contours have been generated in GIS domain in the form of line coverage representing different elevations of the study area. The altitude of the study area varies 1344m minimum near Seund to maximum of 6248m at an unnamed peak in the east of the study area (Fig. 6.4). In the GIS domain contours are not only the representative of elevations but also the main source of building slope, aspect and Digital Terrain Model (DEM). The contour interval has been kept at 120m.

6.2.4 EDA : Aspect

Aspect has an important role to play in the utilisation of the habitat in the Himalayan landscape. The aspect map has been derived from the contour map (Fig. 6.5). The area coverage under different aspect categories is given in Table 6.5. The maximum area is found in North direction i.e. 45.75 sq.km each whereas the minimum area lies in the North-West direction i.e 29.13 sq.km.

Table 6.5 : Area estimation under different aspect categories

Aspect	Area in sq.km	Percentage
North	45.75	17
North East	29.87	12
East	32.42	11
South East	31.35	12
South	29.44	13
South West	33.32	14
West	34.29	12
North West	29.13	9
Total	265.6	100

6.2.5 EDA : Slope

Slope is an important parameter for habitat characterisation. The slope map has also been derived from the contour map using GIS functionality (Fig. 6.6). The slope categories have been decided on the basis of species sighting data in respect of musk deer and western tragopan (Table 6.6).

Table 6.6 : Area estimation under different slope categories

Category	Area in sq.km	Percentage
0-20	45.6	17
21-50	149.3	56
51-70	45.1	17
71-90	25.5	10
Total	265.6	100

6.2.6 EDA : Digital Elevation Model (DEM)

In order to have a better visualisation of the terrain and topography of the study area a Digital Elevation Model (DEM) has been generated from the contour map using GIS functionality (Fig. 6.7).

6.2.7 EDA : Landuse/Landcover

The complete details of the landuse/landcover mapping of the study area have already been discussed in section 2.1.12. The landuse/landcover map of EDA is given in Fig. 6.8 and the area estimation under different categories have been provided in Table 6.7.

Table 6.7 : Area 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

6.2.8 EDA : 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.

6.2.8.1 Methodology : For the Change Detection Analysis the following data sources were used:

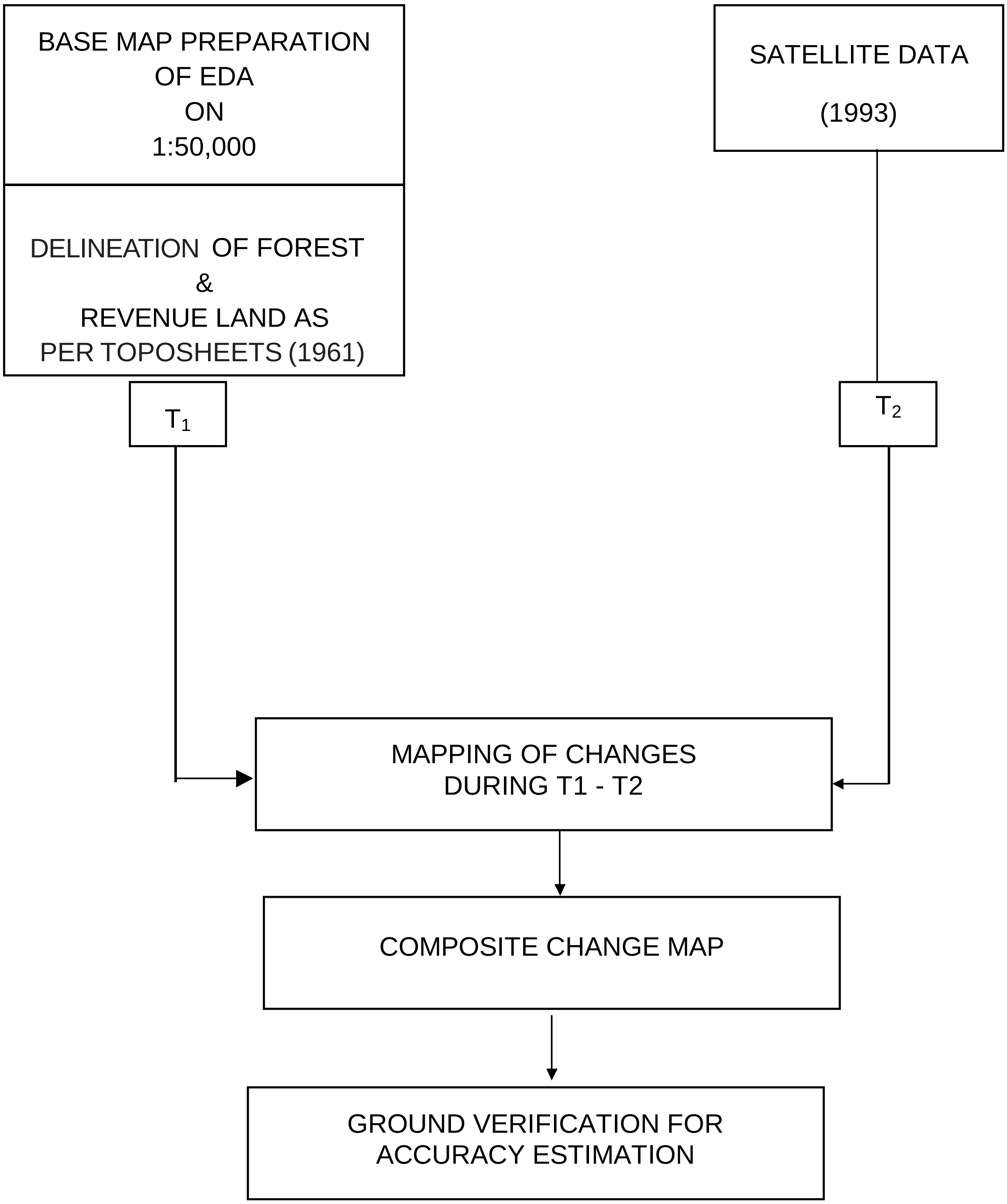
(i) SOI Toposheet 1961

(ii) Satellite Imageries 1993

(iii) Census Data 1961 and 1991

The methodology used in detecting changes in landuse/landcover is shown in Fig. 6.9.

Fig. 6.9 : Flow chart shown steps in Change Detection Analysis



6.2.8.2 Results : The changes in biomass consumption between 1961 and 1991 are given in Table 6.8.

Table 6.8 : EDA : Changes in biomass consumption between 1961 - 1991

Waterhsed/ Sub Water Shed	No. of House-holds 1961	No. of House-holds 1991	Fuelwood Consumption 1961 '00 kg	Fuelwood consumption 1991 '00 kg	%change in Fuelwood Consumption between 1961-1991	Fodder 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	

The number of households in EDA have increased from 1364 in 1961 to 2465 in 1991 and the fuelwood consumption has also registered 78% increase during this period. Similiary, the fodder consumption has also increased during this period. The Habitation/Agriculture/Orchard areas in EDA in 1961 and 1993 are shown in Fig. 6.10 and 6.11 respectively and the changes occurring are depicted in Fig. 6.12 and Table 6.9. There has been an increase of about 9 sq km in the areas under Habitation/Agriculture/Orchard and a decline of about 4 sq km of forest area during the period 1961 to 1993.

Table 6.9 : EDA - Population changes in EDA alongwith areas under Habitation/ Agriculture/Orchards

EDA Population 1961	EDA Population 1991	Name of Water-shed	Total Area sq.km	Change between 1961-91 sq.km	% Increase	Area not Currently Under cultivation	% Decrease	% Increase Population (1961-91)
3041	2710	Jiwa	23.5	1.16	4.93	0.34	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

CHAPTER 7 : HABITAT SUITABILITY MODELLING IN GHNPCA

7.1 INTRODUCTION

In the Great Himalayan National Park Conservation Area (GHNPCA) 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 (1990) assessed the status of goral in GHNPCA in late 1989. The GHNPCA has rich biodiversity as compared to the other areas in similar altitude in the 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 also been recognized as one of the globally important "Endemic Bird Areas" by the International Council for Bird Preservation (ICBP, 1992). Himalayan musk deer (*Moschus chrysogaster)* has been recorded in the Tirthan valley in GHNP (Gaston *et al*., 1981). Habitat includes a wide range of components 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 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 analysis, 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, 1991a).

Porwal and Roy (1991a&b) used habitat suitability rating technique in various management sectors of Kanha National Park, Madhya Pradesh. 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.

7.2 HABITAT CHARACTERIZATION

The Great Himalayan National Park Conservation Area (GHNPCA) supports a population of endangered pheasants, especially Western Tragopan and Himalayan Musk Deer. Considering the significant conservation importance of these species their habitat characterization has been attempted in this study. K. Ramesh, S. Sathyakumar and G. S. Rawat (1999) and Vinod , T. R. and S. Sathyakumar (1999) collected field data on Western Tragopan and Musk Deer respectively as part of the WII project and their sighting data has been used for habitat characterization.

7.3 HABITAT OF WESTERN TRAGOPAN (*Tragopan melanocephalus*)

Pheasants are commonly known as game birds. The distribution of these pheasants extends from Eastern Shore of the Black Sea to the Caspian Sea (Hill & Robertson 1988). Western Tragopan are distributed in temperate coniferous forest having sufficient understorey (Islam, 1982). These pheasants are generally observed to select specific habitat conditions. During winter when the habitat is snow bound and has low 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 parameters required for western tragopan based on field observation and literature: - (Islam, 1982; Ali & Ripley, 1983; Duke, 1990; Gaston, *et al*., 1993; Prasad, 1993; Pandey, 1993) are given below.

- It inhibits spruce (*Picea smithiana)*, deodar (*Cedrus deodara*) and brown oak (*Quercus semicarpifolia*) forests at the upper edge of the tree line 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 inhibits the dense vegetative cover (canopy cover) (Prasad, 1993).

7.3.1 Field Observations

The inventory data for Western Tragopan is based on radio collared female bird in spring season (breeding season). The territory of the bird was worked out to be about 500 m (K. Ramesh, S. Sathyakumar and G. S. Rawat 1999). On the basis of sighting evidences the minimum and maximum elevation have been determined to be between 2750m and 2890m respectively. Likewise slope category has been considered to be min. 25^{0} and max. 45^{0} respectively.

7.4 HABITAT OF MUSK DEER (*Moschus chrysogaster)*

Musk deer is a ungulate which usually lives singly, in well spaced territories and occurs in relatively low densities. Isolation depends on the relief of the area.

According to Sathyakumar *et al.*, (1992) the Himalayan musk deer is threatened due to two major pressures namely-

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

It is a nocturnal animal of the subalpine and alpine scrub between the elevations 2500 m to tree line, approximately 3800 m. It rests all day in dense undergrowth of subalpine to alpine scrub. The biotic pressures in the tree line area affect its abundance and habitat.

The habitat parameters required for musk deer are summarized below. These are based on field observations and literature survey-

- Musk deer prefers 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).
- Because of seasonal latitudinal migration, a plentiful cover in spruce, fir forest, salix juniper-berch association is truly controlling factor (Dang, 1968).
- No recorded instance of musk deer drinking at pool, lake or streams is known but they have been observed on high cliff rock possibly for salt, lichens or water (Dang, 1968).
- Most preferable hollows occupied by deer is salix-juniper followed by rhododendron and birch thicket (Dang, 1968).
- Caves are often found to have been used by musk deer based on pile of dung pellets. High caves and overhangs are used during autumn when they move higher for feeding on lichen and mosses (Sathyakumar, 1994).
- They feed on high cliff and rocky terrain especially in evening and night hours (Green, 1985).

7.4.1 Field Observations

The inventory data collected for musk deer was for spring season. The territory of the animal was observed to be near about 1000 m (Vinod, T. R. and S. Sathyakumar, 1999). On the basis of sighting evidences the minimum and maximum elevation has been considered to be 3300m and 3760m respectively. Likewise slope condition range has been considered to be min. 30 ^{0} and max. 55 ^{0} respectively.

7.5 METHODOLOGY

Visual interpretation of IRS IB LISS II (with ground resolution of 36.25m) was carried out for preparing landuse/landcover map. Ground survey was done for evolving a classification scheme for vegetation mapping. Other ground data and restrictive factors for animal species were incorporated based on inventory data. Contour were digitized and interpolated to develop a Digital Terrain Model (DEM) and the 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, GIS. Spatial modelling was done to determine the habitat suitability of western tragopan and musk deer. 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 and habitat characterization by done through overlay analysis.

7.6 HABITAT ANALYSIS

7.6.1 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. Grid size can be changed as per the required level of details. Considering the territory of western tragopan and musk deer grid size 500m and 1000m respectively were used. Interspersion values provide an indication of an area in terms of homogeneity and heterogeneity (Table 7.1 and 7.2).

Table 7.1 : Interspersion values for Western Tragopan (Grid size 500m)

	Area in sq. km.	Percentage
Homogeneous	209.96	17.93
	143.24	12.23
	152.35	13.01
	172.94	14.77
	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 7.2 : Interspersion values for Musk Deer (Grid size 1000m)

	Area in sq. km.	Percentage
Homogeneous	91.83	7.84
	97.14	8.29
	130.16	11.11
	156.94	13.4
	177.8	15.18
	176.27	15.05
	154.91	13.22
	119.18	10.21
Heterogeneous	66.77	5.70
Total	1171	100

7.6.2 Juxtaposition

The juxtaposition is a measure of proximity of habitat type and relative adjacency, accomplished by defining the grid, which has been placed on forest type map based on the field observation of the habitat size. Grid wise interspersion and juxtaposition was calculated in GIS domain. The western tragopan and musk deer habitat preferences of vegetation cover were given weightages to produce the juxtaposition map (Tables 7.3 and 7.4).

Table 7.3 : Juxtaposition Weightages : Western Tragopan (Spring Data)

	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	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 (*Pinusroxburghii*)	0	1	4	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Temp. mixed conifer	3	10	6	8	6	2	8	6	3	2	1	0	5	5	2	1	7	5	0	0	8	0	0	0	0	0	2	2
Subalpine M-conifer	0	6	3	4	1	0	1	7	1	1	0	0	0	0	0	0	3	7	0	0	5	0	0	0	0	0	1	0
Conifer & broad leaved mixed	2	5	7	5	1	3	4	6	5	4	3	0	8	5	1	1	2	2	1	0	7	0	0	0	0	0	0	5
Broad leaved & conifer mixed	2	5	3	6	2	3	6	5	4	3	2	0	3	6	3	1	3	3	0	0	2	0	0	0	0	0	0	3
Subtropical broad leaved	0	5	3	3	3	0	6	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Temp. broad leaved	1	7	4	4	5	0	5	8	2	1	1	1	1	1	0	0	5	7	0	0	5	0	0	0	0	0	0	0
Subalpine broad leaved	0	7	8	5	7	0	9	10	0	1	7	0	4	6	1	0	5	6	1	0	7	0	4	0	0	0	4	1
Riperian	0	3	1	5	4	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Secondary scrub	0	2	1	4	3	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dryalpine scrub	0	0	0	0	0	0	1	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Subtropical grassland	1	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Temperate grassland	0	5	1	3	2	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Subalpine grassland	0	1	3	4	2	0	4	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alpine grassland	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Habilation/Agri/Orchard	0	4	2	3	2	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cliffs	0	7	5	2	3	0	3	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Exposed rock with slope grassess	0	7	5	4	2	0	2	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alpine exposed rocks with grasses	0	0	0	1	1	0	0	0	0	0	0	0	0	0	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	0	0	0	0	0	0	0	0	0	0	0	0	0	0
River	0	8	5	7	2	0	5	7	0	0	0	0	0	0	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	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	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	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	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	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Permanent snow	2	2	1	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plantation	0	2	0	5	3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 7.4 : Juxtaposition Weightages : Musk Deer (Spring Data)

	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	Alpine grassland	Habitation/Agri/Orchard	Cliffs	Exposed rock with slope grassess	Alpine exposed rocks with grasses	Landslide	River	Sand bar	Lakcs	Morain	Morainic island	Glacier	Permanent snow	Plantation
Conifer (*Pinus roxburghii*)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Temp. mixed conifer	0	0	3	1	1	0	0	3	0	0	4	0	0	3	2	0	1	1	0	0	0	0	0	0	0	0	0	2
Subalpine M-conifer	0	3	7	4	4	0	1	10	0	1	10	0	2	6	4	0	2	2	2	0	1	0	0	0	0	6	6	2
Conifer & broad leaved mixed	0	1	4	3	3	0	1	4	0	0	5	0	0	6	3	0	1	1	1	0	0	0	0	0	0	2	2	2
Broad leaved & conifer mixed	0	1	4	3	3	0	1	4	0	0	5	0	0	6	3	0	1	1	1	0	0	0	0	0	0	2	2	2
Sobtropical broad leaved	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Temp. broad leaved	0	0	1	1	1	0	0	5	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	4	8	1
Subalpine broad leaved	0	3	10	4	4	0	5	9	0	1	10	0	2	5	4	0	2	2	2	0	0	0	0	0	0	0	0	1
Riperian	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Secondary scrub	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dryalpine scrub	0	4	10	5	5	0	0	10	0	0	10	0	4	8	6	0	0	0	0	0	0	0	0	0	0	2	8	0
Subtropical grassland	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Temperate grassland	0	0	2	0	0	0	0	2	0	0	4	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Subalpine grassland	0	3	6	6	6	0	1	6	0	0	8	0	1	3	2	0	2	2	1	0	1	0	0	0	0	2	2	0
Alpine grassland	0	2	4	3	3	0	0	4	0	0	6	0	1	2	2	0	2	2	1	0	0	0	0	0	0	1	1	0
Habitation/Agri/Orchard	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cliffs	0	1	2	1	1	0	0	2	0	0	0	0	0	2	2	0	6	2	3	0	0	0	0	0	0	1	1	0
Exposed rock with slope	0	1	2	1	1	0	0	2	0	0	0	0	0	1	1	0	3	2	2	0	0	0	0	0	0	1	1	0
Alpine exposed rocks with	0	0	2	1	1	0	0	2	0	0	0	0	0	1	1	0	3	2	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	0	0	0	0	0	0	0	0	0	0	0	0	0	0
River	0	0	1	0	0	0	0	0	0	0	0	0	0	1	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	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	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	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	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glacier	0	0	6	2	2	0	4	0	0	0	2	0	0	2	1	0	1	1	0	0	0	0	0	0	0	0	0	0
Permanent snow	0	0	6	2	2	0	4	0	0	0	2	0	0	2	1	0	1	1	0	0	0	0	0	0	0	0	0	0
Plantation	0	2	2	2	2	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

7.7 RESULTS AND DISCUSSION

Habitat Suitability Index (HSI) for Western Tragopan and Musk Deer have been developed by assigning appropriate weightages to each parameter, i.e. landuse/landcovercover, interspersion, juxtaposition and restrictive factors. The process involved in developing HSI is shown in Fig. 7.1. Developing Habitat Suitability Indices (HSI) for indicator species is a well accepted practice for characterisation of habitats. In the present study an attempt has been made to determine the habitat suitability and availability of potential habitats for western tragopan and musk deer, based on several gr ound based parameters as well as using spatial analytical techniques. Tables 7.5 and 7.6 give area under various habitat suitability classes for western tragopan and musk deer respectively. Figures 7.2 and 7.3 visually depict the habitat suitability classes for the above species in GHNPCA.

Table 7.5 : Area under each habitat suitability class for Western Tragopan

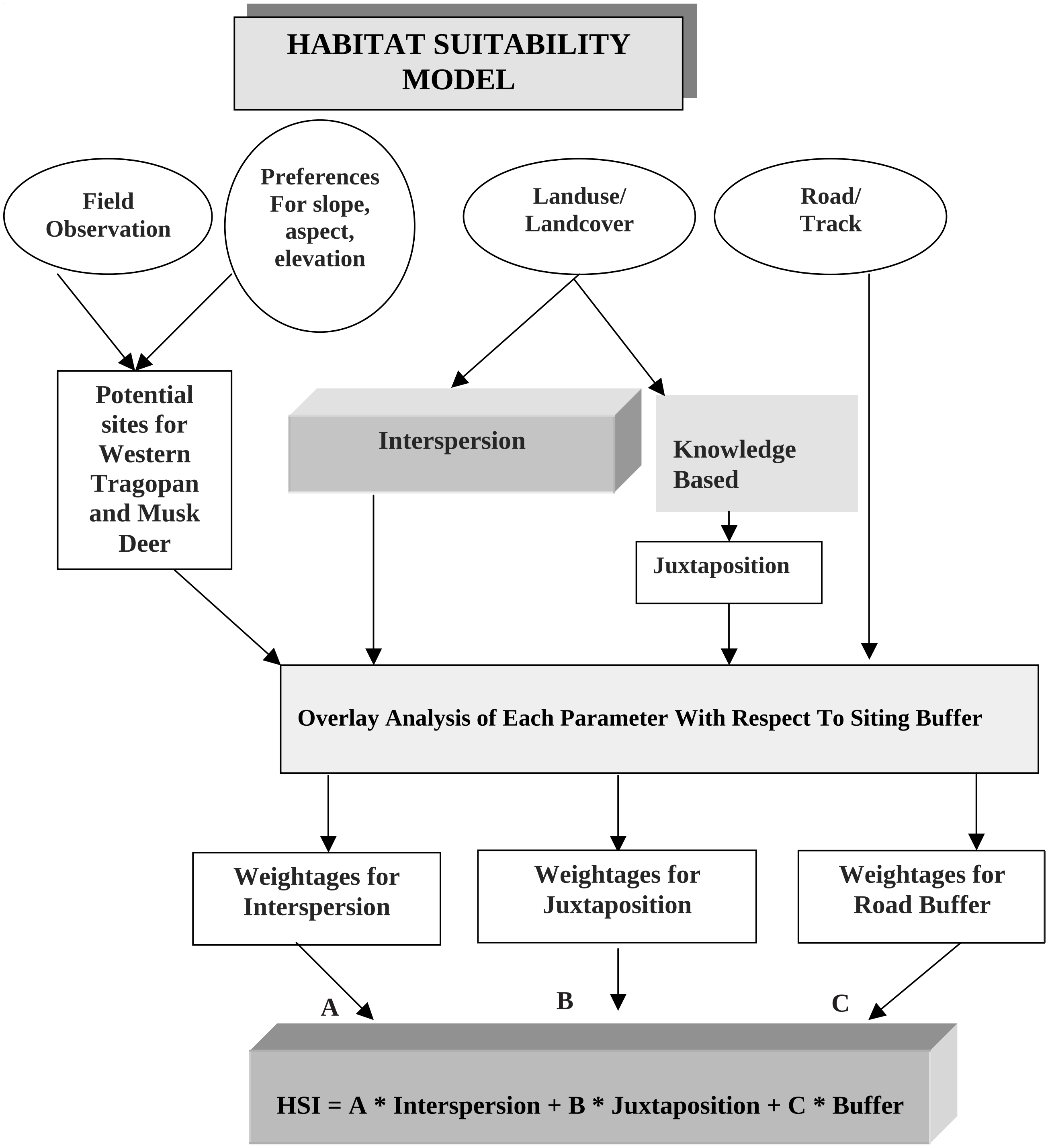
Habitat Suitability Class	Area (km^2)	%
Low	788.96	67.37
Medium	259.73	22.18
High	122.3	10.44
Very High	0.01	0.00
TOTAL	1171	100.00

Table 7.6 : Area under each habitat suitability class for Musk Deer

Habitat Suitability Class	Area (km^2)	%
Low	636.69	54.37
Medium	240.85	20.57
High	248.22	21.20
Very High	45.24	3.86
TOTAL	1171	100.00

It is apparent from Table 7.5 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 also about 54% of the area is having a low suitability whereas about 21% area has a high suitability. Appropriate management interventions would have to be employed to increase the habitat suitability for these species in the GHNPCA. It is to be stated that the HSI modelling undertaken in the study is based on a very small dataset and would have to be refined in order to take into account the influence of seasonal variations in abundance and other associated parameters in order to arrive at definite conclusions.

Fig. 7.1 : Flow chart showing process involved in developing Habitat Suitability Index (HSI)



CHAPTER 8 : CONCLUSION AND RECOMMENDATIONS

- This task has resulted in the development of a very comprehensive spatial database of the Great Himalayan National Park Conservation Area (GHNPCA) in GIS domain. Resource maps have been developed on the physical, floral, faunal and socio-economic attributes, which are of direct relevance and use by the GHNPCA management.

- It is recommended that the spatial database developed at WII under the FREE-GHNP Project should be transferred to the PA headquarters at Kullu, for which appropriately configured hardware and specialized GIS software would be required.

- The database has both spatial and non-spatial attributes and it would be necessary for the GHNPCA Management to periodically update the records in order to incorporate temporal changes.

- In this task 1993 satellite imageries have been used to prepare the landuse/landcover map. It is suggested that satellite data is again procured in 2003 so that a change detection analysis for a ten year period (2003-1993) can be carried out.

- The most immediate and substantial use of the GHNPCA database would be in preparation of the Management Plan of the area, for which appropriate steps must be initiated by the PA authorities.

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