A SPATIAL ANALYSIS OF DIFFERENT FOREST COVER TYPES USING GIS AND REMOTE SENSING TECHNIQUES.

A case study in Shivapuri area, Nepal.

Ana Isabel Tan Sotomayor
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A case study in Shivapuri area, Nepal.

by

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Submitted to the Forest Science Division in partial fulfillment of the requirements for the degree of Master of Science in Geo-information for Forest and Tree Resource Management.

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ABSTRACT

In 1976 the government of Nepal initiated the Shivapuri Water Development Project, in which the main objective were to increase the water supply of high quality drinking water through the conservation and rehabilitation of the watershed, and to develop Shivapuri as a recreational area. In addition, the Shivapuri Watershed is an important wildlife reserve with a rich flora and fauna. In order to manage and conserve the area, surveys need to be carried out to monitor the state of the resources. One of these was undertaken by Acharya in 1999 with the main objective to contribute to the methods and knowledge base needed for planning and managing biodiversity conservation.

Because Acharya’s work was based on terrestrial survey, the method is time consuming and requires much effort. The research described in this thesis was made in order to investigate if Landsat-TM is suitable to assess the species richness, stem density and basal area of three forest strata in the Shivapuri area. The use of remotely sensed images would then allow making faster studies and monitoring the forest cover and their spatial characteristics.

To fulfill this objective, the vegetation databases and the models of spatial distribution patterns of tree species developed by Acharya in 1999 were used. All this information was compared with the Landsat TM image in order to find the suitability of this image for the spatial vegetation distribution in the area.

The analysis involved using both statistical and geostatistical methods to obtain the relationship between vegetation characteristics data and the information obtained from Landsat TM image. The pure radiance was selected from the band 5 and these values were correlated with the vegetation data. The result showed that no correlation between the two sets of data exists. Then the image transformation such, NDVI, S NDVI, Ratio image and Sum normalized were made with the objectives to enhance the forest areas into the image, and reduce the shadow effects and noise. The digital values per each were selected and again correlated with field data. The application of the previous methods gave also a low correlation, however NDVI was used as the best one.

With that data the kriging model was developed in ILWIS and Surfer, which was fitted, using data from semivariogram models (sill, nuggets and range). This model was compared with the model obtaining from the data field. The result showed that the estimation of the spatial forest variation in the area using date of Landsat TM imagery is unreliable for monitoring forests characteristics. The image spatial resolution did not have sufficient capability to show the high spatial variation into the forest area.

However, the modeling with Forest Canopy Density Map program showed very good capacity to bring information about the actual forest cover. The comparison of this information with the modeling of human disturbance made by Acharya showed a good agreement. In both cases, the same spatial characteristic of the vegetation exists. Therefore, the use of this program is recommended for the future monitoring of the forest cover type in the area.
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TABLE OF CONTENTS

LIST OF TABLES ........................................................................................................ vi

1. INTRODUCTION ................................................................................................. 1
   1.1 Biodiversity ...................................................................................................... 1
   1.2 Problem Definition ........................................................................................ 2
   1.3 Research Objectives ..................................................................................... 5
   1.4 Research Questions ..................................................................................... 5
   1.5 Research Approach and Outline of the Thesis ........................................... 5

2. TERRESTRIAL WORK IN SHIVAPURI AREA ................................................. 7
   2.1 Spatial Variability of Forest Parameters in the Shivapuri Area ............... 7
   2.2 Characteristics of the Shivapuri Study Area ............................................ 8
      2.2.1 Location ................................................................................................... 9
      2.2.2 Climate .................................................................................................... 10
      2.2.3 Topography ............................................................................................ 10
      2.2.4 Vegetation ............................................................................................. 11
      2.2.5 Forest Types .......................................................................................... 12
   2.3 Field Data ..................................................................................................... 12
      2.3.2 Data Collection ...................................................................................... 14

3. REMOTE SENSING IN VEGETATION STUDIES ........................................... 16
   3.1 Introduction .................................................................................................. 16
   3.2 The Reflectance Characteristics of the Vegetation .................................... 17
   3.3 Landsat-Tm Imagery .................................................................................. 19
   3.4 Image Transformations ................................................................................ 20
      3.4.1 Normalized Difference Vegetation Index .............................................. 20
      3.4.2 Forest Canopy Density .......................................................................... 20

4. MATERIALS AND METHODS ......................................................................... 22
   4.1 Materials ...................................................................................................... 24
   4.2 Preparatory Work Before Going to the Field ............................................. 24
      4.2.1 Preparatory Image Processing ................................................................. 24
   4.3 Materials Selected For The Field Work .................................................... 28
   4.4 Field Work Data Collection ....................................................................... 28
   4.5 Post Field Work ......................................................................................... 29
4.6 Preparation of Reference Image .......................................................................... 30
  4.6.1 Best Band Selection ......................................................................................... 31
4.7 False Color Composite .......................................................................................... 33
4.8 Image Classification .............................................................................................. 34
  4.8.1 Supervised Classification ................................................................................. 34
4.9 Relationship Between Vegetation Radiance and Forest Vegetation Parameter.35
4.10 Image Correction ................................................................................................. 36
  4.10.1 Sum-Normalization Image Classification ...................................................... 36
4.11 Ratio Image Classification .................................................................................. 38
4.12 NDVI ..................................................................................................................... 38
4.13 Standard Deviation ............................................................................................. 39
4.14 Forest Canopy Density Map............................................................................... 40
4.15 Data Collection And Processing......................................................................... 42
4.16 Kriging Model...................................................................................................... 43
4.17 Final Output......................................................................................................... 43
4.18 Accuracy Analysis ............................................................................................... 44
5. ANALYSIS OF THE IMAGE AND RESULT ..................................................... 46
  5.1 Relationship Between Vegetation Radiance and Forest Vegetation Parameter.46
  5.2 Geostatistical Analysis .......................................................................................... 47
    5.2.1 Model Fitting .................................................................................................... 48
    5.2.2 Spatial Modeling .............................................................................................. 55
    5.2.3 Trend ................................................................................................................ 59
  5.3 Final Comparision Between Digital Values And Field Data............................. 63
    5.3.1 Making The Maps Consistent ........................................................................... 64
    5.3.2 Evaluation of Agreement................................................................................ 68
  5.4 FCD Map................................................................................................................ 72
  5.5 Conversion of FCD Maps Into GIS And IIWIS Environment.......................... 73
6. CONCLUSIONS AND RECOMENDATION ...................................................... 76
  6.1 Conclusions ............................................................................................................ 76
  6.2 Recommendations .................................................................................................. 77
References: ................................................................................................................ 78
Appendix1 Kappa statistics.................................................................................... 81
7. Appendix 2 ............................................................................................................... 84
LIST OF TABLES

Table 2-1 Slope categories in Shivapuri Area ................................................................. 10
Table 2-2 Area (ha) of different forest types in the Shivapuri area .................................. 12
Table 2-3 Extract from the database of Acharya ............................................................. 14
Table 3-1 Principal applications for vegetation of the Landsat7-TM (Bakker et al., 2000) .... 19
Table 4-1 Small examples of the database with radiance collect from the Landsat-TM data .... 29
Table 4-2 Small examples of the database collect from the Landsat7-TM data (Standard Deviation with filter 3x3) .......................................................................................................................... 30
Table 4-3 Correlation Matrices .......................................................................................... 33
Table 4-4 Bands correlation and statistic parameter .......................................................... 37
Table 5-1 Correlation analyses between band 5 of Landsat7-TM and Forest Parameter Site 1 . 47
Table 5-2 Correlation analyses between band 5 of Landsat7-TM and Forest Parameter Site 2 . 47
Table 5-3 Count model parameters site 1 .............................................................................. 48
Table 5-4 Two-dimensional tables in which two raster map was reclassified. ......................... 64
Table 5-5 Confusion Matrix for Landsat7-TM Species Richness Map in the site1 .............. 68
Table 5-6 The proportion of each class used in the calculation of Var. (K) ......................... 68
Table 5-7 Confusion Matrix for Landsat7-TM Species Richness Map in the site 2 ................. 69
Table 5-8 The proportion of each class used in the calculation of Var. (K) ............................. 70
Table 5-9 Confusion Matrix for Landsat7-TM Stem Density Distribution Map in the site1 ...... 71
Table 5-10 The proportion of each class used in the calculation of Var. (K) ......................... 71
Table 5-11 Percentage of forest cover according with the range classes ............................... 72
LIST OF FIGURES

Figure 1-1 Example of the spatial forest variation obtained from Acharya in his terrestrial survey of the Shivapuri area, Nepal. .................................................................3
Figure 1-2 Research approach.................................................................................................6
Figure 2-1 Location of the study area. Source: Ohio State University ..................................9.
Figure 2-2 Location of the study area and sample plot. The symbol ● indicate plots of survey site...13
Figure 3-1 The behavior of the reflectance of different cover types.........................................17
Figure 4-1 Flow chart showing the conceptual framework.........................................................22
Figure 4-2 Flow chart showing the conceptual framework.........................................................23
Figure 4-3 Image covering Shivapuri area. ..............................................................................31
Figure 4-4 three different FCC combinations in with the vegetation areas appear with different tonalities. In the image (1) the combination used was 5,4,3. Image (2) the combination was 4,5,3, and in the image (3) the combination was 4,3,2 ........................................34
Figure 4-5 Supervised classification of the Landsat TM image ..................................................35
Figure 4-6 Sum -normalizations image of the band 5. ................................................................37
Figure 4-7 Ratio image, in which is possible to appreciate the forest variation. The ratio image selected was (TM4/TM3)*80. .................................................................38
Figure 4-8 NDVI of the area, in this map we can see the high values with the red and pink color, which are represent forest, it are covering most of area .................................................................39
Figure 4-9 Standard Deviation of maximum NDVI showing habitat heterogeneity in the site 1 and 2.40
Figure 4-10 Modeling human disturbances made by Acharya using data field .........................41
Figure 5-1 Graphs showing the model fitting for the DV of NDVI in the site 1 ............................49
Figure 5-2 Graphs showing the model fitting for the DV of NDVI Standard Deviation in the site 1...50
Figure 5-3 Graphs showing the model fitting for the DV of Ratio image in the site 1 .......................51
Figure 5-4 Graphs showing the model fitting for the DV of Sum Normalized .........................52
Figure 5-5 Graphs showing the model fitting for the DV of NDVI Standard deviation image in the site 2 .......53
Figure 5-6 Graphs showing the model fitting for the DV of ratio image in the site 2 .....................54
Figure 5-7 Spatial variations developed from image transformation Digital Values ..................55
Figure 5-8 Spatial variations of species richness (a) and stem density (b), site1 (lower) and site2 (upper) .56
Figure 5-9 Spatial distribution of vegetation site 1, (a) NDVI, (b) Standard deviation, and (c) species richness .................................................................57
Figure 5-10 Spatial distribution of vegetation site 2, (a) NDVI, (b) Standard deviation, and species richness .................................................................58
Figure 5-11 Spherical models developed from NDVI data in the site number 2 ...........................59
Figure 5-12 Models made with the digital value characterizing the scale of variation....................62
Figure 5-13 Models made by Acharya characterizing the scale of variation ...............................63
Figure 5-14 The coincidence map (Species richness and NDVI) in the site 1 ...............................65
Figure 5-15 The coincidence map (Species richness and NDVI) in the site 2 .............................66
Figure 5-16 The coincidence map (Stem density and NDVI) in the site 1 .................................67
Figure 5-17 Percentage of forest cover according with the range classes ..................................73
Figure 5-18 Map of the forest canopy density ...........................................................................74
Figure 5-19 Histogram showing the proportion of the forest covers ........................................74
1. INTRODUCTION

The diversity manifested by the countless kinds of genetic materials, varied species and ecosystem types has enormous value. The variety of distinct microorganisms, plant, animals and habitats can influence the productivity and services derived from the ecosystems. Biodiversity provides direct economic benefits in term of food, medicine and industrial raw materials, and supplies the functional ingredients for natural ecosystems to provide an array of essential services to man (photosynthesis, regulation of absorption and breakdown of the hydrologic cycle and climate, absorption and breakdown of pollutants and many others). Plants and animals, like human beings, have an established right to existence; therefore we should be concerned with their value and conserve their diversity (Smitinand, 1994)

1.1 Biodiversity

International agreement emerging from the United Nations Conference on Environment and Development in 1992 (e.g. Convention on Biological Diversity, Agenda 21, and Guiding Principles on Forest) challenge forest management agencies to maintain biological diversity in forests (Bunnell, 1999). As rates of habitat and species destruction continue to rise, the need for conserving biodiversity has become increasingly imperative during the last decade (Wilson, 1988). Sustainable forest management is generally accepted as the only way to maintain this resource for the present and the future generation. In order to design meaningful biodiversity conservation strategies, comprehensive information on the distribution of species, as well as information on changes in distribution with time, is required.

Biodiversity is defined “as the total variety of life and the major features of biodiversity can be distinguished into at least three conventional divisions, such as genetic diversity, species or taxonomic diversity, and ecosystem diversity” (Acharya, 1999).

Basically the survey methods to study and monitoring the forest diversity use the following indices to indicate the biodiversity in one particular context:

1) Biodiversity as species richness
2) Biodiversity as qualitative variance
3) Internal interaction
4) Index of Habitat Diversity
Chapter 1. Introduction

Many authors have studied the biological biodiversity in different ways such as: Shannon’s Index, and various inverse function of Simpson’s Index of Concentration (the converse of Biodiversity). Two type of biodiversity index exist, alpha and beta diversity. Alpha diversity is the number of species within a chosen area community such as one type of woodland or grassland. Beta diversity is the difference between species composition of different areas. Diversity is therefore measure by recording number of species and their abundance in a specific spatial location (Nangendo, 2000).

Because the biodiversity of an area varies from place to place, methods have been developed to study the spatial variation of parameters such as species richness. A recent example of terrestrial biodiversity survey is the survey carried out by Acharya to assess the forest biodiversity in the Shivapuri area, Nepal (Acharya, 1999). In his work information such as species richness, species density and basal area for three forest strata (dominant stratum, small stratum and natural regeneration) was collected. The characteristics of the forest diversity in the area were described to the high level of detail. In his work, Acharya used a statistic models for characterizing the spatial variation of the different forest type in the area. That research showed the spatial change of species richness and different forest structure parameters such as stem density, and basal area (Figure 1.1). Acharya’s work was totally based on detailed terrestrial observations and measurements. The purpose of the present study is to assess whether there is any relation between these terrestrial data and some characteristics of remotely sensed imagery of the Shivapuri area. If remote sensing can provide useful information, then it may be possible to reduce the cost of biodiversity surveys.

1.2 Problem Definition

The government of Nepal has established a network of protected areas; one of this is locate in Shivapuri area, which has great ecological, cultural and economic values. The area is rich in forest vegetation; varying from tropical to temperate within an area of 216 km². Shivapuri is a very important natural area in Nepal because it is a source of water supply for Kathmandu valley, a very rich endowment of biodiversity, a variety of undisturbed natural ecosystems and potential area for ecotourism and recreation for the Valley. This is the only one protected area confined to the Mid-hills due to be strategically important for biodiversity conservation (Acharya, 1999). In the area are 133 species of shrub from 39 families, 277 species of herbs from 63 families, 31 species of epiphytic plants from 8 families, 5 species of parasitic from 2 families and more than 129 species of mushroom, 177 species of birds and 19 mammals, which have dependence on the forest to survive (Acharya, 1999). All this biodiversity depends in some grade of the forest ecosystem for their existence. However, the biodiversity of this region is under serious threat from the high levels of human activities, farmer in the reserve are heavily dependent on the forest for fuel wood, fodder, and bedding materials for animals. During the winter, 88% and 63% of the households of the reserve and the buffer zone, respectively, lop trees for fodder (Acharya, 1999).
For preserving the different forest ecotopes and all intrinsic biodiversity is necessary to apply efficient technique for the study the local vegetation, Geographical Information System and Remote Sensing may be bring the possibility of made quantitative assessment with explicit spatial location of biodiversity. Then appear the necessity of study and monitoring of the area in short time, low cost and frequently intervals. RS and GIS seem to have a potential for measuring and monitoring a variety of biological resources, including biodiversity. Several works are made in the field of biodiversity studies using Landsat-TM data. However the available literature about of research with this image is confusing, even contradictory, despite the fact that Landsat TM has excellent spectral resolution for studying vegetation.

Example of success research in which was used Landsat TM are the following:

- Ravan et al. (1995) mapped 20 0.1-ha sites in a northern tropical deciduous forest, a thorn forest area in northern India, into 10 vegetation types using two-date Landsat-TM data (Nagendra, 2001).
- Wolter et al. (1995) used Landsat-TM to map the Chequamegon National Forest in U.S. Nineteen forest types were mapped, and 11 with single species stands, and eight with mixed species. The Landsat7-TM data was acquired for the period in which all species all species were in leaf flush. The TM image

Figure 1-1 Example of the spatial forest variation obtained from Acharya in his terrestrial survey of the Shivapuri area, Nepal.
was used to separate forest from non-forest, and to stratify into broad categories of conifer, hardwood and mixed (Nagendra, 2001).

- In 1992 was made a research in which he looked the relationship between plant species richness and landscape richness using landscape richness data extracted from Landsat TM in 1992. One of those conclusions was reflectance classes of pixels were used as a measure of landscape richness (Podolsky, Freilich, & Knehr, 1992).

Examples of non-success work with Landsat TM are the following:

- Coleman et al. (1990) use Landsat-TM data to differentiate large stands of four pine species. This study concludes that individual pines species stands have highly similar reflectance and are not separable using single date Landsat-TM imagery.
- Woodcock et al. (1994) made the work mapping forest vegetation using Landsat-TM imagery and a Canopy reflectance Model. They conclude that, the estimation of tree size using a single date of Landsat TM imagery is unreliable.

The present study will investigate whether Remote Sensing (using Landsat-TM data) and GIS are the adequate techniques to identify the forest characteristics in the Shivapuri area and to compare the result of geostatistic techniques (using the regionalized digital numbers) with the Acharya vegetation models. Another goal of this work is to build the human disturbance map using Forest Canopy Density Mapper (a semi-expert remote sensing system, developed by ITTO-JOFCA for quantitative assessment of forest canopy density).

For this research, Landsat7-TM data was selected due to its high spectral (7 band) and spatial resolution (30x30m pixel size). This image was used before in other research due to has several important characteristic, specifically (1) high signal to noise ratio, (2) high precision of radiometric data, (3) high cartographic accuracy, and (4) high spectral dimensionality, particularly mid-infrared bands (Scott et al., 2000).

The specific suitability of the Landsat-TM image will depend upon the nature of the land areas under consideration. For example, in Nepal a range of factors such as, terrain, shadow, haze and heterogeneity of the vegetation will affect the image. These factors will most probably disturb the quality of the output.
1.3 Research Objectives

1- To determine the relation between Acharya’s data, such as species richness, and forest structure parameters (stem density and basal area) and radiance values on each band of Landsat7-TM image.

2- To look for the possibility to create the final models relating TM image characteristics and Acharya’s model of their spatial variation in species richness, stem density and basal area for tree, small tree and for natural regeneration.

3. To determine quantitatively from TM imagery, the influence of the human disturbance over the forest area and to compare it qualitatively with Acharya’s result.

1.4 Research Questions

1- Is there any correlation between TM image characteristics and species richness, stem density basal area data?

2- Is it possible to create model in which we can use Landsat TM data to characterize the spatial variation of species richness and forest structure parameters?

3- Is there any relation between the results obtained by Acharya in 1997 and the result of this work?

4- Is FCD program suitable to determine the human disturbance over the forest area?

1.5 Research Approach and Outline of the Thesis

Because this research involves examining possible relationships between terrestrial data and remotely sensed imagery, a three-step approach is used to answer the research questions presented above (Figure 1.2). First, in chapter 2, the results of Acharya’s work are reviewed and the main features of his terrestrial database are described. In order to examine possible relationships between these data and remotely sensed imagery, it is necessary to determine which image characteristics are most likely to be relevant. Chapter 3 therefore reviews previous research on the application of remote sensing to vegetation studies. The third step of the research is to compare Acharya’s terrestrial data with the Landsat image. The methods used for this are described in chapter 4. The remainder of the thesis presents the results of this comparison (chapter 5) and a discussion (chapter 6).
Figure 1-2 Research approach
2. TERRESTRIAL WORK IN SHIVAPURI AREA

The biodiversity of forested regions today is the result of complex historical interactions among physical, biological, and social forces over time, often heavily influenced by cycles of various sorts. Fire, agriculture technology, and trade have been particularly powerful human influences on forests. Virtually all our planet’s forest have been affected by the cultural patterns of human use, and the resulting landscape is an ever-changing mosaic of unmanaged and managed patches of habitat, which vary in size, shape, and arrangement. Because change factors, human influence and small climatic variation can cause very substantial changes in vegetation, the biodiversity for any given landscape will vary substantially over any significant time period.

(McNeely, 1994).

The purpose of this chapter is to present a brief review of the Acharya’s (1999) research. The chapter is divided into three sections. Section 2.1 summarizes the main results of Acharya’s work. These indicate important spatial behavior that may possibly be revealed on remotely sensed imagery. Section 2.2 describes the main characteristics of the Shivapuri study area. Finally, Section 2.3 describes the terrestrial data obtained by Acharya. These data form the basis of the research described in later chapters of this thesis.

2.1 Spatial Variability of Forest Parameters in the Shivapuri Area

In his research, Acharya assessed tree species diversity in the Shivapuri area and developed models to relate diversity to exogenous factors. The author offered a description and analysis of a model of spatial distribution patterns of tree species, and analyzed tree species diversity in relation to possible (exogenous) causal factors. He arrived in his work to the following conclusions:

1. Species richness and forest structure parameters show large and small-scale spatial variations. Such variations are most evident for trees and small trees. Values for these variables increase with a gently sloping trend across the study sites and show large short-range random variation. Variation of very small trees is relatively indistinct. This could be due to inadequacy of the sampling design (too large spacing) for this category.
2. In general, the values of species richness, stem density and basal area are lowest near the settlement areas, and gradually increase towards inside the forest, reaching maximum values between the settlements and the least disturbed part of the forest.
3. Two explanatory variables, distance from the nearest settlements and altitude, are effective spatial predictors, particularly for large-sized stems (trees). But, the
contribution of altitude is less than the influence of the distance from the nearest settlements.

This work permits us, to understand the distribution and characteristic of the tree species in the area and demonstrate a positive correlation between altitudes with species richness and their parameters and negative correlation between settlements distance and forest quality. He also developed different models of spatial distribution of the vegetation in the area.

2.2 Characteristics of the Shivapuri Study Area

Nepal is a fairly small, landlocked country, having a peculiar and diverse flora and fauna. It is located between China on the north and India on the south, east and west. It lies between 80º4' to 88º12' East longitude and 26º22' to 30º27' North latitude. The total land area is 147,181 km². The east-west length is 885 km and mean width is 193 km north to south (CBS, 1998).

Latitudinal, the geographical location of Nepal gives it a subtropical climate. Its topography, however, is so extreme that the altitudinal range extends from about 70 m to 8848 m within a short average width of 193 km north to so south. The altitudinal variation has resulted into diversities in climate and vegetation types.

Nepal is divided into five physiographic zones stretching from east to west across the country:

1. High Himal, also called Himalayan zone (about 4000m above sea level). This zone covers about 23% of the total geographic area of the country.
2. High mountains (lower range 2300 to 3000 m and upper range 4000m). This zone covers about 20% of the total area of the country.
3. Middle mountains: these are also called the middle hills and cover about 30% of the total geographic area.
4. Siwalik: this covers about 13% of the total area. The altitude ranges from 120 m to 2000 m. and
5. Terai: It covers about 14 % of the geographic area of Nepal. In this zone, the altitudinal range lies between 70 m to 330 m.

In Nepal we can find difference of altitude, which goes from 60m in the South to 8,848m in the north. As the altitude increases we can see a change in the vegetation character, which goes from tropical, through subtropical and temperate, to alpine. For this reason the forest diversity in Nepal has peculiar characteristic typical only in this phytogeographic region. The distribution of vegetation generally follows altitudinal zones. The total forest area is about 37.4% of the total geographic area of the country 5.4 million hectares of which about 3.6 million hectares are in the Hills and mountainous regions and 1.8 million hectares in the Terai.
2.2.1 Location

The area is located in Shivapuri Watershed and Wildlife Reserve. This area lies in the middle mountain region of Nepal. Geographically Shivapuri Watershed extends from 27° 45' to 27° 52' northern latitude and 85° 15' to 85° 30' eastern longitude. The area is located 12 km north of Kathmandu city and has an altitude ranging from approximately 1360m to 2732m above sea level. The protected area is about 97.36 km² and is surrounded by a boundary wall. The upper slopes are covered with forest (Amatya, 1993). The Shivapuri area covers 8433.6 ha (see Figure 2.1).

Figure 2.1 Location of the study area. Source: Ohio State University, (http://kaladarshan.arts.ohio-state.edu/maps/)

2.2.2 Climate

The climate is of the monsoon type. The rainy season starts in June and lasts four months. The other months are relatively dry. However, just before the rainy season occasional thunderstorms with hail occur. The maximum temperature recorded in December/January is 0.3°C. In the foothills, the temperature seldom drops below 0°C. During winter, morning fogs cover the surrounding valleys. The hilltops and sometimes the high-altitude zone of the northern aspect are covered with snow during the winter. The average rainfall recorded in Kakani is 2,727 mm (based on data from 1972 to 1990). Of the total rainfall, 84% occurs from June to September.

2.2.3 Topography

The Watershed has steep mountainous topography, especially inside the protected area where about half of the land has slope of more than 30 degrees (Table 2.1). In contrast to the mid-hills of Nepal, only the concave type of sloping terraces are found in the Shivapuri area. The width of the terraces varies from place to place, even within a parcel, depending on geology and landforms of the terrain.

<table>
<thead>
<tr>
<th>Slope class (%)</th>
<th>Area in ha.</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-3</td>
<td>1063</td>
<td>5.0</td>
</tr>
<tr>
<td>3-15</td>
<td>1515</td>
<td>7.2</td>
</tr>
<tr>
<td>15-30</td>
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<td>15.3</td>
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<td>More than 60</td>
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<td>11.7</td>
</tr>
<tr>
<td>Total</td>
<td>21300</td>
<td>100.00</td>
</tr>
</tbody>
</table>

Table 2.1 Slope categories in Shivapuri Area

2.2.3 Soils

The soil is loamy on the northern side, and sandy-loam on the southern side, and sandy-loam on the southern side. In most of the protected area, due to dense vegetative cover and high humus deposits, the run-off rate is relatively low. There is a high nutrient content in the soil. On the other hand, in areas where the forest cover is very poor, the run-off and the soil losses are relatively high.
Chapter 2. Terrestrial work in Shivapuri area

In the southern portion of the buffer zone area, the land is highly productive and the soils are normally loamy to silty loam and moderately well drained.

Basically, the soils of this watershed can be classified into following three types.

- Soils of tectonic Valley
- Soils of Hilly Lands
- Soils of Mountains

2.2.4 Vegetation

The forests constitute one of the major natural resources of this watershed. Due to the substantial difference of altitude within a short distance a great diversity of flora exists in this area. The vegetation varies from tropical sal forest in the north near Likhukhola to the sub-tropical vegetation in the southern foothill, with *Alnus*, *Schima*, *Castanopsis* and *Pinus* species. Higher altitudes are characterized by temperate forest of *Quercus semicarpifolia* on the top of the Shivapuri hill (Amatya, 1993). In total, the area has 98 tree species belonging to 37 families.

In the area are 133 species of shrub from 39 families, 277 species of herbs from 63 families, 31 species of epiphytic plants from 8 families, 5 species of parasitic from tow families and more than 129 species of mushroom, 177 species of birds and 19 mammals, which have dependence on the forest to survive (Acharya, 1999). All this biodiversity depends in some grade of the forest ecosystem for their existence.

Out of the total forest area of 8434 ha, about 82 percent comprises of Upper Mixed Hardwood type, where a great biodiversity of plants and animals exists. Chirpine is the second largest, covering nine percent of the total forest area. Most of the Chirpine forests are plantations scattered all over the southern slope of the watershed. Lower Slopes Mixed Hardwood contains 5.2 percent of the total forest area with *Schima* and *Castanopsis* as major species. Oak forest covers only 3.2 percent but this forest is very much used for fodder and fuelwood. Sal and Terai Hardwood types are negligible and occur only in the lower par of the Likhu Kholo. Upper Slope mixed Hardwood type occupies the maximum area both in the protected as well as buffer zone. The protected area does not contain Sal, Terai Hardwood and Slopes Mixed Hardwood types and the buffer zone is devoid of *Quercus* forest (His Majesty's government of Nepal & FAO, 1994).
2.2.5 Forest Types

Six forest types are identified in the Shivapuri Watershed (Table 2.2) (Amatya, 1993). These are:

a. Sal forest
b. Terai Hardwood forest
c. Lower Slopes Mixed Hardwood forest
d. Chirpine forest
e. Oak forest
f. Upper Slopes Mixed Hardwood Forest

<table>
<thead>
<tr>
<th>Forest Type</th>
<th>Protected Area</th>
<th>Buffer Zone Area</th>
<th>Total Area</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sal</td>
<td>-</td>
<td>33.6</td>
<td>33.3</td>
<td>0.4</td>
</tr>
<tr>
<td>Terai Hardwood</td>
<td>-</td>
<td>39.6</td>
<td>39.6</td>
<td>0.5</td>
</tr>
<tr>
<td>Lower slopes mixed hardwood</td>
<td>-</td>
<td>442.3</td>
<td>442.3</td>
<td>5.2</td>
</tr>
<tr>
<td>Chirpine forest</td>
<td>311.6</td>
<td>440.9</td>
<td>752.5</td>
<td>8.9</td>
</tr>
<tr>
<td>Oak forest</td>
<td>269.1</td>
<td>-</td>
<td>269.1</td>
<td>3.2</td>
</tr>
<tr>
<td>Upper slopes mixed hardwood forest</td>
<td>6111.3</td>
<td>785.5</td>
<td>6898.8</td>
<td>81.8</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>6692.0</strong></td>
<td><strong>1741.6</strong></td>
<td><strong>8433.6</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

Table 2-2 Area (ha) of different forest types in the Shivapuri area.

2.3 Field Data

The field data to be used in this research was collected by Acharya in 3 sites (intensive plots). The main information collected was species richness, stem density and basal area. All this data was collected for 3 categories: tree, small tree and natural regeneration. Also an extensive sample was made; in which was collect the same information (see figure 2-2).

**Site 1. Tarebhir site:** This site is located on the lower elevation of the southern aspect of the Shivapuri Wildlife reserve, adjoining the buffer zone. Altitude ranges from about 1880 m to 2385 m above mean sea level. Traces of past agricultural activities and remnants of abandoned houses can be observed. Shrub land and grassland are found on
the lower elevation, whereas temperate forest dominated by *Quercus* species are found on the upper elevation. Forest vegetation is highly degraded in the southern part, near Tarebhir, despite strict protection since 1984.

**Site 2. Bagdwar site**: Named after Bagdwar, a religious place, this site is located adjacent to Site 1 on the southern aspect. The village Okhreni is located to the east of this site (within the wildlife reserve). Altitude ranges from about 1870 m to 2622 m amsl. The high altitude zone, which is pristine, holds temperature forest dominated by *Quercus* spp. and *Rhododendron arboreum*. At lower altitudes, sub-tropical forests are found where *Schima wallichii, Castanopsis tribuloides*, and *Alnus nepalensis* are dominant.

**Site 3. Sinche site**: This site is located on the northern aspect. The area is steeper than Site 1 and 2. Altitude ranges from about 1540 m to 2425 m amsl. Traces of past agricultural activities and remnants of abandoned houses can be observed as in Site 1, but less frequently. Scrubland is found at the lower elevation whereas temperate forest dominated by *Quercus* species are found at the higher elevation (Acharya, 1999).

Figure 2-2 Location of the study area and sample plot. The symbol ● indicate plots of survey site.
2.3.2 Data Collection

At each sample point coordinates were recorded and three concentric sample plots were defined. At all plots, the diameter at breast height (dbh, which is at 1.3 m above ground) of each individual stem was measured and recorded with its species name. Plot size corresponded to species-area curves for conveniently classified three size classes of stem: very small trees (dbh <5cm): 50m², small trees (dbh=5 to 12 cm): 200m², and trees (dbh>12cm):400 m². These size classes, however, are not independent categories, but rather indicate relatively mature, less mature and immature stems, respectively. The plots for trees were used measure slope, aspect and altitude (Acharya, 1999).

The spatially distributed (but georeferenced) plot level data comprised seven variables: three species richness variables, and four forest structure parameter variables. The number of species of trees, small trees and very small trees are all species richness (SR) variables. Similarly, stem density (SD), and basal area (BA), i.e., the area covered by the stem of trees and small trees, is called forest structure parameter variables. For very small trees, SD and BA are not available, because in the study area like in many tropical areas, there is a high risk of misidentification. Also, seasonal bias could occur while measuring very small trees. From here onwards, SR, SD and BA for tree will be denoted as SRt, SDt and Bat, respectively, whereas the subscript S applies to small trees and V to very small trees. Data on SR and SD values were obtained by counting, whereas BA values were calculated from dbh measurements of each stem in the sample plot.

A small extract of Acharya’s database is shown in table 2.3.

<table>
<thead>
<tr>
<th>x</th>
<th>y</th>
<th>SRT</th>
<th>ABT</th>
<th>BAT</th>
<th>SRS</th>
<th>ABS</th>
<th>BAS</th>
<th>SRR</th>
<th>Altitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>634000</td>
<td>307790</td>
<td>3</td>
<td>8</td>
<td>0.29</td>
<td>6</td>
<td>38</td>
<td>0.161</td>
<td>8</td>
<td>250</td>
</tr>
<tr>
<td>634165</td>
<td>307790</td>
<td>10</td>
<td>23</td>
<td>0.66</td>
<td>8</td>
<td>24</td>
<td>0.119</td>
<td>14</td>
<td>250</td>
</tr>
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<td>307790</td>
<td>11</td>
<td>20</td>
<td>0.41</td>
<td>14</td>
<td>40</td>
<td>0.223</td>
<td>15</td>
<td>150</td>
</tr>
<tr>
<td>634875</td>
<td>307790</td>
<td>6</td>
<td>9</td>
<td>0.21</td>
<td>7</td>
<td>43</td>
<td>0.242</td>
<td>10</td>
<td>450</td>
</tr>
<tr>
<td>635160</td>
<td>307790</td>
<td>9</td>
<td>23</td>
<td>0.66</td>
<td>14</td>
<td>40</td>
<td>0.196</td>
<td>13</td>
<td>650</td>
</tr>
<tr>
<td>635450</td>
<td>307790</td>
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<td>16</td>
<td>0.5</td>
<td>7</td>
<td>34</td>
<td>0.159</td>
<td>14</td>
<td>725</td>
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<td>634000</td>
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<td>6</td>
<td>0.15</td>
<td>7</td>
<td>41</td>
<td>0.199</td>
<td>8</td>
<td>575</td>
</tr>
<tr>
<td>635450</td>
<td>307900</td>
<td>6</td>
<td>24</td>
<td>0.76</td>
<td>10</td>
<td>33</td>
<td>0.165</td>
<td>15</td>
<td>400</td>
</tr>
<tr>
<td>634585</td>
<td>307890</td>
<td>12</td>
<td>22</td>
<td>0.96</td>
<td>10</td>
<td>39</td>
<td>0.194</td>
<td>13</td>
<td>450</td>
</tr>
</tbody>
</table>

Table 2-3 Extract from the database of Acharya.
Chapter 2. Terrestrial work in Shivapuri area

Descriptive statistics such as histograms were derived for all variables. The models characterizing small and large scale of variation of the different parameters are also developed in Acharya’s thesis.
Chapter 3. Remote sensing in vegetation studies

3. REMOTE SENSING IN VEGETATION STUDIES

3.1 Introduction

For design of meaningful conservation strategies, comprehensive information on the distribution of species, as well as information on changes in distribution with time, is required. It is nearly impossible to acquire such information purely on the basis of field assessment and monitoring. Remote sensing (RS) provides a systematic, synoptic view of earth cover at regular time intervals, and has been useful for this purpose (Nagendra, 2001). The integration of these tools can increase the accuracy of forest analysis at different spatial scale.

The use of these techniques in forest resource assessment is important because they offer us some advantages such as: information collection of the forest with low cost, few time consume and less human resources. This is especially applicable for mountainous regions like Nepal, where the topography is the main obstacle. However it is important to think about the negative effect of the shadow in that type of relive and the possibility of presence of haze and cloud. That entire factor makes a negative influence in the real accuracy of the work.

For the studies of species distribution using RS patterns researcher are using different ways according to their research. These ways may be categorized into three types:

1. Direct mapping of individual plants or associations of single species in relatively large, spatially continuous units.
2. Technique involves habitat mapping using remote sensed data and predictions of species distribution based on habitat requirement.
3. Establishment of direct relationships between spectral values recorded from remote sensors and species distribution patterns recorded from field observation may assist in assessing species diversity.

Spatial forest structure can be quantified from measures of the composition and structure of landscape patches mapped from element obtained by remote sensing. For example, from classification forest type, leaf area index (LAI), or other defined elements of the surface, patch relationships that affect landscape dynamics, i.e., diversity, complexity, association and connectivity can be calculated. The variety and relative abundance of patch type are measures of composition and include patch richness, patch diversity and diversity index (Franklin, 1994).

The purpose of this chapter is to review some important concepts of how to assess and monitor forest vegetation with remote sensing (RS). The remainder of the chapter is divided into 3 sections. Section 3.2 describes the main reflectance characteristics of vegetation. Section 3.3 provides an overview of the Landsat 7 TM sensor and platform system used to acquire the imagery used in this research. Finally, section 3.4 describes some important image transformation techniques that appear to be particularly useful for relating remotely sensed imagery to forest biodiversity parameters.
3.2 The Reflectance Characteristics of the Vegetation

When using remote sensing imagery it is always necessary to distinguish between the spectral class (based on reflectance of energy) and the information classes (based on human perception of what constitutes a community of plants) which will be used to create the patch / mosaic landscape (Franklin, 1994).

The reflectance characteristic of vegetation depends on the properties of the leaves including the orientation and the structure of the leave canopy. The proportion of the radiation reflected in the different part of the spectrum depends on the leaf pigmentation, leaf thickness and composition (cell structure) and on the amount of water in the leaf tissue. In the visible portion of the spectrum, the reflection from the blue and red light is comparatively low since these portions are absorbed by the plant (mainly by chlorophyll) for photosynthesis and the vegetation reflects relatively more green light.

![Figure 3-1 The behavior of the reflectance of different cover types.](image)

The reflectance in the near infrared is highest but the amount depends on the leaf development and the cell structure of the leaves. In the middle infrared the reflectance is mainly determined by free water in the result in less reflectance (Figure 3.1). They are therefore called water absorption band. When the leaves dry out, for an example during the harvest time of the crops, the plant may change the color. At this stage there is no photosynthesis, causing reflectance in the red portion of the spectrum to be higher. Also, the leave will be dry out resulting in higher reflectance in the middle infrared whereas the reflectance in the near infrared may decrease. As a result, optical RS data provide information about the type of plant and also about his health condition (Bakker, Janssen, & Weir, 2000).

Many feature types manifest combinations of digital numbers based on their inherent spectral reflectance characteristics in a remotely sensed image. With this notion in mind it
was envisaged that the reflectance characteristics of the different tree species would be manifested in the pixel reflectance values (Alimudoa, 1999).

The estimations of relationships between spectral values and species distributions may be useful for the limited purpose of indicating areas with higher levels of species diversity, and can be applied over spatial extent of hundreds of square kilometers. Habitat maps appear most capable of providing information on the distribution of large numbers of species in a wider variety of habitat types. This is strongly limited by variation in species composition, and best applied over limited spatial extents of tens of square kilometers (Nagendra, 2001).

Species of tree with similar spectral reflectance during certain phonological stages typically have different phonologies. Images take on data in which two species are at different phonological stage makes it easier to distinguish species (Verbyla, 1995). The difference between species reflectance can be considerable and may permit their discrimination. Such discrimination may be possible on the basis of relative differences in the spectral reflectance curves of the vegetation (Mather, 1987). In areas where the vegetation structure varies greatly, structural rather than species differences may predominate in imagery. (Lavers, 1997) and show a significant correlation between near infrared reflectance and the density.

The apparent significant relationship between spectral reflectance and species distributions depends no only on the species in question, but also the area. In addition, depending on season, weather and other condition, spectral values for a given location can vary greatly from image to image. That means that for each image the model of relationship between imagery and species composition might require to be calculated afresh. Such a tedious process will be reducing the applicability of this methodology over large areas (Nagendra, 2001).

Near infrared (Verbyla, 1995), middle infrared (Everitt, Escobar, Blasquez, & Hussey, 1986) and thermal infrared band (Salisbury & Milton, 1987) have been strongly recommended for species discrimination. Near infrared data responds to green biomass, and is believed useful for differentiating species that differ in the foliage content (Nixon, Escobar, & and Menges, 1985). The middle infrared band responds to leaf water content, and has been demonstrate useful for the separation of succulent plant from non-succulents (Everitt et al., 1986).

Several such catalogues of the spectral properties of leaves have been derived, mostly from laboratory determinations. In the field spectral response may be quiet different (Barret & Curtis, 1982). The trees with broad leaf may be reflecting most of the non-absorbed radiation back. Needle-leaf canopy trees, especially dose with highly random needle orientation, will be scattering most of the receive radiation in random and different direction. Several others confounding variables like sunlight, dust, humidity as well as contributions from branches, bark and the underlying soil add to the confusion (Verbyla, 1995).
For forest and tree identification is necessary to be clear about the spectral resolution. Different species of plants respond differently to light in the electromagnetic spectrum (Verbyla, 1995). In theory, remote sensing data of adequate spectral resolution can be used to distinguish between plants of different species. A challenging task is to identify the appropriate spectral bands.

### 3.3 Landsat-TM Imagery

The Landsat programme is the oldest Earth Observation programme. It started in 1972 with the Landsat-1 satellite carrying the MSS multispectral sensor. After 1982, the Thematic Mapper (TM) replaced the MSS sensor. There are many applications of Landsat Thematic Mapper data (Table 3.1): Land cover mapping, land use mapping, soil mapping, geological mapping, sea surface temperature mapping, etc. (Bakker et al., 2000).

<table>
<thead>
<tr>
<th>Band</th>
<th>Wavelength (µm)</th>
<th>Principal Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Green 0.52-0.60</td>
<td>Designed to measure green reflectance peak of vegetation for vegetation discrimination and vigor assessment.</td>
</tr>
<tr>
<td>3</td>
<td>Red 0.63-0.69</td>
<td>Designed to sense in a chlorophyll absorption region aiding in plant species differentiation.</td>
</tr>
<tr>
<td>4</td>
<td>NIR 0.76-0.90</td>
<td>Useful for determining vegetation types, vigour, and biomass content, for delineating water bodies, and for soil moisture discrimination.</td>
</tr>
<tr>
<td>5</td>
<td>MIR 1.55-1.75</td>
<td>Indicative of vegetation moisture content and soil moisture.</td>
</tr>
<tr>
<td>6</td>
<td>TIR 10.4-12.5</td>
<td>Useful in vegetation stress analysis, soil moisture discrimination, and thermal mapping applications.</td>
</tr>
<tr>
<td>7</td>
<td>MIR 2.08-2.35</td>
<td>Sensitive to vegetation moisture content.</td>
</tr>
</tbody>
</table>

Table 3-1 Principal applications for vegetation of the Landsat7-TM (Bakker et al., 2000)

The principal applications for vegetation assess of the Landsat7-TM are: band 2 is designed to measure green reflectance peak of vegetation for vegetation discrimination and vigor assessment; band 3 designed to sense in a chlorophyll absorption region aiding in plant species differentiation; band 4 useful for determine vegetation types, vigor, and biomass content; band 5 indicative of vegetation moisture; band 6 useful in vegetation stress analysis and band 7 also sensitive to vegetation moisture content (Bakker et al., 2000).
3.4 Image Transformations

From the discussion in sections 3.2 and 3.3 above, it is clear that a single band of Landsat imagery is of limited usefulness. Instead, it is better to apply an appropriate image transformation that makes use of the particular advantages of two or more bands.

3.4.1 Normalized Difference Vegetation Index

One of the most known RS method used to determine the vegetation index is NDVI (Normalized Vegetation Index); it is based on the spectral properties of green vegetation contrasting with its soil background. This index has been found a strong vegetation signal and good spectral contrast from most background materials (Tucker, Rushton, Sanderson, Martin, & Blaiklock, 1997). NDVI also strongly reduces the impact of varying illumination conditions and shadowing effects caused by variations in solar and viewing angle. NDVI is a measure derived by dividing the difference between near-infrared and red reflectance measurements by their sum (Seller, 1989):

\[
NDVI = \frac{(NIR - R)}{(NIR + R)}
\]

High positive values of NDVI correspond to dense vegetation cover that is actively growing, where negative values are usually associated with bare soil, snow, clouds or non-vegetated surfaces. Oindo in 2001 made a research in which examine the relationships between the species richness of vascular plants and different animal’s communities. In his study he applied NDVI and it is variability (standard deviation) were correlate with data of species richness and abundance of individuals at a landscape in Kenya.

3.4.2 Forest Canopy Density

Landsat7-TM however is an attractive data to study the forest condition for example; ITTO used this image during the project on “Rehabilitation of logged-over Forest in Asia-Pacific Region”. In this methodology the forest status is assessed on the basis of forest canopy. The methodology is identified as “Forest Canopy Density Mapping Model or FCD Model”.

The FCD model is based on the growth phenomenon of forest and the biophysical spectral response of the area. It is calculated in percentage for each pixel considering the physical feature like vegetation and soil, the relative feature like shadow of vegetation and heat radiated by vegetation and soil and the data derived from the biophysical feature of the ground. In this FCD model current forest status can be determined without incurring much cost and time in selecting training areas and accuracy check, but based purely on reflectance and expert knowledge to set threshold with histogram.
The FCD is a useful model analysis the forest cover, using LANSAT TM data. The components of this model are 4: vegetation index (VI), bare soil (BI), thermal (TI) and shadow (SI).

Advance vegetation index AVI reacts sensitively for the vegetation quantity compare with NDVI. Shadow index increases as the forest density increases. Thermal index decrease as the vegetation quantity increases. Black colored soil area shows a high temperature. Bare soil index increases as the bare soil exposure degrees of ground increase. These index values are calculated for every pixel (FCD-Mapper, 1993).
4. MATERIALS AND METHODS

This chapter describes the satellite image and other materials used in the research and outlines the main methods applied.

Main method:

![Flow chart showing the conceptual framework.](image)

Collection of reflectance per plot and per band

To create the data base with all reflectance value
Chapter 4. Materials and methods

Figure 4-2 Flow chart showing the conceptual framework.

International Institute for Geo-information Science and Earth Observation (ITC)
4.1 Materials

The main materials used in this research are:

1. The database developed by Acharya. The procedures used by Acharya to collect the basic data have been described in the previous chapter. The database itself was compiled using values such as three species richness variables, and four forest restructured parameter variables (Stem density and basal area). A copy of the original database was available on a CD-ROM.
2. Landsat 7 Thematic Mapper image from March 1997.
3. Topographic maps 1:25000.

4.2 Preparatory Work Before Going to the Field

Before going to the field, the following activities were carried out:

1) Literature review related to the study topic.
2) Examination of the database of the field data compiled by Acharya.
3) Examination of the Landsat7-TM image.
4) Locating the sample units or plots (made by Acharya in his work) on the topographic maps.
5) To make a system correction, atmospheric correction, georeferenced and resample of the Landsat7-TM image.
6) Locating the sample plots on the Landsat7- TM image.
7) Calculation of NDVI image.
8) Make a false color composite.
9) Make a supervised classification.
10) Collection of the Digital Number (DN) per plots and per band (excluding band 6) of the Landsat7-TM image.
11) Collection of equipment required for fieldwork.

4.2.1 Preparatory Image Processing

4.2.1.1 Georeferencing

To compare the terrestrial data with the image characteristics, it is essential that both datasets be correctly spatially referenced to one another. Because Acharya’s terrestrial data were already located on the 1:25000 topographic maps, theses maps were also used to georeference the satellite image. If satellite image is geographically referenced to a base-map, one can overlay the location of field plots on the image to obtain pixel
Chapter 4. Materials and methods

Intensities associated with each of the field plots. Then, if the field data is spatially correlated with the intensity of the remotely sensed image, it is possible to develop a model describing this spatial continuity (Cliff & Ord, 1981).

When an image (raster map) is created, the image is stored in row and column geometry in raster format. There is no relationship between the rows/column and real world coordinates (UTM, geographic coordinates, or any other reference map projection). In a process called geo-referencing the relation between row and column number and real world coordinates are established. Georeferencing will be done by specifying reference points (tie points) that relate for distinct points their row/column number with the corresponding X/Y coordinate (Feingersh, 2001).

In the georeferencing process of the Landsat7-TM image for this research 12 ground control points (GCPs) were identified in the image as well as in the topographic sheets (1:25000, Kathmandu, Shivapuri and Sundarijal). The topographic sheets were selected as the required map projection system. This was made in various stages, the first one was a preliminary stage which. As identical points on both sources road crossings, waterways, typical morphological structures, etc were identified.

Based on the given table and by using ILWIS program, transformations were made by using different equations that calculated the image coordinates for each individual GCP. As some GCPs were inaccurately identified some differences were found, however the resulting sigma (root mean square error) in this process was good enough, approaching the value of ±0.4 pixels or 12m on the ground.

4.2.1.2 Resampling

Resampling is a process where the pixel must be rearranged to form new array of (square) pixels that fit the rows and columns of the raster database. The spacing of the grids is chosen according to the pixel size required in the corrected image and need not be the same as that in the original geometrically distorted version.

Various resampling algorithms are available to make a decision regarding a new value of each pixel. The main methods are: nearest neighbor, bilinear interpolation, and cubic convolution. The choice of the resampling algorithm depends, among others on the ratio between input and output pixel size and the purpose of the resample image data (Bakker et al., 2000).

The selected resample algorithm used in this research was nearest neighbor. In this interpolation method, the pixel value is a signed the nearest value in the original image. This pixel is then transferred to the corresponding display grid location. This procedure is very fast and also retains the values of the original image. This was important because this research relates image characteristics to terrestrial data.
4.2.1.3 Haze correction

Haze has an additive effect to the overall image, resulting in higher DN value, and as such, it is reducing the contrast. The haze contribution was estimate for each band, and subtracts value from all measurement pixels in the relevant band. This correction was necessary because of the haze visible in the area that is mainly influenced for the tropical climate in the region. By correction, we estimate for each band the haze contribution, and subtract this value from all measurements (pixels) in the relevant band.

4.2.1.4 False Color Composite (FCC)

With the objective of enhancing the vegetation in the image the FCC (band 4=red, band 3+green and band 2=blue) technique was selected. The result looks like similar to prints of color infrared photography (CIR). The most striking characteristic of false color composite is that vegetation appears in a red-purple color. In the visible part of the spectrum, plants reflect mostly green light, but their infrared reflection is even higher. Therefore, vegetation in a false color composite is shown as a combination of some blue but even redder, resulting in a reddish tint of purple (Bakker et al., 2000).

4.2.1.5 Topographic correction (shadow removal).

The topographic effect is defined as the variation in radiances from inclined surfaces as the variation in radiances from inclined surfaces compared to radiances from a horizontal surface as a function of the orientation of the surfaces relative to the light source and sensor position (Holben & Justice, 1980). In 1979 Holben and Justice measured the topographic effect on remotely sensed data and showed the effect to be most extreme at low solar elevations and greatest for slopes in the principal plane of the sun. They also showed by Landsat simulation study that the topographic effect can produce a considerable variation in radiances associated with a given cover types and may lead to poor cover classification results (Sah, 1996).

One of the earliest attempts to simulate and quantify this topographic effect involved the measurement of differential spectral radiance from uniform sand surface under various slope and angle combinations (Holben & C.O., 1981). It was found that the magnitude of the topographic effect varied as a function of the solar inclination, azimuth and terrain’s degree of slope and aspect. This effect can produce wide variations in the radiance associated with a perceived uniform (i.e., homogeneous) cover type. Based on this simulation study, it was suggested that a model should be developed that would incorporate solar and terrain geometries to reduce the topographic effect, which in theory, would improve automated multispectral classification (Sah, 1996).
The reflectance varies as a function of slope and aspect and that such terrain variations complicated the task of discriminating woodland categories with remotely sensed data. Removal or reduction of the topographic effect before classification will reduce the variation associated with the radiance for a given cover type and thereby increase the likelihood that classes can be separated. There are various methods used for minimizing shadow effect from the satellite data, i.e., sum normalization, ratio image, NDVI etc.

Sum normalization is used to make the input data independent of the influence of external factors such as sun angle or relief. The addition or summation of input data is a representation of this influence. The ratio between the individual input bands and this sum (=Intensity) results in Intensity independent data. If the results are displayed they appear to be flat.

\[ B_i = \left( \frac{B_i}{\sum B_i} \right) \times 255 \]

Where \( B_i \) is a band, \( I = 1 \) to \( N \), \( \sum B_i \) is \( (B_1 + B_2 + \ldots + B_n) \) and 255 is a compensation factor.

By dividing the digital number (DN) in one band by the corresponding DN in another band for each pixel, a ratio image can be produced. The resulting values of the ratio image are stretched and plotted as a new image. The ratio images minimize differences in illumination conditions, thus suppressing the expression of topography (Sah, 1996).

Topographic effect has been largely reduced in this situation because the ratios of the two bands at A and B are the same value (Mather, 1987).

Ratioing is a trick, which provides the user a guide range of possible outcomes with a range from 0 to infinity.

\[ B = \left( \frac{BR}{BIR} \right) \times 80 \]

Where \( R = \) Red, \( IR = \) Infrared, 80 is a compensation factor.

The compensation factor is needed because the result of the ratio can be smaller than 1.

### 4.2.1.6 Image Classification

The principles of image classification are that a pixel is assigned to a class based on its feature vectors, by comparing it to predefined clusters in the feature space. Doing so for all image filter results in a classified image. With the objective of converting the image data into thematic data with the most important characteristics of the vegetation in the area supervised classification was used. The spectral characteristics of the class identifying sample areas (training area) were defined.
Chapter 4. Materials and methods

One requirement of supervised classification is to be familiarized with the area characteristics; in this case we used the field data.

4.2.1.7 Normalized Different Vegetation Index (NDVI)

The normalized different difference vegetation index is preferred to the simple index for global vegetation monitoring because NDVI help to compensate for changing illuminations, condition, surface slope, aspect, and other extraneous factors. In this research we use the following formula:

NDVI = ((TM4-TM3)/(TM4+TM3))*127+128

4.3 Materials Selected For The Field Work

1) Topographic maps (1995), scale 1:25 000
2) Garmin GPS (Global Position System) receiver
3) Suunto compass
4) Altimeter
5) 25m measuring tape
6) Pocket calculator
7) Pen, pencils and eraser
8) Graph and writing paper
9) Chalk (tree maker)
10) Photograph camera
11) Ruler and protector.
12) False color composite (FCC) map in large scale (1:25000)

Topographic map, and FCC map was selected to locate the sampling units/plots in the field. The Photograph camera and tape was selected to collect photos of the different vegetation types into the different plot. GPS, compass and altimeter was selected to obtain the orientation in the terrain.

4.4 Field Work Data Collection

Because the basic field data was already available, the visit to the field was carried out for two reasons:
1) To become familiar with the forest conditions at a number of Acharya’s original sampled locations
2) To meet personally with Acharya to clarify some aspects of his original research.
Chapter 4. Materials and methods

Sampling points located into the map were identified in the field using the map, GPS. The sample units were located by distance measurement from the reference points that were apparent on both ground and topographic map. In total, 18 plots were visited.

Photographs were made at each of the 18 plots, and data such as composition, stage of develops, slope, density and type of forest (natural and artificial) were recorded. Within the time available, it was impossible to visit more plots. Two main factors restricted field data collection:

1. Landslides and collapsed roads: these were so severe that access by 4-wheel drive vehicle was not possible in the northern part of the area.
2. Heavy rain and leech plagues made walking difficult and uncomfortable.

4.5 Post Field Work

After the completion of the fieldwork, further data analyses were carried out at ITC.

The main technical image processing procedures involved in this research were:

- NDVI calculation,
- Image classification,
- Calculation of image Standard Deviation Calculation using the filter 3x3 (Table 4-2).
- Collection of the Digital Number of the field plot located in the image (Table 4-1).
- Forest Canopy Density detection.

The image was downloaded and processed mainly by using ILWIS 3.0 and with the objective to determine the forest cover characteristic Forest Canopy Density Mapper was applied.

<table>
<thead>
<tr>
<th>x</th>
<th>y</th>
<th>TM1 Digital Number</th>
<th>TM2 Digital Number</th>
<th>TM3 Digital Number</th>
<th>TM4 Digital Number</th>
<th>TM5 Digital Number</th>
<th>TM6 Digital Number</th>
<th>TM7 Digital Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>637445</td>
<td>3074220</td>
<td>62</td>
<td>34</td>
<td>40</td>
<td>88</td>
<td>107</td>
<td>132</td>
<td>45</td>
</tr>
<tr>
<td>637730</td>
<td>3074220</td>
<td>57</td>
<td>31</td>
<td>35</td>
<td>62</td>
<td>74</td>
<td>127</td>
<td>24</td>
</tr>
<tr>
<td>638040</td>
<td>3074220</td>
<td>99</td>
<td>52</td>
<td>71</td>
<td>90</td>
<td>130</td>
<td>127</td>
<td>50</td>
</tr>
<tr>
<td>638350</td>
<td>3074220</td>
<td>49</td>
<td>21</td>
<td>19</td>
<td>57</td>
<td>35</td>
<td>129</td>
<td>12</td>
</tr>
<tr>
<td>638640</td>
<td>3074220</td>
<td>51</td>
<td>24</td>
<td>25</td>
<td>87</td>
<td>74</td>
<td>123</td>
<td>21</td>
</tr>
<tr>
<td>637130</td>
<td>3074475</td>
<td>50</td>
<td>22</td>
<td>26</td>
<td>51</td>
<td>54</td>
<td>125</td>
<td>19</td>
</tr>
<tr>
<td>637445</td>
<td>3074475</td>
<td>60</td>
<td>30</td>
<td>36</td>
<td>83</td>
<td>108</td>
<td>133</td>
<td>38</td>
</tr>
<tr>
<td>637730</td>
<td>3074475</td>
<td>59</td>
<td>27</td>
<td>31</td>
<td>78</td>
<td>82</td>
<td>126</td>
<td>26</td>
</tr>
</tbody>
</table>

Table 4-1 Small examples of the database with radiance collect from the Landsat-TM data.
With the objective to find the relevance of Landsat7-TM image, the field data and the data from Landsat7-TM were correlated, and for analysis of the behavior of the Landsat7-TM image descriptive statistics was made. EXCEL and the SPSS statistic package were used for this work.

The image selected for this research as it mentioned in the previous chapters was Landsat7-TM. The image was selected for the following reasons (1) The availability of the image (2) Cover all Shivapuri area (3) the image have been taken during the same year in which Acharya made his research field work [1997] (4) Higher spectral dimensionality (particularly mid-infrared bands) (5) The successful obtained with image in previous vegetation study research¹. Furthermore, as indicated in chapter 3, Landsat7-TM is very useful for study the vegetation characteristics such as greenness, vegetation types, vigor, and biomass content, etc. Finally the image is compatible with FCD Mapper program.

### 4.6 Preparation of Reference Image

In this research the image of 1997 have been used because it was the only one available. The present image does not have a good quality due to the existences of mountain shadows and clouds. See figure 4-3.

Topographic maps for Shivapuri area published by His Majesty’s Government of Nepal, Survey Department in 1994 (sheets No. 2785 02C and 2785 02D) covering the study area were available, and were used to obtain the digital elevation model.

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¹ See Literature review section for details
Chapter 4. Materials and methods

Radiometric and relieve correction were applied to enhance image. However many shadow still continued in the northwest parts of the study area. For that reason, the site #3, called Sinche, was not selected.

A number of distinct points like road junction, water pool corners, airport run ways, permanent river confluence and road junction were selected from the topographic maps. These points were taken to cover the whole the study area as far as possible; in total 12 points were used as ground control point (GCPs) for image georeferencing.

4.6.1 Best Band Selection

After the georeference processing the subset of the study area was made.

In this subset, the correlation matrix was calculated to analyze and select the best band of the image. Satellite data often show a degree of correlation, meaning that when the spectral values in one band are high the values in another band are expected to be high as well. Plotting values from highly correlated bands in a feature space will result in an
Chapter 4. Materials and methods

ellipsoid denoting that the two bands contain dependent information. From a set of highly correlated bands only one adds real value while the other ones may be derived or estimated. Calculating a correlation matrix helps detecting the redundancy and identifies possible reductions in the number of bands.

The selection was made on the basis of visual inspection and correlation matrix analysis of the image and analyzing the statistical values. The band with the lowest correlation and the highest variation was selected as well as the S value and mean. In this case, both bands 4 and 5 had high information content. Band 5 was selected because, according to the correlation matrix parameter, this band has the lowest correlation values, i.e. this band brings information independent of the other bands (See 4-3).

According to the histogram behavior the bands 4 and 5 showed a normal distribution curve, both bands give the representative radiance range and this means more information, nevertheless the amplitude of the data in the band 5 is the highest, this is another reason for why the band 5 was chosen (See 4-3).

<table>
<thead>
<tr>
<th></th>
<th>Sub map tm1</th>
<th>Sub map tm2</th>
<th>Sub map tm3</th>
<th>Sub map tm4</th>
<th>Sub map tm5</th>
<th>Sub map tm7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sub map tm1</td>
<td>1.00</td>
<td>0.92</td>
<td>0.93</td>
<td>0.39</td>
<td>0.61</td>
<td>0.75</td>
</tr>
<tr>
<td>Sub map tm2</td>
<td>0.92</td>
<td>1.00</td>
<td>0.97</td>
<td>0.59</td>
<td>0.78</td>
<td>0.86</td>
</tr>
<tr>
<td>Sub map tm3</td>
<td>0.93</td>
<td>0.97</td>
<td>1.00</td>
<td>0.48</td>
<td>0.75</td>
<td>0.87</td>
</tr>
<tr>
<td>Sub map tm4</td>
<td>0.39</td>
<td>0.59</td>
<td>0.48</td>
<td>1.00</td>
<td>0.78</td>
<td>0.59</td>
</tr>
<tr>
<td>Sub map tm5</td>
<td>0.61</td>
<td>0.78</td>
<td>0.75</td>
<td>0.78</td>
<td>1.00</td>
<td>0.92</td>
</tr>
<tr>
<td>Sub map tm7</td>
<td>0.75</td>
<td>0.86</td>
<td>0.87</td>
<td>0.59</td>
<td>0.92</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Mean per band:

TM1=49.58  TM2=22.34  TM3=21.84  TM4=71.25  TM5=62.24  TM6=17.33

Std. per band:

TM1=6.75  TM2=4.60  TM3=6.89  TM4=15.09  TM5=16.29  TM6=6.56
Chapter 4. Materials and methods

4.7 False Color Composite

To enhance the visualization of the vegetation and to prepare the image for the future classification various false color composite were made; however the combination mostly used for TM image is the one displays in red green and blue taking the respective bands 5, 4, and 3 (ILwis, 1997). Other combination were made in order to obtain the vegetation area appears in a red purple color in the combination 4,3,2; in different green tonalities in the combination 5,4,3, and in the orange tonality in the combination 4,5,3.

The color composites images were created and displayed on the screen combining the spectral values of the three individual bands. Each bands was displayed using one of the primary color. The best image for forest type identification was the 4,5,3 (see fig 4-4), and then this combination was used.

Table 4-3 Correlation Matrices and Histogram behavior per band.
Chapter 4. Materials and methods

4.8 Image Classification

One of the first steps before classifying the image is to enhance the image in a way to provide rough information of forestland cover differentiation. The simplest way is to combine different bands like infrared, red and green for false color composite (Figure 4.2).

The image classification was made with the objective to extract vegetation information from Landsat7-TM image. In this research unsupervised and supervised classification were used.

After arriving at an acceptable classification result, a 3x3 majority filter was applied to label the undefined isolate pixels. The accuracy of the image classification was evaluated using the data field of the Acharya’ database.

4.8.1 Supervised Classification

The type of classification was performed was the maximum likelihood supervised classification, where the pixel sampling took place for homogeneous reflectance areas.

The maximum likelihood classifier was chosen, because, it is the one which can obtain some reliable results, since box classifier would introduce problem when overlapping and minimum distance classifier is insensitive to the variances in each classes (see Figure 4-5).

Figure 4-4  Three different FCC combinations of the study sites shown in figure 4.3. The vegetation areas appear with different tonalities. In the image (1) the combination used was 5,4,3. Image (2) the combination was 4,5,3, and in image (3) the combination was 4,3,2.
4.9 Relationship Between Vegetation Radiance and Forest Vegetation Parameter.

To evaluate the potential of remote sensing for assessing species diversity is an increasingly urgent task (Nagendra, 2001). According to the classification of species distribution patterns using remote sensing, the study was categorized into the class 3. This classification was mentioned in the section 3.4.2.

In this class exists an establishment of direct relationships between spectral radiance values recorded from remote sensors and species distribution patterns recorded from field observations.
Chapter 4. Materials and methods

This type of species assessment was selected due to it could assessing species diversity and brings us the possibility to compare the Acharya field data and Landsat TM image as one of the main objective.

The forest vegetation parameter (species richness, stem density and basal area for tree strata; species richness, species density and basal area for small tree strata and species richness for natural regeneration of tree and species richness for natural regeneration of small tree) has been related with the radiance collected from the Landsat TM band 5m (see tables 4-3 and 4-4).

The radiance per plot from the band 5 in Landsat-TM was selected; this point corresponds to the same plot taken by Acharya in 1997. With the point data, statistics analyses were made in which the relation between data field (such as species richness, stem density and basal area) and radiance of image was correlated. This was made with the goal of finding out the correlation between the radiance value of Landsat-TM image and the forest parameters.

4.10 Image Correction

Remote sensing plays an important role in the mapping of land covers in mountainous areas since two decades ago. Usually we need to make an atmospheric correction and geometric correction to remove or decrease the influences of the atmosphere and terrain relief on the remote sensed data (Chavez, 1989) due to it different images correction were made. However is important to know that for the mountainous areas image, we cannot derive the exactly vegetative reflectance because of the atmospheric correction packages (Lin, 2001).

4.10.1 Sum-Normalization Image Classification

The following formulas produced several sum-normalized images:

- \[ Tm1n = \frac{TM1}{(TM1+TM2+TM3+TM4+TM5+TM7)} \times 255 \]
- \[ Tm2n = \frac{TM2}{(TM1+TM2+TM3+TM4+TM5+TM7)} \times 255 \]
- \[ Tm3n = \frac{TM3}{(TM1+TM2+TM3+TM4+TM5+TM7)} \times 255 \]
- \[ Tm4n = \frac{TM4}{(TM1+TM2+TM3+TM4+TM5+TM7)} \times 255 \]
- \[ Tm5n = \frac{TM5}{(TM1+TM2+TM3+TM4+TM5+TM7)} \times 255 \]
- \[ Tm7n = \frac{TM7}{(TM1+TM2+TM3+TM4+TM5+TM7)} \times 255 \]

Where 255 is the multiplication factors to increase the spectral value of the image. After producing these images, an unsupervised classification process was performed.
Chapter 4. Materials and methods

The best band selection was made on the basis of visual inspection and correlation matrix analysis of the sum normalized image and analyzing the statistical values. The image with lowest correlation and higher variation mean and Standard Deviation was selected. In this case was selected the band TM5 (table 4-4).

<table>
<thead>
<tr>
<th></th>
<th>Tm2n</th>
<th>Tm3n</th>
<th>Tm4n</th>
<th>Tm5n</th>
<th>Tm7n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tm2n</td>
<td>1.00</td>
<td>0.64</td>
<td>-0.57</td>
<td>-0.70</td>
<td>-0.23</td>
</tr>
<tr>
<td>Tm3n</td>
<td>0.64</td>
<td>1.00</td>
<td>-0.72</td>
<td>-0.27</td>
<td>0.31</td>
</tr>
<tr>
<td>Tm4n</td>
<td>-0.57</td>
<td>-0.72</td>
<td>1.00</td>
<td>-0.01</td>
<td>-0.46</td>
</tr>
<tr>
<td>Tm5n</td>
<td>-0.70</td>
<td>-0.27</td>
<td>-0.01</td>
<td>1.00</td>
<td>0.63</td>
</tr>
<tr>
<td>Tm7n</td>
<td>-0.23</td>
<td>0.31</td>
<td>-0.46</td>
<td>0.63</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Mean per band:
- TM2n=23.43
- TM3n=22.61
- TM4n=74.31
- TM5n=64.23
- TM7n=17.64

Std. per band:
- TM2n=1.98
- TM3n=2.92
- TM4n=7.89
- TM5n=55.88
- TM7n=73.08

Table 4-4 Bands correlation and statistic parameter

In the obtained image the higher values (pink, red and orange) represent the forest area, the color green and blue are covering no forest areas (Figure 4-6).

Figure 4-6 Sum-normalizations image of the band 5.
Chapter 4. Materials and methods

4.11 Ratio Image Classification

The selection of the ratio image was made on the basis of visual inspection and correlation matrix analysis of the ratio image. The image showing the lowest correlation and higher variation between the two images was selected. The following ratio image of data sets was selected (Figure 4-7).

![Ratio Image](image)

Figure 4-7 Ratio image, in which is possible to appreciate the forest variation. The ratio image selected was (TM4/TM3)*80.

4.12 NDVI

With the objective to make transformation to enhance the vegetation discrimination, NDVI was calculated (Figure 4-8). The characteristic in the result map was that upper values in the scale after the vegetation index has been stretched are due to the vegetation vigour. Similarly, thematic features like water, bare soil, urban areas etc.; reflect less in infrared band and have a lower value in NDVI scale.
Remote sensing plays an important role in the mapping of land covers in mountainous areas since two decades ago. Usually we need to make an atmospheric correction and geometric correction to remove or decrease the influences of the atmosphere and terrain relief on the remote sensed data (Chavez, 1989) due to different images correction were made. However, it is important to know that for the mountainous areas image, we cannot derive the exactly vegetative reflectance because of the atmospheric correction packages (Lin, 2001).

4.13 Standard Deviation

The Standard Deviation of NDVI is related to variability of vegetation cover for selected individual regions. Highly variable areas are endowed with more species (Oindo, 2001). This affirmation is in agreement with the spatial heterogeneity hypothesis of species richness (Walker et al. 1992). Oindo suggested that Standard deviation in remote sensing allows us to estimate habitat heterogeneity (Figure 4-9).

Figure 4-8 NDVI of the area, in this map we can see the high values with the red and pink color, which are represent forest, it are covering most of area.
However in the image is possible to see the higher grade of habitat heterogeneities (Standard deviation of NDVI) near the Southwest and Northeast near the settlements, that confirm that spatial heterogeneity can also result from frequent or intense disturbances caused by human activity; primarily land use that alters and degrades habitat to serve human needs (McNeely, 1994).

4.14 Forest Canopy Density Map

Among various methods are available to assess forest canopy density, the terrestrials are one of then, these methods are huge used, overall in developed country in which the accessibility of RS and GIS resources is low. As was mention in the chapter 1 one of this type of study was developed in 1997 by Acharya (the work was published in 1999) using parameter such as species richness, species density and basal area developed a terrestrial survey in which the FCD was estimated, with this information plus two explanatory (exogenous) variables, distance from the nearest settlements and altitude, were effective spatial predictors, particularly for large-sized stems (trees). In his work the contribution of altitude is less than that of distance from the nearest settlements. Hence, human influence may have been the main cause for the observe pattern of species richness and forest structure parameters.

In general he conclude that, the values of species richness, stem density and basal area are lowest near the settlement areas, and gradually increase towards inside the forests, reaching maximum values between the settlement and the least disturbed parts of the forest. Human influence may have been the main cause for the observed pattern (see Figure 4-10).
One objective of our present research is the follow “To determine quantitatively the influence of the human disturbance over the forest area (determining the FCD using RS and GIS technique) and to compare qualitatively with Acharya’s result”.

Basically FCD is an alternative parameter to measure density from satellite image. Crown density influences light penetration, surface reflection and rainfall penetration. It is possible to be measurement by satellite remote sensing (Maharjan, 2001).

For to obtain that purpose the Semi-Expert Remote Sensing System for Forest Canopy Density Mapping (FCD Model) was selecte d. This method was developed recently as was mention in the chapter 1 for ITTO-JOFCA with the objective to quantify canopy density on the basis of different biophysical characteristics of the ground condition. Correlation of ground based assessment data and result of remote sensing based assessment verified an accuracy of more based assessment data and results of remote sensing based assessment verified an accuracy of more or less 90% using the FCD Model. The application of test was implemented in some countries including Nepal.

Generally, in conventional remote sensing method i.e. image classification; canopy is divided into only in low, medium and high-density class. However, FCD model gives 10 classes and density is expressed in percentages: i.e.10%, 20% etc. FCD classification gave better result classification for forest canopy density than supervised classification (Maharjan, 2001).

The study was carried out in Shivapuri area in the Site 1 and Site 2. The Site 1 Tarebhir, it is located on the lower elevation of the southern aspect of Shivapuri Wildlife Reserve near the village with the same name; this site is located adjoining the buffer zone. The local people from the village have making heavy influences over the forest vegetation, which is characterizing for highly depredated. The Site 2 Bagdwar, a religious place, this site is located adjacent to the site 1 on the southern aspect. The village Okhereni is located to the east of this site.
4.15 Data Collection And Processing

The digital values of the pixel located in the same area as the field was recorded and imported to both ILWIS and SURFER programs. Kriging was then used to develop models of spatial variation from these basic point data. Beside an input point map, Kriging requires a semi-variogram model, including the type of the model and values for the parameter nugget, sill and range (ILWIS, 1997). The Semi-variogram was calculated in the ILWIS program. The semi-variogram shows us how spatial continuity change as a function of distance and direction. The main attributes are:

*Range.* - is the distance within sample points are dependent, when the distance between points increase also increase the variance.

*Sill.* - is the maximum distance where sample points are no longer correlated and there for variance no longer increase.

*Nugget effect.* - is the variance value at a zero distance. Theoretically the variance between points at zero distance should be 0, however, several factors as the most common sampling errors explained that.

![Graph showing Variance, Sill, Range, and Nugget effect](image)

Interpolation Methods

One of the main issues in geostatistics is the prediction of values of a variables distributed in space or in time. This prediction is based on interpolation methods where the predicted values for a larger area come from the surveyed values of a variable. However, the selection of the best interpolation method is related to specific needs as:

- Type of estimations local or global
- Mean estimations or the distribution of the data values
- Point estimations or area estimations
The kriging method (basic concept).

One of the most common techniques for interpolation is the kriging method. Kriging estimations are based on the function between individual values of a variable (s), its variance, covariance and its spatial relation (distance and direction). One of the advantages of this method is that kriging estimations minimize the variance of the errors by creation of a probabilistic model of the data set. Due that exhaustive data set of the study area is not always available, there is uncertainty about the areas that were not surveyed, and the error and variance of the error is impossible to calculate. Geostatistical estimations are based on a probabilistic model that includes these uncertainties. The probabilistic model incorporates the data set a result of a random process, however this does not mean that the studied phenomena presents a random behavior. However this model of a random behavior allows us to predict non-surveyed values by a weighted average of values according to the distance around a surveyed point. Kriging method also estimates the confidence intervals of the calculated estimations as well as assesses the accuracy of the estimations.

To use kriging method a summarize of the main steps is given as follow:

Exploratory data analysis to identify the main characteristics of the data set
Spatial data analysis to recognize the spatial characteristics of the data set. Creation of the total variogram with the use of the data set and after creation of the experimental variogram
Selection of the model that better explain the pattern of the experimental variogram
Calculation of the kriging estimations and the estimation errors.

4.16 Kriging Model

For determine the wait factors the weight factors in Kriging a semi-variogram model (based on the output of the Spatial correlation operation) was developed, the distribution of input points, and are calculated in such a way that they minimize the estimation error in each output pixel. The estimated or predicted values are thus a linear combination of the input values and have a minimum estimation error. The optional error map contains the standard errors of the estimated (ILWIS, 1997).

The kriging was developed in Surfer, the same program in which in 1999 Acharya developed the models of vegetation in the area.

4.17 Final Output

The models developed were imported into the ILWIS 3.0 software package and the following steeps was made:

- The vegetation spatial variation models (made using data field) and vegetation spatial variation models (made using dates from Landsat TM image) were digitized.
Chapter 4. Materials and methods

- A new domain was created, with the objective of developing the final comparison between the data field modeled by Acharya and the DV obtained from transformation made into the Landsat7-TM image (So far, here the underlying assumption of the analysis is that there is a relationship between data field and data obtained from Landsat7-TM. Here we want to find out the coincident areas using the same domain for both maps).

- For make the classification, the species richness values were divided into 7 different classes. The selected intervals were 2 and then the class was divided in the following way: very low 0-2, low 3-5, low medium 6-8, high 9-11, very high 12-14, rich more than 14. In the case of Stem density, the selected interval was very low 0-5, low 6-11, low medium 12-16, medium 17-21, high 22-26, very high 26-31 and high 32-36 and Rich are more than 37% of density. In the case of NDVI, the lower values correspond to the lower forest presence and the class domain was made follow this concept and making intervals of the 6 values.

After that operation we give the following numerical range:

- Rich=7
- Very high=6
- High=5
- Medium=4
- Low medium=3
- Low=2
- Very low=1

- The polygon map was created from the segment map using a new domain.
- This map was rasterized.
- 2 dimensional tables were created in which the values given come from the subtraction of the two maps.
- From 2 dimensional tables a final map was generated.

4.18 Accuracy Analysis

- With the objective of finding out the accuracy of image classification confusion matrix was developed, confusion matrix is a table with the columns representing the reference (observed) classes, and the row the classified (mapped) classes (Rossiter, 2001).
- The kappa statistics calculation was the next step; Kappa represents the agreement between the classified forestland cover and the observed forest. The kappa statistic is a powerful technique in its ability to provide information about single matrices as well as to statistically compares matrices.
- Although kappa statistics are usually used to assess the accuracy of classified images, they may also be used to compare two raster maps (Weir, 1988).
The Kappa factor is given by the formula:

\[
Kappa (k) = \frac{Po-Pe}{1-Pe}
\]

Where:
Po- is the proportion of correctly classified cases
Pe- is the proportion of correctly classified cases expected by chance.

- Multinomial test of accuracy; this test was made based on the confusion matrix data.
5. ANALYSIS OF THE IMAGE AND RESULT

5.1 Relationship Between Vegetation Radiance and Forest Vegetation Parameter.

To evaluate the potential of remote sensing for assessing species diversity is an increasingly urgent task (Nagendra, 2001). In this research, the classification of species distribution patterns using remote sensing was done according to Nagendra’s classification 3 (see section 3.1). In this classification, direct relationships between spectral radiance values recorded from remote sensors and species distribution patterns recorded from field observations are established. This type of species assessment was selected because it could bring us the possibility to compare the Acharya field data and Landsat TM image as one of the main objectives of this research.

The radiance per plot from the band 5 in Landsat-TM was selected at the same locations where Acharya collected his field data in 1997. With the point data, statistical analyses were made in which the relation between field data (such as species richness, stem density and basal area) and radiance of image was correlated.

Scatter plot of the reflected radiance vs. Species richness and Forest structure parameter in the 3 strata revealed that they do not have any relationship. In that task the fitted regression linear model was used. The coefficient of determination (R²) of the linear model was so low showing any correlation (see table 5.1 and 5.2). It means that the radiance recorded from Landsat-TM image does not bring any information about heterogeneity vegetation of Shivapuri area.

One important limitation could be the different plot size from which the reflectance values were obtained. It could have created errors in the estimation of the real heterogeneity characteristic of the vegetation in the area. Price and Jakubauskas (1997) found the same limitation with this Landsat TM image. They attempted to relate Landsat TM data and species composition in 70 stand and only 31% of the all species were explained.

In our study, the sizes of the field plot were as follows: 50 m² for very small tree, 200 m² for small tree and 400 m² for tree. The pixel size of Landsat TM cover 900m² and then there is a real possibility of loosing information at the moment in which there is the comparison between the data field and the radiance from the pixel due to the pixel that covers a higher area than the field plot in this study. Landsat TM has a 30 m x 30 m pixel size, and it can not be distinguished the characteristics of smaller areas like 50 or 200 m², and the spectral information of the individual pixel is an average of the radiance of all vegetation in the pixel.
Chapter 5. Analysis of the image and result

<table>
<thead>
<tr>
<th>Species</th>
<th>Parameter</th>
<th>Determination Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tree stratum</td>
<td>Sp richness</td>
<td>R²=0.1007</td>
</tr>
<tr>
<td></td>
<td>Stem density</td>
<td>R²=0.1355</td>
</tr>
<tr>
<td></td>
<td>Basal area</td>
<td>R²=0.171</td>
</tr>
<tr>
<td>Small tree stratum</td>
<td>Sp richness</td>
<td>R²=0.0171</td>
</tr>
<tr>
<td></td>
<td>Sp density</td>
<td>R²=0.0225</td>
</tr>
<tr>
<td></td>
<td>Basal area</td>
<td>R²=0.0071</td>
</tr>
</tbody>
</table>

Table 5-1 Correlation analyses between band 5 of Landsat7-TM and Forest Parameter Site 1.

<table>
<thead>
<tr>
<th>Species</th>
<th>Parameter</th>
<th>Determination Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tree stratum</td>
<td>Sp richness</td>
<td>R²=0.0019</td>
</tr>
<tr>
<td></td>
<td>Stem density</td>
<td>R²=0.004</td>
</tr>
<tr>
<td></td>
<td>Basal area</td>
<td>R²=0.0013</td>
</tr>
<tr>
<td>Small tree stratum</td>
<td>Sp richness</td>
<td>R²=0.0034</td>
</tr>
<tr>
<td></td>
<td>Sp density</td>
<td>R²=0.0737</td>
</tr>
<tr>
<td></td>
<td>Basal area</td>
<td>R²=0.0737</td>
</tr>
<tr>
<td>Natural regeneration</td>
<td>Sp richness natural regeneration of tree</td>
<td>R²=0.0007</td>
</tr>
</tbody>
</table>

Table 5-2 Correlation analyses between band 5 of Landsat7-TM and Forest Parameter Site 2.

5.2 Geostatistical Analysis

The geostatistical analysis as it was mentioned previous is a useful tool in environmental analysis. In this research it was used to characterize the scale of vegetation variation using data from different image transformations.

An explanation of all the process involved in this analysis will be given on the following paragraph. First Digital values were extracted from the spatial transformation made to the Landsat7-TM image such as NDVI (0-255), NDVI and standard deviation, Sum normalized and Ratio images. The values correspond with the field data of Acharya. The collected digital values were linked with the Surfer program. This software was chosen in order to compare them with the geostatistical analysis made by Acharya. The ILWIS program was selected for analyzing the variogram model and also for developing the complete geostatistic analysis.

Spatial continuity of an h-scatter plot can be summarized using different indices. These are; the correlation function, the covariance function, and the moment of inertia traditionally called the variogram (Isaaks E.H. & R.M., 1989). Throughout the
geostatistical analysis the variogram has been used and for each variable the values of its main features; nugget; sill and range, have been indicated (Nangendo, 2000).

The variogram calculations have been done using ILWIS software packages; this parameter was calculated with the objective to determine the rate of a regionalized variable along a specific orientation (usually distances). Semi-variogram values are defined as the sum of the squared differences between pairs of points separated by a certain distance divided by two times the number of points in a distance class. By plotting experimental semi-variogram values against distance classes in a graph, you obtain a semi-variogram. By finding a model or function, which fits these experimental semi-variogram values, you can obtain necessary input information (such as model type, sill, range, and nugget) for kriging.

For this research ordinary kriging was selected (point interpolation method).

### 5.2.1 Model Fitting

In the site number 1, four semi-variogram models have been fitted NDVI, NDVI Standard deviation, Ratio image and Sum normalized. The values were fitted with either a Gaussian models or Spherical model due to was the best curve fitted according with our data the lag spacing using was 500m with the objective of grouping most of the point at the short distance and to reduce the number of pair (Table 5-3).

The spherical model gave the best fit. The local trends follow more or less the same behavior in NDVI, NDVI Standard deviation and Ratio image. The local trend of Sum normalized is continuous and gradual.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Nugget</th>
<th>Sill</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>NDVI</td>
<td>30</td>
<td>220</td>
<td>800</td>
</tr>
<tr>
<td>NDVI standard deviation</td>
<td>5.5</td>
<td>10.2</td>
<td>1000</td>
</tr>
<tr>
<td>Ratio image</td>
<td>1000</td>
<td>4000</td>
<td>500</td>
</tr>
<tr>
<td>Sum normalized</td>
<td>78</td>
<td>98</td>
<td>2020</td>
</tr>
</tbody>
</table>

Table 5-3 Count model parameters site 1.
1) NDVI site 1

The NDVI showed that for the distance 0, a total of 12 pairs exists, for the distance 500m, a total of 267 pairs, for the distance 1000m, a total of 292 pairs and for the distance 2000m, a total of 74 pair.

The curve was adjust following the spherical model as was mentioned, for the short distances good spatial dependence exists; however for the distance 2000m for the abnormal behavior don’t was possible to fitted that point and due to it was deselected. That behavior means that for 2000m of distance, there is no spatial dependence. For that reason that last point was not fitted and was not selected (see figure 5.1).

Distance | Nr Pairs
---|---
0 | 12
500 | 267
1000 | 292
1500 | 257
2000 | 74

Figure 5-1 Graphs showing the model fitting for the DV of NDVI in the site 1.
2) NDVI Standard deviation. Site 1

The NDVI Standard deviation variogram showed that for the distance 0, 12 pairs, for the distance 500, 267 pairs, for the distance 1000, 292 pairs, for the distance 1500, 257 pairs and for the distance 2000, 74 pairs (Figure 5-2).

The scatter plot in the NDVI standard deviation showed a behavior similar to NDVI, namely for higher distance, there is low dependence. The spherical model was fitted ignoring the pair into the distance 2000 and them 74 pairs were deselected.
3) Ratio image site 1

The ratio image variogram showed that for the distance 0.0, 12 pairs, for the distance 500, 267 pairs, for the distance 1000, 292 pairs, for the distance 1500, 257 pairs and for the distance 2000, 74 pairs (Figure 5-3). As before, at higher distances (from 2000m) there is no spatial dependency. These points were therefore not selected.
Chapter 5. Analysis of the image and result

4) Sum normalized site 1

The sum normalized variogram showed for 0 m distance 2 pairs of point, for 300 m 124 pairs, 600 m of distance 153 pairs, 900 m of distance 164 pairs, 1200 m of distance 185 pairs, 1500 m of distance 179 pairs, 1800 m of distance 74 pairs and 2100 m of distance with 21 pairs (Figure 5-4). The general behavior is continuous and slow. However for the distance 0 m and 1200 the behavior not according to the behavior expected from the curve. For that reason, these two points were not selected.

In general the presence of point out of the normal behaviors of the data means no spatial dependence. The problems may appear for many reasons that are not completely clear. However the influence of the shadows and the image resolution maybe can be a main influence factors.

![Graph showing the model fitting for the DV of Sum Normalized Variogram](image)

**Distance** | **Nr-Pairs**
---|---
0 | 2
300 | 124
600 | 153
900 | 164
1200 | 185
1500 | 179
1800 | 74
2100 | 21

Figure 5-4 Graphs showing the model fitting for the DV of Sum Normalized Variogram
5) NDVI stands deviation site 2

The Variogram of NDVI standard deviation in the site 2 showed that for the distance 0m, 11 pairs, for the distance 500m, 294 pairs, for the distance 1000m, 304 pairs, for the distance 1500, 240 pairs and for the distance 2000m, 53 pairs (Figure 5-5).

The behavior of the curve shows that, for the distance 0m and distance 2000m, there is no spatial dependence. At the large distance case that is normal, but in the closed area that means that it is probably due to distortion into the image as was mention in the previous analysis.

Figure 5-5 Graphs showing the model fitting for the DV of NDVI Standard deviation image in the site 2.
6) Ratio image site2

<table>
<thead>
<tr>
<th>Distance</th>
<th>Nr Pairs</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>11</td>
</tr>
<tr>
<td>500</td>
<td>294</td>
</tr>
<tr>
<td>1000</td>
<td>304</td>
</tr>
<tr>
<td>1500</td>
<td>240</td>
</tr>
<tr>
<td>2000</td>
<td>53</td>
</tr>
</tbody>
</table>

Figure 5-6 Graphs showing the model fitting for the DV of ratio image in the site 2.

The Variogram are showing that for the distance 0m are 11 pairs, for the distance 500m 294m pairs, for the distance 1000m are 304 pairs, for the distance 1500m are 240 pairs and for the distance 2000 is possible to fine 53 pairs (Figure 5-6).

For large distances (1500m and 2000m), the spatial dependency decreases and the semi variance too. For that reason this two point were deselected. However is important to see that we lost 293 numbers of pairs, that will be make negative influence in the future model development.
Chapter 5. Analysis of the image and result

5.2.2 Spatial Modeling

The Surfer and ILWIS software has been used for the generation of all the geostatistical maps. Kriging in Surfer is carried out using its in-built algorithms to produce a grid file, which is the used to produce a contour map for visualization of the variable’s distribution over the area. The obtained maps are very detailed. In each map, the lower values, is shown with black-filled contour and the upper values with light colors.

5.2.2.1 Site 1

The NDVI and Standard deviation of NDVI show clear similar spatial patterns in which the higher values are located in transverse area with the light color and the low values are locate in the north and south respectively, the ratio image show patters so similar how ever the values are inverse, in the case of sum normalizes map it are showing a complete different characteristic of the curve (see figure 5.7).

![Figure 5-7 Spatial variations developed from image transformation Digital Values.](image-url)
Acharya in 1999 made spatial variations of vegetation in the area, he used the same geostatistic procedures, for the site1 the characteristic of the model showed that in the case of species richness transversal line pass across the model this line indicates medium and high values. In the north part is possible to see an area with higher values and in the south are located the lower values, the similar spatial patterns is possible to recognize in the stem density spatial variation model (see figure 5-8).

The visual comparison of the models developed with the data of the forest structure parameter and the model developed from Landsat7-TM show that some similar spatial patterns between NDVI and Species richness, and NDVI and stem density. However this relation are only using qualitative characteristics. This is because it was necessary to export to ILWIS with the objective of making a real quantitative comparison (see figure 5-9).

Figure 5-8 Spatial variations of species richness (a) and stem density (b), site1 (lower) and site2 (upper)
Chapter 5. Analysis of the image and result

Figure 5-9 Spatial distribution of vegetation site 1, (a) NDVI, (b) Standard deviation, and (c) species richness.
5.2.2.2 Site 2

The distributions of spatial patterns show that trend of the curve occur in many direction, in the south part appear areas with high values; in the case of NDVI, highest values of vegetation appear in image indicating higher values of forest cover.

![Figure 5-10 Spatial distribution of vegetation site 2, (a) sum normalized, (b) NDVI, (c) NDVI Standard deviation and (d) Ratio image.](image)

The spatial patterns in the map are showing scattering areas, which show the no homogeneous distribution.
When we compare the model of spatial variation of species richness in a qualitative point of view, it is not possible to determine homogeneous areas (See figure 5.10).

With the objective of a fine detail, it was developed kriging in ILWIS program for NDVI value (see figure 5.11) in which more of forest areas appears.

![Figure 5-11 Spherical models developed from NDVI data in the site number 2](image)

**5.2.3 Trend**

One of the methods used by Acharya for making his data analysis was trend surface analysis (TSA). With this method he obtained models of large-scale variation (trends) of response variables and with these he created predictive surfaces.

TSA is “a simple way to model global spatial variation of any variable of interest such as SRt, SRs and SRv and also this method fits a regression surface to observations with functions of the coordinates X1 and X2 as explanatory variables. For two-dimensional
Chapter 5. Analysis of the image and result

surface, represented by orthogonal axes X1 (east-west direction) and X2 (north-south direction), the value of a dependent variable such as SRt can be expressed as a (polynomial) function:

\[
SRt = Bo \quad \text{no trend}
\]

\[
SRt = Bo + B1x1 + B2x2 \quad \text{linear trend (first degree)}
\]

\[
SRt = Bo + B1x1 + B2x2 + B3x1^2 + B4x1x2 + B5x2^2 \quad \text{quadratic trend (second degree)}.
\]

TSA is therefore a special case of polynomial regression. Coefficients $\beta_i$ of the fitted functions (no trend and quadratic trend) are estimated, and can be used in turn to interpolate the data to unvisited location” (Acharya, 1999 p37-38).

The models made by Acharya characterizing large-scale variation showed a significant positive correlation of SRt, SDt and BAt with the independent location variables x1 and x2 in Sites 1 and 2 (R ranging from 0.41 to 0.76). “Also in Site 3, all response variables with the exception of SRt and SRs were positively correlated with the coordinates (R=0.48 to 0.69). This indicates that when the value of the coordinate increase from the origin, the value of response variables also increases linearly. A large R-value indicates a smooth, uniformly dipping plane, with relatively small deviations from the plane” (Acharya, 1999 p46).

According to Acharya’s research, the quadratic second-degree trend function was selected to describe the existing trend. The models show spatial variation of species richness and forest structure parameter; the trend is stronger for SRt and SDt. Thus for all variables, the variation is unlikely to be caused by chance. The trends are visible from one corner of the study site to the other. The trend is significant in the x2 (north south) direction for all variables (see figure 5.13).

In order to compare the data from Landsat TM (sum normalize, NDVI, NDVI Standard deviation and ratio-image) with the models developed by Acharya from the field data, trend surface model representations were developed (Figure 5-12). The data show no correlation of NDVI, NDVI standard deviation, sum normalized and ratio-images. All the values were close to 0. This indicates that when the values of coordinates increase from the origin, the values of the response variables go in unpredictable ways and do not linearly increase. This behavior is completely different from the linear increase observed in the models obtained with the field data (see figure 5.13). The only cases where a slight trend is apparent from visual examination, is the ratio image and NDVI data. These give some slight positive correlation with the coordinate, showing slight trend in the x2 (north south) direction (see figure 5.12 b and d).
Chapter 5. Analysis of the image and result

a) Sum
  Normalize

b) NDVI
c) NDVI Stand deviation

d) Ratio image

Figure 5-12 Models made with the digital value characterizing the scale of variation.
The visual comparison between models made with the data field and the model developed with the digital values showed that, some similar features in the south areas, in which the values decrease; that characteristic is more evident in the wire frame map obtained from NDVI values and Ratio image, the feature look similar of species richness, species density and basal area of the tree stratum.

The evident different in the surface of the both model bring the idea how different is the behavior of the Digital value in the image of Landsat7-TM and the real characteristic of forest distribution in the area.

5.3 Final Comparison Between Digital Values And Field Data
To make the final comparison between the field data modeled by Acharya and the Digital value obtained from transformation made in the Landsat7-TM image, the ILWIS 3.0 software package was used. So far here, the underlying assumption of the analysis is that there is a relationship between data field and data obtained from Landsat7-TM. To verify this assumption, we want to find out the coincident areas. ILWIS requires that the two data sets have the same domain (data type).

### 5.3.1 Making The Maps Consistent

To make the classification the species richness values was divided in 7 different classes. The selected intervals was 2 and then the class was divided in the following way: very low 0-2, low 3-5, low medium 6-8, high 9-11, very high 12-14, rich more than 14. In the case of Stem density the selected interval was very low 0-5, low 6-11, low medium 12-16, medium 17-21, high 22-26, very high 26-31 and high 32-36 and Rich are more than 37 % of density. In the case of NDVI, the lower values correspond to the lower forest presence, and the class domain was made following this concept, by making intervals of the 6 values. After that operation we give the following numerical range:

- Rich=7  
- Very high=6  
- High=5  
- Medium=4  
- Low medium=3  
- Low=2  
- Very low=1

For making the combination and to obtain the possible relation between that two maps a two-dimensional table was made in which the two raster maps one from dates field and the others from NDVI was combined (see table 5.4). The numerical values since 1 to 7 was subtracted according with the coincidence of the two-dimensional table. After it the data from the table was used with the objective to obtain the output final map in which the low values are corresponding to the values with high coincidence and the higher values are corresponding to the areas with low coincidence (see figures 5.14, 5.15 and 5.16).  

Table 5-4 Two-dimensional tables in which two raster map was reclassified.

<table>
<thead>
<tr>
<th></th>
<th>high</th>
<th>low</th>
<th>low-medium</th>
<th>medium</th>
<th>rich</th>
<th>Very high</th>
<th>Very low</th>
</tr>
</thead>
<tbody>
<tr>
<td>high</td>
<td>0.0</td>
<td>3.0</td>
<td>2.0</td>
<td>1.0</td>
<td>2.0</td>
<td>1.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Low</td>
<td>3.0</td>
<td>0.0</td>
<td>1.0</td>
<td>2.0</td>
<td>5.0</td>
<td>4.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Low-medium</td>
<td>2.0</td>
<td>1.0</td>
<td>0.0</td>
<td>1.0</td>
<td>4.0</td>
<td>3.0</td>
<td>2.0</td>
</tr>
<tr>
<td>medium</td>
<td>1.0</td>
<td>2.0</td>
<td>1.0</td>
<td>0.0</td>
<td>3.0</td>
<td>2.0</td>
<td>3.0</td>
</tr>
<tr>
<td>rich</td>
<td>2.0</td>
<td>5.0</td>
<td>4.0</td>
<td>3.0</td>
<td>0.0</td>
<td>2.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Very high</td>
<td>1.0</td>
<td>4.0</td>
<td>3.0</td>
<td>3.0</td>
<td>1.0</td>
<td>0.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Very low</td>
<td>4.0</td>
<td>1.0</td>
<td>2.0</td>
<td>3.0</td>
<td>6.0</td>
<td>5.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>
Figure 5-14 The coincidence map (Species richness and NDVI) in the site 1.
Figure 5-15 The coincidence map (Species richness and NDVI) in the site 2.
Figure 5-16 The coincidence map (Stem density and NDVI) in the site 1.
5.3.2 Evaluation of Agreement

Confusion Matrix and Kappa Statistic for Species Richness Map Site 1

To assess the accuracy of an image classification, it is common practice to create a confusion matrix. In a confusion matrix, the classification results are compared to additional ground truth information. The strength of a confusion matrix is that it identifies the nature of classification errors, as well as their quantities. A similar approach can be used to compare two maps of the same area, but made by different methods (Weir, 1988). This is the same problem as in this research, where we want to compare the maps made from the field data with those from the Landsat TM data. Both maps have the same 7 classes:

1- Very low
2- Low
3- Low-medium
4- Medium
5- High
6- Very High
7- Rich

Table 5-5 Confusion Matrix for Landsat7-TM Species Richness Map in the site1.

<table>
<thead>
<tr>
<th></th>
<th>Very low</th>
<th>Low</th>
<th>Low-medium</th>
<th>Medium</th>
<th>High</th>
<th>Very-high</th>
<th>Rich</th>
<th>Unclassified</th>
<th>Accuracy</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very low</td>
<td>245</td>
<td>28</td>
<td>581</td>
<td>922</td>
<td>92</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.13</td>
<td>1868</td>
</tr>
<tr>
<td>Low</td>
<td>204</td>
<td>74</td>
<td>380</td>
<td>660</td>
<td>19</td>
<td>22</td>
<td>20</td>
<td>0</td>
<td>0.05</td>
<td>1379</td>
</tr>
<tr>
<td>Low-medium</td>
<td>128</td>
<td>228</td>
<td>446</td>
<td>879</td>
<td>253</td>
<td>164</td>
<td>82</td>
<td>0</td>
<td>0.20</td>
<td>2180</td>
</tr>
<tr>
<td>Medium</td>
<td>49</td>
<td>15</td>
<td>499</td>
<td>588</td>
<td>503</td>
<td>315</td>
<td>19</td>
<td>0</td>
<td>0.30</td>
<td>1988</td>
</tr>
<tr>
<td>High</td>
<td>0</td>
<td>7</td>
<td>291</td>
<td>433</td>
<td>175</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0.19</td>
<td>916</td>
</tr>
<tr>
<td>Very-high</td>
<td>0</td>
<td>31</td>
<td>306</td>
<td>134</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.00</td>
<td>472</td>
</tr>
<tr>
<td>Rich</td>
<td>0</td>
<td>52</td>
<td>61</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.00</td>
<td>115</td>
</tr>
<tr>
<td>Reliability</td>
<td>0.39</td>
<td>0.17</td>
<td>0.17</td>
<td>0.16</td>
<td>0.17</td>
<td>0.00</td>
<td>0.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>626</td>
<td>435</td>
<td>2564</td>
<td>3618</td>
<td>1043</td>
<td>511</td>
<td>121</td>
<td></td>
<td></td>
<td>8918</td>
</tr>
</tbody>
</table>

Table 5-5 Confusion Matrix for Landsat7-TM Species Richness Map in the site1.

<table>
<thead>
<tr>
<th>Class</th>
<th>Very low</th>
<th>Low</th>
<th>Low-medium</th>
<th>Medium</th>
<th>High</th>
<th>Very-high</th>
<th>Rich</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>(P_j)</td>
<td>0.0702</td>
<td>0.0488</td>
<td>0.2875</td>
<td>0.4056</td>
<td>0.1169</td>
<td>0.0572</td>
<td>0.0013</td>
<td>1</td>
</tr>
<tr>
<td>(P_j^3)</td>
<td>0.00034</td>
<td>0.00012</td>
<td>0.0244</td>
<td>0.0689</td>
<td>0.0017</td>
<td>0.00021</td>
<td>0.000001</td>
<td>0.09567</td>
</tr>
</tbody>
</table>

Table 5-6 The proportion of each class used in the calculation of Var. (K).
The error matrix brings the information about how well the areas were classified. After the error matrix process we are going to analyze the information on it. Analyzing a table we can found the average reliability was 15.22% (this values mean how well our areas were identify) in our case the values is so low showing no good relationship between two map. The class very high (0%) and rich (0%) was out of any relation in the process. It means that 100% of both classes was omitted. In the cases of the classes low (0.17%), low medium (0.17%), medium (0.16%), and high (0.17%) the values are so low showing no good reliability. In the case of class Very low (0.39%), this class has the higher reliability in comparison with the other class however that percent continuous so low. In general the reliability for Species Richness map in the site 1 is poor with an overall accuracy of 17.13 and an average accuracy of 12.52%.

As explained in section 4.18, the kappa statistic can be used to see if these values are simply due to chance. To calculate kappa, the observed agreement (Po) is compared with the expected agreement (Pe).

**Observed agreement, Po=0.171338**

Expected agreement, Pe= 0.035976

Kappa, $K = -0.0335$

The 95% confidence limits for Kappa are (-0.4%) - (-0.24%).

The Kappa Statistic is -0.0335. A value so close to zero means that the agreement between the two maps may be explained by chance. In other words, there is no agreement between the two maps.

**Confusion Matrix and Kappa Statistic for Species Richness Map site2**

<table>
<thead>
<tr>
<th></th>
<th>Very low</th>
<th>Low</th>
<th>Low-medium</th>
<th>Medium</th>
<th>High</th>
<th>Very high</th>
<th>Rich</th>
<th>Unclassified</th>
<th>Accuracy</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very low</td>
<td>0</td>
<td>87</td>
<td>61</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.00</td>
<td>148</td>
</tr>
<tr>
<td>Low</td>
<td>0</td>
<td>83</td>
<td>140</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.37</td>
<td>223</td>
</tr>
<tr>
<td>Low-medium</td>
<td>244</td>
<td>399</td>
<td>570</td>
<td>685</td>
<td>222</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.27</td>
<td>2120</td>
</tr>
<tr>
<td>Medium</td>
<td>0</td>
<td>0</td>
<td>72</td>
<td>8</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.90</td>
<td>80</td>
</tr>
<tr>
<td>High</td>
<td>55</td>
<td>772</td>
<td>1524</td>
<td>398</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.00</td>
<td>2749</td>
</tr>
<tr>
<td>Very-high</td>
<td>0</td>
<td>78</td>
<td>505</td>
<td>1130</td>
<td>28</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.00</td>
<td>2749</td>
</tr>
<tr>
<td>Rich</td>
<td>0</td>
<td>229</td>
<td>442</td>
<td>75</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.00</td>
<td>1741</td>
</tr>
<tr>
<td>Reliability</td>
<td>0.00</td>
<td>0.0</td>
<td>0.18</td>
<td>0.03</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.00</td>
<td>7807</td>
</tr>
</tbody>
</table>

Table 5-7 Confusion Matrix for Landsat7-TM Species Richness Map in the site 2
Chapter 6. Conclusions and recommendations

<table>
<thead>
<tr>
<th>Class</th>
<th>Very low</th>
<th>Low</th>
<th>Low-Medium</th>
<th>Medium</th>
<th>High</th>
<th>Very high</th>
<th>Rich</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>PJ</td>
<td>0.04</td>
<td>0.21</td>
<td>0.42</td>
<td>0.30</td>
<td>0.03</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>PJ³</td>
<td>0.00006</td>
<td>0.009</td>
<td>0.07</td>
<td>0.027</td>
<td>0.00002</td>
<td>0</td>
<td>0</td>
<td>0.10601</td>
</tr>
</tbody>
</table>

Table 5-8 The proportion of each class used in the calculation of Var. (K).

**Observed agreement, Po=0.0928**

**Expected agreement, Pe= 0.020**

**Kappa, K = -0.0478**

95% confidence limited for Kappa (-0.0546) to (-0.041)

As in the previous case, the Kappa Statistic so close to zero that the agreement between the two maps may be explained by chance.
### Confusion Matrix And Kappa Statistic for Species Density Site2

<table>
<thead>
<tr>
<th></th>
<th>Very low</th>
<th>Low</th>
<th>Low-medium</th>
<th>Medium</th>
<th>High</th>
<th>Very high</th>
<th>Rich</th>
<th>Unclassified</th>
<th>Accuracy</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very low</td>
<td>447</td>
<td>139</td>
<td>40</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.71</td>
<td>626</td>
</tr>
<tr>
<td>Low</td>
<td>99</td>
<td>150</td>
<td>59</td>
<td>41</td>
<td>57</td>
<td>25</td>
<td>0</td>
<td>0</td>
<td>0.35</td>
<td>431</td>
</tr>
<tr>
<td>Low-medium</td>
<td>911</td>
<td>364</td>
<td>390</td>
<td>281</td>
<td>333</td>
<td>263</td>
<td>0</td>
<td>0</td>
<td>0.15</td>
<td>2542</td>
</tr>
<tr>
<td>Medium</td>
<td>1430</td>
<td>633</td>
<td>277</td>
<td>427</td>
<td>427</td>
<td>321</td>
<td>32</td>
<td>0</td>
<td>0.12</td>
<td>3547</td>
</tr>
<tr>
<td>High</td>
<td>1430</td>
<td>633</td>
<td>277</td>
<td>427</td>
<td>427</td>
<td>321</td>
<td>32</td>
<td>0</td>
<td>0.12</td>
<td>3547</td>
</tr>
<tr>
<td>Very high</td>
<td>1</td>
<td>97</td>
<td>92</td>
<td>213</td>
<td>74</td>
<td>5</td>
<td>20</td>
<td>0</td>
<td>0.01</td>
<td>502</td>
</tr>
<tr>
<td>Rich</td>
<td>0</td>
<td>44</td>
<td>55</td>
<td>12</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>112</td>
</tr>
<tr>
<td>Reliability</td>
<td>0.15</td>
<td>0.10</td>
<td>0.38</td>
<td>0.34</td>
<td>0.19</td>
<td>0.01</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>2980</td>
<td>1535</td>
<td>1025</td>
<td>1242</td>
<td>1098</td>
<td>796</td>
<td>89</td>
<td>8765</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5-9 Confusion Matrix for Landsat7-TM Stem Density Distribution Map in the site1

- **Average Accuracy = 22.15 %**
- **Average Reliability = 16.66 %**
- **Overall Accuracy = 18.54 %**

<table>
<thead>
<tr>
<th>Class</th>
<th>Very low</th>
<th>Low</th>
<th>Low-medium</th>
<th>Medium</th>
<th>High</th>
<th>Very high</th>
<th>Rich</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>(P_j)</td>
<td>0.34</td>
<td>0.17</td>
<td>0.12</td>
<td>0.14</td>
<td>0.13</td>
<td>0.09</td>
<td>0.01</td>
<td>1</td>
</tr>
<tr>
<td>(P_j^3)</td>
<td>0.0393</td>
<td>0.0049</td>
<td>0.0017</td>
<td>0.003</td>
<td>0.0021</td>
<td>0.00072</td>
<td>0.000001</td>
<td>0.051721</td>
</tr>
</tbody>
</table>

Table 5-10 The proportion of each class used in the calculation of Var. (K).

**Observed agreement, \(P_o=0.1851\)**

**Expected agreement, \(P_e=0.0398\)**

**Kappa, \(K = 0.0485\)**

95% confidence limit for Kappa (0.0399)-(0.0572)

As in the previous two cases, the Kappa Statistic (0.0485) is close to zero and the small agreement between the two maps may be mainly explained by chance.
5.4 FCD Map

The FCD map was generated using FCD mapper (Semi expert system) software. For the final output of the system, user defines option selected to categorize 10 different canopy classes in classification. These 10 classes are as follows; class 0 represents no tree area but these areas mainly consist of grassland, stream bank and rest are agricultural with settlement, hill shadow and few other areas etc.

The FCD final map show the higher degradation of forest cover density near settlement and when the is easy to see when the distance from the settlement increase the forest canopy density is also increasing so we have a direct relation with Acharya human disturbance research Table 5.9 and figure 5.17 show areas coverage by each FCD class.

<table>
<thead>
<tr>
<th>Range</th>
<th>% Forest cover</th>
<th>Min-Max range</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>12.21</td>
<td>0-0</td>
</tr>
<tr>
<td>1</td>
<td>0.08</td>
<td>1-10</td>
</tr>
<tr>
<td>2</td>
<td>0.55</td>
<td>11-20</td>
</tr>
<tr>
<td>3</td>
<td>0.76</td>
<td>21-30</td>
</tr>
<tr>
<td>4</td>
<td>2.44</td>
<td>31-40</td>
</tr>
<tr>
<td>5</td>
<td>4.36</td>
<td>41-50</td>
</tr>
<tr>
<td>6</td>
<td>8.99</td>
<td>51-60</td>
</tr>
<tr>
<td>7</td>
<td>14.18</td>
<td>61-70</td>
</tr>
<tr>
<td>8</td>
<td>27.11</td>
<td>71-80</td>
</tr>
<tr>
<td>9</td>
<td>17.57</td>
<td>81-90</td>
</tr>
<tr>
<td>10</td>
<td>1.31</td>
<td>91-100</td>
</tr>
</tbody>
</table>

Table 5-11 Percentage of forest cover according with the range classes
In the representation of the Forest Canopy Density map class 0 represents no forest area, in these areas are located the settlement Okhreni in the northeast and Tarebhir in the south both of these places have been influenced over surround forest areas, clear in the map appear how the forest canopy reduce the cover percent when the distance of settlement decrease. The higher values of forest canopy density are located in the farther areas. This conclusion is coincident with the conclusion by Acharya “The values of species richness, stem density and basal area are lowest near the settlement areas, and gradually increase towards inside the forests, reaching maximum values between the settlements and the least disturbed parts of the forest”.

5.5 Conversion of FCD Maps Into GIS And ILWIS Environment

FCD mapper gives map statistics and also gives FCD classes area (ha) according to the grid system used. Once the FCD map is already, it was saved into BMP cover extra information than exact image area. Sub map was made according to the original georeferenced raster map using same row and column number.

Sub map has still color domain. It was converted into gray scale. After converting in to the gray scale, the slicing was carried out with the objective of classifies the values of a raster map. Ranges of values of the input map are grouped together into one output class. A domain group should be created beforehand; it lists the upper boundaries of the groups and the group names. All this was made according to canopy classes (Class 0 to 10) same as with the final output map of the FCD mapper. Classified FCD map in ILWIS raster map was georeferenced. The area covered by each class was calculated and a table was made for all FCD maps.
Chapter 6. Conclusions and recommendations

Figure 5-18 Map of the forest canopy density

Figure 5-19 Histogram showing the proportion of the forest covers.
Chapter 6. Conclusions and recommendations

<table>
<thead>
<tr>
<th></th>
<th>Npix</th>
<th>npixpct</th>
<th>Area (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Close canopy</td>
<td>253</td>
<td>2.25</td>
<td>232897.6</td>
</tr>
<tr>
<td>Low</td>
<td>340</td>
<td>3.02</td>
<td>312985.0</td>
</tr>
<tr>
<td>High density</td>
<td>1977</td>
<td>17.55</td>
<td>1819915.5</td>
</tr>
<tr>
<td>Dense</td>
<td>4919</td>
<td>43.67</td>
<td>4528156.1</td>
</tr>
<tr>
<td>Medium</td>
<td>863</td>
<td>7.66</td>
<td>794429.5</td>
</tr>
</tbody>
</table>

The forest canopy density class was reduced since 10 class in FCD map to 7 class in the new slicing map, new domain was generate in which 2 class are representing no forest area and 5 represent the total of forest covers.
Chapter 6. Conclusions and recommendations

6. CONCLUSIONS AND RECOMMENDATION

6.1 Conclusions

The following conclusions are drawn based on the Landsat TM data analysis, and the comparison with the data collected of the different forest type.

1-Is there any correlation between TM image characteristics and species richness, stem density basal area data?

For the comparison of the two areas using straight line model showed no relationship between radiance data field data. The spatially distribution of the forest variables (species richness, stem density, and basal area in to the tree stratum, small tree stratum and natural regeneration) and radiance from Landsat TM in the site 1 did not have any relationship with the data field, and in the site 2 the relation is almost zero. This is probably related to higher levels of distortion in to the image due to the irregular characteristic of the terrain in the area that mean a lot of shadows. And showed the necessity of make transformation into the image due to the impossibility of work with the original image.

2-Is it possible to create model in which we can use Landsat TM data to characterize the spatial variation of species richness and forest structure parameters?

From above research study we conclude that there is the possibility to create model using Landsat TM data to characterizing the spatial variation of Species richness and forest structure parameter using wire frame models and contour maps.

With Digital Values the NDVI, Stand deviation of NDVI, Sum normalize and ratio image the follow two models were created, (1) wire frame model and (2) contour map. In wire frame model the trend showed that a some positive patter between NDVI and ratio image. The count or map model showed the patter of the forest areas distribution according with the nuggets sill and rages parameters given to the kriging.

In general the models were developed in with the spatial variation was showed The NDVI and ratio image wire frame model was the best according with the characteristic of the model developed Species density, basal Area and Species Richness which showed the same trend.
3-Is there any relation between the results obtained by Acharya in 1997 and the result of this work?

Analyzing the behavior of the data in this research we can see it poor result for the estimation of high spatial variation of the species richness and forest structure parameter of Shivapuri area using Landsat-TM image. The definitive statement in this research is the follow the estimation of the spatial forest variation in the area using date of Landsat-TM imagery is unreliable.

4- Is FCD programmer is suitable to determine the human disturbance over the forest area?

The FCD final map showed the high degradation of the forest cover density near settlement and when the distance from the settlement increase we can see that, the forest canopy density also increasing. So we have a direct relation between Human disturbance model and the final map of FCD.

6.2 Recommendations

According with the result of this research we arrive to the follow conclusion:

1- For the future research concern the ability to improve spatial variability of species richness and forest structure parameter estimates using image with either finer spatial resolution, multiple look angle, or possible multiple sun angle.

2- Due to the importance of Shivapuri area such as botanical, Kathmandu valley water supply, soil conservation, etc is necessary to study and monitoring the forest resource in the way of determine the grade of disturbance and the possibility of the make a recuperation plan. Forest Canopy Density is recommended for make this type of study due to this easy model is design for analysis the growth phenomenon on forest.
References:


ILWIS. (1997). The integrated land and water information system (Version 2.1). Enschede: ITC.

Lavers, C. (1997). *The use of satellite imagery to estimate Dunlin Calidris alpina abundance in Caithness and Sutherland and in the Shetland Islands.*


Appendix 1  Kappa statistics

The main calculation for accuracy evaluation is shown below:

Site 1 (SSR).

Overall and per-class statistics for the confusion matrix SRR and NDVI for the site 1:

For Site 1:

[1] Number of observations: 8918
[1] Summary of naive statistics
[1] Overall accuracy, stdev, CV%: 0.1713, 0.004, 2.3
[1] 95% confidence limits for accuracy: 0.1635 ... 0.1792
[1] User's accuracy
[1] 0.1312 0.0537 0.2046 0.2958 0.1910 0.0000 0.0000
[1] Producer's reliability:
[1] 0.3914 0.1701 0.1739 0.1625 0.1678 0.0000 0.0000
[1] Summary of kappa statistics
[1] Overall kappa, stdev, & CV%: -0.0335, 0.0048, -14.4
[1] 95% confidence limits for kappa: -0.0429 ... -0.024
[1] Per-class kappa, stdev, & CV%, for user's accuracy:
[1] 0.0656 0.0051 -0.1164 -0.1850 0.0839 -0.0608 -0.0138
[1] 0.0071 0.0058 0.0111 0.0157 0.0137 0.0028 0.0013
[1] 10.8 113.3 -10.5 -11.0 16.3 -4.6 -9.2
[1] Per-class kappa, stdev, & CV%, for producer's reliability:
[1] 0.2301 0.0183 -0.0933 -0.0777 0.0725 -0.0559 -0.0131
[1] 0.0237 0.0207 0.0089 0.0067 0.0119 0.0026 0.0012
[1] 10.3 113.3 -9.6 -8.6 16.4 -4.7 -9.4
Site 2 SSR

**Overall and per-class statistics for the confusion matrix SRR and NDVI for the site2:**

[1] Number of observations: 7807  
[1] Summary of naive statistics  
[1] Overall accuracy, stdev, CV%: 0.0929, 0.0033, 3.5  
[1] 95% confidence limits for accuracy: 0.0864 ... 0.0993  
[1] User's accuracy  
[1] 0.0000 0.3722 0.2689 0.9000 0.0000 0.0000 0.0000  
[1] Producer's reliability:  
[1] 0.0000 0.0504 0.1758 0.0305 0.0000    NaN    NaN  
[1] Summary of kappa statistics  
[1] Overall kappa, stdev, & CV%: -0.0478, 0.0035, -7.3  
[1] 95% confidence limits for kappa: -0.0546 ... -0.041  
[1] Per-class kappa, stdev, & CV%, for user's accuracy:  
[1] -0.0398 0.2042 -0.2504 0.8567 -0.0342 0.0000 0.0000  
[1] 0.0023 0.0404 0.0151 0.0480 0.0022 0.0000 0.0000  
[1] -5.9 19.8 -6.0 5.6 -6.3 NaN NaN  
[1] Per-class kappa, stdev, & CV%, for producer's reliability:  
[1] -0.0193 0.0224 -0.1314 0.0205 -0.5435 NaN NaN  
[1] 0.0016 0.0047 0.0081 0.0025 0.0129 NaN NaN  
[1] -8.3 20.7 -6.2 12.4 -2.4 NaN NaN  

(Note that NaN means "not a number", dividing by zero)
Site 1 Species density:

**Overall and per-class statistics for the confusion matrix Stem Density and NDVI for the site1:**

[1] Number of observations: 8765
[1] Summary of naive statistics
[1] Overall accuracy, stdev, and CV%: 0.1854, 0.0042, 2.2
[1] 95% confidence limits for accuracy: 0.1773 ... 0.1935
[1] User's accuracy
[1] 0.7141 0.3480 0.1204 0.2050 0.0100 0.0000
[1] Producer's reliability:
[1] 0.1500 0.0977 0.3805 0.3438 0.1876 0.0063 0.0000
[1] Summary of kappa statistics
[1] **Overall kappa**, stdev, & CV%: **0.0485**, 0.0044, 9.1
[1] 95% confidence limits for kappa: 0.0399 ... 0.0572
[1] Per-class kappa, stdev, & CV%, for user's accuracy:
[1] 0.5668 0.2096 0.0413 -0.0248 0.0911 -0.0889 -0.0103
[1] 0.0267 0.0270 0.0066 0.0052 0.0135 0.0059 0.0011
[1] 4.7 12.9 15.9 -20.8 14.8 -6.6 -10.7
[1] Per-class kappa, stdev, & CV%, for producer's reliability:
[1] 0.0846 0.0511 0.1274 -0.1023 0.0824 -0.0541 -0.0129
[1] 0.0051 0.0069 0.0200 0.0211 0.0122 0.0039 0.0012
[1] 6.0 13.5 15.7 -20.7 14.8 -7.1 -9.5
7. Appendix 2

The follow photos were taken in different plot into Shivapuri area, we can see the high levels of spatial forest variation in the area.

**Photo 1** Natural Oak forest

**Photo 2** Shrub areas
**Photo 3** Dense Forest with high posture.

**Photo 4** In the photo note the vegetation variation since dense forest to scarce cover
Photo5 Artificial depredated Pine Forest; note the rich broadleaved natural regeneration.

Photo6 Forest with low posture.
### Appendix 3 Data tables used in Statistic and Geostatistic analysis

<table>
<thead>
<tr>
<th>id</th>
<th>x</th>
<th>y</th>
<th>TM1</th>
<th>TM2</th>
<th>TM3</th>
<th>TM4</th>
<th>TM5</th>
<th>TM7</th>
<th>SRT</th>
<th>NOTR</th>
<th>BAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>637445</td>
<td>3074220</td>
<td>30</td>
<td>16.2</td>
<td>18</td>
<td>0</td>
<td>0</td>
<td>18.7</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>637730</td>
<td>3074220</td>
<td>34.8</td>
<td>19.6</td>
<td>25.9</td>
<td>40.3</td>
<td>0</td>
<td>21.2</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>638040</td>
<td>3074220</td>
<td>24.2</td>
<td>12.9</td>
<td>18.1</td>
<td>8.8</td>
<td>12.7</td>
<td>6.7</td>
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