ANALYSIS OF FOREST FUEL WOOD EXTRACTION AND ITS MANAGEMENT IN MARGALLA HILLS NATIONAL PARK USING GIS AND MULTIVARIATE STATISTICS

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May Allah ensure the success all of us here and in the hereafter.

Syed Mubashar Hussain Gardazi

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List of Acronyms and Abbreviations

abnd.dod	Abundance/cover of *Dodonaea viscosa*
ANOVA	Analysis Of Variance
CDA	Capital Development Authority
CTI	Compound Topographic Index
dedod	Density of *Dodonaea viscosa*
DTM	Digital Terrain Model
FAO	Forest and Agriculture Organization
GAM	Generalized Additive Model
GIS	Geographic Information System
GLM	Generalized Linear Model
GPS	Global Positioning System
GRASP	Generalized Regression Analysis and Spatial Prediction
Htdod	Height . *Dodonaea viscosa*
IUCN	World Conservation Union
LPG	Liquefied Petroleum Gas
MHNP	Margalla Hills National Park
MIR	Mid Infrared
NASA	America's National Space Agency
NBR	Normalized Burn Ratio
NDMI	Normalized Difference Moisture Index
NDVI	Normalized Difference Vegetation Index
NIR	Near Infrared
PAC	Principal Component Analysis
Padod	Presence Absence of *Dodonaea viscose*
RMS	Root Mean Square
RS	Remote Sensing
SDM	Species Distribution Modelling
SOI	Survey of India
SPI	Stream Power Index

SRS	Satellite Remote Sensing
TM	Thematic Mapper
TPI	Topographic Position Index
TWI	Topographic Wetness Index
WISDOM	Wood Fuel Integrated Supply and Demand Overview Mapping Model
WRS	World Reference System
WWF	World Wide Fund for Nature

Abstract

Fuel wood extraction is a major cause of deforestation in the country and is major cause of the loss of biodiversity. MHNP, the only protected area in Federal Capital Territory is under fuel wood extraction pressure of *Dodonaea viscosa*, a native species of the region. No baseline data exists on its availability and vulnerability in the region. This study focused on the geographical distribution of *Dodonaea viscosa*, its abundance and vulnerable locations in MHNP. Methodology involved the use of Generalized Additive Model (GAM) in Geographic Information System (GIS) to asses and evaluated the status of *Dodonaea viscosa* in the study area. A backward stepwise GAM was fitted to the field data of the species against the predictor variables including spectral, spatial and topographic variables. The results had shown *Dodonaea viscosa* potentially covering an area of 13894.55 hectares which is approximately 79% of the total area of the park (i.e. 17386 hectares) and lower values (like 0-61) of its presence are near to settlements shown its vulnerable locations. The study evaluated those special predictor variables (like (1) distance to settlements, (2) Normalize Difference Vegetation Index, (3) Elevation) which were important factors in controlling the distribution, abundance and vulnerability of *Dodonaea viscosa*.

Chapter 1: Introduction

Fuel wood extracted from natural forests is one of the most important energy sources for cooking and heating in rural areas throughout the globe. Even the fuel wood extraction at low intensities may strongly impact the structure and composition of natural forests (Rüger et al., 2008). Local patterns of fuel wood collection are heterogeneous which affected the larger forest area to fulfill the domestic energy needs and local market supply (Bhatt and Sachan, 2004, Troncoso et al., 2007, Madubansi and Shackleton, 2007, Miah et al., 2009, Démurger and Fournier, 2010). In recent decades, increase in population accelerated forest change to agricultural fields or pastures led to enhanced stress on the remaining forests to satisfy needs for fuel wood (Echeverrı´a C, 2007). It is about half of the world nearly 3 billion people ,which are using fuel wood in their daily lives, and 1billion people (20% of world population) live in forest-scarce countries (Population Action International, Washington DC 1999). It is estimated that more than 70% population in developing countries use fuel wood as most important energy sources in the form of charcoal or firewood (Ramos et al., 2008).The principal sources of these fuels/fuel wood used are the native forest/vegetation (Kataki and Konwer, 2002) which contain tree felling as the largest share for the overall fuel wood used. The extraction of fuel wood has become important in ecological degradation worldwide, cutting down the trees played important role in the loss of wildlife and biodiversity especially in developing countries (He et al., 2009, Jumbe and Angelsen, 2010, Brouwer and Falcão, 2004) where the forest ecosystems provide considerable amount of energy in the form of fuel wood for subsistence of human societies.

Pakistan is an energy deficient country in the south Asian region where 54% of the energy requirements are fulfilled by conventional sources while the rest of 46% of the energy requirement is obtained from biomass that is fuel wood and agriculture residues (Tahir et al., 2010). The total forest area is 2.5% of the land area of Pakistan where as the annual deforestation rate in the country is 4.6% which is the second highest in the world, signifies the loss of ecological services in national context (Khan and Khan, 2009). These forest resources mainly fuel wood is consumed to meet domestic energy needs and in small businesses e.g. brick kilns (Tahir et al., 2010).

1.1- National Parks and Human Conflicts

National parks are the protected areas to be managed for recreation and ecosystem protection. Globally there are 3900 national parks covering an area of 4.5 million kilometres square (Curry, 2009). The worldwide policy for national parks is determined by World Park Congress held every decade: 2003 (5th in) South Africa. These protected areas experienced the problems like hunting, habituation and resource exploitation (fuel wood extraction) by the locals. Native's involvement in the management is usually deployed to build stability in development and conservation of the national parks. In many cases a feeling of alienation among local community members towards government policies have led to a lack of commitment on their part to external conservation strategies (García-Frapolli et al., 2009) and as a matter of fact communities are not appropriately consulted before creation of national parks and not subsequently included in decision making process. This became the cause of conflicts and resistance from the locals when the conservation programs brought into practice which focus on the minimization of humans activities in the protected area where as the biodiversity is valued in terms of social utility (Lane, 2001). The social need of the protected areas/national parks which resulted in the resource utilization mainly fuel wood, stressing the conservation policies to create the information on the resources status of national parks and integrate the policies into social and cultural fabric of the region in which they are located.

1.2- National Parks in Pakistan and Community Conflicts

In order to protect the flora and fauna in a natural state Pakistan has established many areas which are referred to as national parks. These areas are accessible to the public for research, education and recreational activities. Chapter 2 explains the location of national parks and their status (fig.2) and their status in the country. The establishment of the national parks and implementation of their conservation strategies faced resistance from the locals' Khunjerab National Park is an example where fuel wood and other resource exploitation continued for a long time because of unsustained agreements between the locals and park authorities (Knudsen, 1999).

1.2.1- Fuel wood Extraction in MHNP

The Margalla Hills National park (MHNP) in close proximity to the national capital city Islamabad was established in 1980 (WWF, 2002). Where the inhabitants of the park have been dependent on fuel wood resources of the park for their subsistence. Previous studies in this area and socioeconomic investigation exposed that *Dodonaea viscosa* (*locally called as Sanatha*) which is abundantly distributed in the park is used as most common fuel wood species in the area along with some other species like *Acacia modesta*, *Acacia nilotica*, *Bauhinia varigata* and *Mallotus philipensis* etc. (Shinwari and Khan, 2000, Jabeen et al., 2009, Shinwari and Shinwari, 2011).

1.3- Vegetation Mapping Tool

GIS (Geographic information system) tools are used in vegetation or species analysis, habitat evaluation and monitoring the progress of conservation activities and quantifying spatial patterns of ecosystems. These tools used to display objects geographically consequent to the attributes in database. GIS techniques and statistical models have already been successfully used for mapping (Dimitriou and Zacharias, 2010) and management of protected areas (Flanagan and Anderson, 2008). GIS based tools analysed fuel wood supply and demand spatial patrons by representation of integrated existing information (Masera et al., 2006).

1.4-Problem statement

The extent of the fuel wood extraction is one that is difficult to measure as often there is not a recognizable market structure. It is however a fundamental need of the people. The MHNP which is under category V (Appendix-iii) of protected areas gives provisions of fuel wood collection to the inhabitants of the park but the dilemma is with the commercial exploitation and theft of fuel wood. The problem will not go away and will rapidly worsen if not addressed. According to previous studies carried out in the area *Dodonaea viscosa* is most abundantly used as fuel wood species in MHNP. No extensive study has been conducted in this regard in the area which could provide sufficient information on the availability and distribution of *Dodonaea viscosa* in MHNP. In order to build the effective future management of this protected area, it was an important need to obtain spatial information on the presence/absence of *Dodonaea viscosa* and its vulnerable locations in MHNP.

1.5-Objectives of the Study

Following are the main objectives of this study.

- To map the spatial distribution of *Dodonaea viscosa* in MHNP using GIS.
- To quantify the availability of *Dodonaea viscosa* in MHNP
- To identify the hotspots of *Dodonaea viscosa* collection.

Chapter 2: Review of literature

2.1- *Dodonaea viscosa*

Dodonaea viscosa is distributed commonly on the dry hills of Sindh, Balochistan, North and South Waziristan, Thal to Kurram , salt ranges and dry hills on the bases of the Himalayas on bare soil , Dir, Swat and Hazara eastwards (Flora of Pakistan). *Dodonaea viscosa* is a terrestrial, woody perennial, with a life span of 5-20 years evergreen shrub from *Sapindaceae* family is indigenous species of Pakistan. Its overall height is 3-20 feet and overall spread is 3-10 feet, flowering months are February and March. *Dodonaea viscosa* was used as medicinal herb in different regions of the world, in western Chats tribes of Shola forest region for headaches, backaches, simple ulcer and stomach pains (Arun and Asha, 2008) later study revealed it inhabits stomachaches and ulcers, also used to cure *Candidiasis* (Patel, 2008). In area of Punjab it is often planted as a hedge plant. It is also used in India (Jain, 1994) as important fuel wood species. In various areas of Pakistan it was also extracted medicinally and as fuel (Jabeen et al., 2009) reported from MHNP. Being a native species of the region which is abundantly distributed in the park not only gives an ever green sight to MHNP but more importantly, it protected the habitat and biodiversity of the region.

2.1.1- *Dodonaea viscosa* as a fuel wood species in MHNP

The MHNP as mentioned in chapter 1 and 3 is present at close proximity to Islamabad. There are some associated villages in MHNP and few within its boundaries where people use *Dodonaea viscosa* as major fuel wood. The previous studies reported it to be the most commonly occurring specie of the area as well as its highest use as fuel wood (Jabeen et al.,

2009) and (Shinwari and Khan, 2000). Socioeconomic investigations and prior studies showed that Dodonaea *viscosa* (locally called as *Sanatha*) was most commonly used to fulfill basic household energy needs (cooking and heating) and was also supplied to markets. The main reasons that were reflected for the preferred use of *Dodonaea viscosa* as a fuel wood were (i) easy to access/ available (ii) easy to extract (iii) fast in burning even if green (iv) raw carbon emitions (less blackening of utensils) like other fuel wood species during cooking, and obviously (v) increasing population pressure.

2.2-National Parks in Pakistan

Pakistan has 19 national parks (Fig.2) which are under the supervision of respective provincial governments and some under private care; few of these are under the conservation scope of IUCN. Pakistan's environmental protection and conservation is within the concurrent constitution of 1973. The oldest national park of Pakistan is *Lal suhanra* in *Bahawalpur* district. This park was established before the independence of the nation. Protection of the wildlife of *Cholistan desert* was the purpose to set up the park. The largest national park of the country is *Central Karakoram* in *Gilgit Baltistan* with an area of 973,845 hectares (Table.2). *Ayubia National Park* is the smallest which covers an area of 1,684 hectors.

Table 2: National parks of Pakistan

	National Park	Province	IUCN Category	Total Area (ha)	Year
1	Ayubia	KPK*	V	1,684	1984
2	Central Karakoram	Gilgit-Baltistan	N/A	973,845	1995
3	Chinji	Punjab	II	6,070	1987
4	Chitral Gol	KPK	II	7,750	1984
5	Deosai Plains	Gilgit-Baltistan	N/A	363,600	1993
6	Ghamot Handrap	AJK**	N/A	27,394	2004
7	Shandhoor	Gilgit-Baltistan	N/A	51,800	1993
8	Hazarganji-Chiltan	Balochistan	V	15,555	1980
9	Hingol	Balochistan	II	699,088	1997
10	Khunjerab	Gilgit-Baltistan	II	227,143	1975
11	Kirthar	Sindh	II	308,733	1974
12	Lake Lulu Sar	KPK	N/A	30,375	2003
13	Lake Saiful Muluk	KPK	N/A	7,876	2003
14	Lal Suhanra	Punjab	V	51,588	1972
15	Machiara	AJK	N/A	13,593	1996
16	Margalla Hills	Federal CapitalTerritory	V	17,386	1980
17	Pir Lasora	AJK	N/A	5,625	2005
18	Sheikh Buddin	KPK	IV	15,540	1993
19	Toli Pir	AJK	N/A	5,045	2005

** Azad Jammu & Kashmir * Khyber Päkhtunkhwa

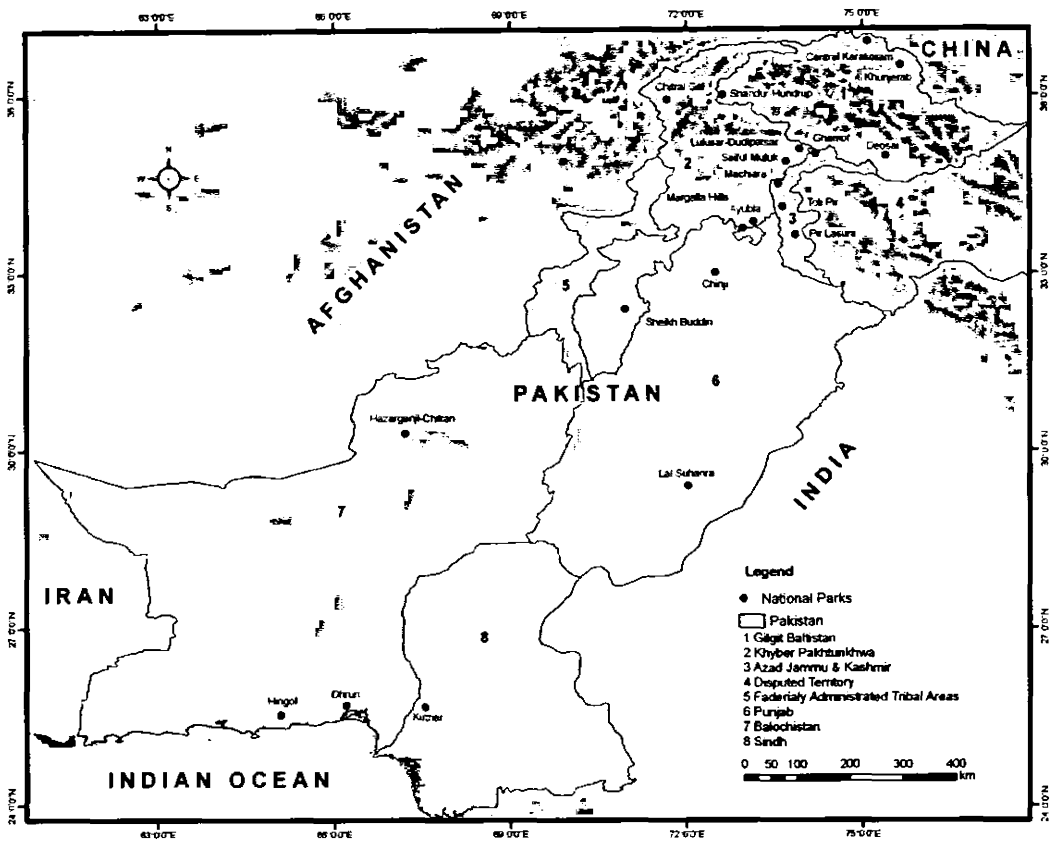


Figure 2: Location of national parks in Pakistan

2.3- Status of the National Parks in Pakistan

National parks are the protected areas which received protection because of their cultural, environmental or similar values. All of Pakistan's national parks (Table.2) are scattered in the four provinces, Gilgit-Baltistan and AJK (fig.2). However only few of the national parks match their global standards. They fall under different categories of IUCN protected areas (Appendix-iii). Preservation of few land areas for specific purpose has rooted in the history (by early rulers) in the region of today's Pakistan. At time of independence Pakistan had legislation inherited from British period like Indian Forest Act 1927 which was later titled as Pakistan Forest Act 1927 (IUCN, 1990). Later different legislations like Pakistan Wildlife Protection Ordinance 1959, to manage protected areas and biodiversity especially national parks in 1974 were the legal requirements giving protection to national parks. Pakistan Environmental Protection Act-1997 which replaced the 1983 ordinance showed its relevance to the biodiversity conservation in necessary screening of the proposed projects and preparation of forestry sector master plan/ biodiversity action plane reversed the accelerating trend of degradation of environment in the country (Government of Pakistan et al., 2000, Government of Pakistan, 2005). According to the Biodiversity Action Plan in 2000, Pakistan was having 14 national parks which are 19 at present as shown in Fig.2. Majority of them lack in management plans, weakness in laws and policies and their enforcements, short of appropriate information in many respect, less involvement of the local community and shortage of professionals (Government of Pakistan et al., 2000, Khan and Zafar Iqbal, 2003). Recently few efforts were made to overcome flaws, by a consultative procedure several national parks were shortlisted to manage the same on par with international standards, which included Lal Sahunra, Kirther, Khunjrab, Chiltan Hazar Gangi, Chitral Goal and Margalla Hills, national parks (Government of Pakistan, 2005).

MHNP which falls in V category of IUCN for protected areas (Appendix-iii) is under the supervision of the Capital Development Authority (CDA) was also partially developed by HWF (Himalayan Wildlife Foundation) in 2005/2006 which was engaged in tourism development and environmental protection, participated in the community based awareness in the area for conservation of the park and also proposed the areas of necessary legislation for this purpose (HWF, 2006).

2.5-Management of fuel wood by GIS an Effective Tool

Sustainable forest fuel management can be defined as "the use of forests land and forest in a way, and at rate, which would preserve their biological diversity, regeneration capacity, productivity and their ability to fulfill, needs of the present and the future, relevant ecological and social functions, on local, national and world levels, and which would not cause damage to other ecosystems" (Mayer, 2000). Geotechnology is considered as one of three magatechnologies of the 21st century along with biotechnology and nanotechnology (Boyd and Foody, 2011), recent advances in geotechnologies of GIS (Geographic Information System) and RS (Remote Sensing) have a solid impact on the ecological research by providing special data information that could enable the more understanding of the ecological system. This technology was effectively applied in forest management (Zagas et al., 2011) the field observations, topographical data, calibrated models, climatic and geological data were also indicators of human presence and were properly combined in GIS environment , particular protective functions for the forest were identified which were the necessary steps in designing and management of southeast Olympus forest.

Assessing the mode of recent fuel wood production patterns and sustainable potential of fuel wood resources through the better knowledge of spatial pattern of fuel wood supply and demand could provide better way for fuel wood management. WISDOM (wood fuel integrated supply and demand overview mapping model) is a GIS based tool (Masera et al., 2006) analysed spatial pattern of fuel wood supply and demand. WISDOM is a strategic planning tool not an operational one which was used to integrate the statistic and spatial data about the production and consumption of fuel wood. It involved the analysis under five main steps, 1) development of special base; which include socio-economic and demographic parameters the data was linked to the map attribute table which could extend by a similar set of attributes or map elements. 2) Demand module; which included the fuel wood consumption data by households and industries both rural and urban. 3) Supply module; involved the data of existing forest inventories and biomass survey. 4) Integrated module; which gave fuel wood deficit= [fuel wood supply- fuel wood demand] <0, and potential pressure on fuel wood= [fuel wood demand/ total assessable fuel wood sources]. 5) Identification of fuel wood hotspots the areas which are under high pressure of supply/demand of fuel wood. The WISDOM based approach was applied on three case studies at the entire country level i.e. Mexico, Senegal and Sylvania which represented contrast in fuel wood dynamics, socio-economic and ecological context and policy implications.

In Alice Spring district of Australia cutting of wood is in progress both for commercial and public purposes (mainly that of native species Acacia aneura tree). One of the studies conducted to find out impacts of fuel wood collection on native species. A general concern was that cutting trees for fuel wood change the hydrological properties of an ecosystem, when combined with pressure of grazing may lead to deterioration of ecosystem functioning and ultimately landscape dysfunction. Facts propose that preserving full ecosystem function is important to the existence of patterned Mulga, which trouble individual components of this landscape and possibly leading to ecosystem degradation. Detailed statistical analysis of the field study resulted that fuel wood collectors were the big causes negatively impacting on the Mugla distribution in the area.

Providing public alternative energy sources or other firewood sources (other then native species) can reduce the pressure on Mugla (Berg and Dunkerley, 2004).

When fuel wood extraction is exceeding the natural growth rate negative environmental and socio-economic impacts appear like forest degradation, shortage and GHG emission. The supply demand pattern of Fuel wood were analysed in selected county-based hotspots in Central Highland Mexico (Ghilardi et al., 2009) . Grid based model was developed to identify the localities that are under high consumption fuel wood pressure and less supply. Twenty localities out of ninety were identified as critical in terms of six indicators (Land cover change 1986-2000, fuel wood users, fuel wood density, households, % of people belonging to an ethnic group, fuel wood balance) related to fuel wood availability and its use. By giving weight to the indicators the fuel wood priority index was constructed on the basis of which pressure exerted over natural forest is calculated ($PF_v = B_v/F_v$ where PF_v is annual fuel wood extraction rate, B_v is balance of fuel wood per locality and F_v is the assessable forest area per locality). The supply demand varies in localities, while fraction of renewable fuel wood varies from 0-96 %. Results showed that non-renewable fuel wood fractions and balance calculated at locality bases could have advantages.

During a study by the interpretation of satellite data using Geographic Information System (GIS) the spatial and temporal patterns of land use in micro watershed of India were analysed. The topographical maps of Survey of India (SOI) were used having scale 1: 50,000 to map land use/cover as in 1967 overlaid by the layers of elevation, slope, aspect, roads and footpaths. Landsat Thematic Mapper (TM) and Indian Remote Sensing Satellite – LISS-III T at 1:50,000 scales were visually interpreted for mapping land use/cover in 1988 and 1997. For layers digitizing purpose PC based GIS was used with a maximum root mean square (RMS) error of 15 m, using ArcInfo (ESRI, Redlands, USA) version 3.4 D (Wakeel et al., 2005) . Results showed that within a period of 30 years from 1967 to 1997 due to various reasons i.e. agricultural expansion, human and live stock population increase etc, the forest cover has severely decreased. However forests managed by local people are more vulnerable in terms of reduced cover from those in government control.

Selective fuel wood extraction favours the invasive alien plant species as it involved the removal of native species for fuel leaving the invasive plant untouched, invasion of the *Lantana camara* is an example in Nairobi Kenya (Furukawa et al., 2011). The relationship between distance from slums and canopy cover (human disturbance gradient and floristic composition) was analysed in the study. Generalize Additive Model (GAM) which was applied on the data collected near and far from slums showed a non-linear relationship, between species richness of non-preferred and preferred species (woody species) with disturbance gradient. The preferred species richness was abundant at 1700m distance from slums and was at rapid decrease near disturbance source. The study suggested use of *Eucalyptus* plantation in the area which could be effective alternative to avoid use of native fuel wood species.

Kolar district in Karnatika state is an example of rural India where 80-90% of energy is obtained by fuel wood to acquire basic domestic needs. Ramachandra explained that rapid change in land use and land cover has affected this traditional fuel availability in the area. An integrated approach was used to compile both non-spatial and spatial data from government institutes (Indian remote sensing satellite; National Remote Sensing

Agency Hyderabad India and Census Directorate, Forest, Agriculture and Horticulture departments), spatial and temporal analysis using RS data, GIS tools and field survey (using GPS) was adopted in study (Ramachandra, 2010). The image processing involves the principal component analysis (PAC) to reduce data set's dimensionality and normalized difference vegetation index (NDVI) to carry land cover analysis (NDVI= [(NIR-RED)/(NIR+RED)]. The mapping of *Prosopis juliflora* (fuel wood specie) was done by considering villages as a sampling unit give a stock of fuel wood availability with 88% accuracy (GPS verification of map).

2.6-Species Distribution Modelling

Ecologists have an increased need for local observations and quantifiers to measure changes from the microcosmic to the macro-cosmic scale using landscape, and statistical or simulation models to extrapolate spatial ecological data (Miller et al., 2004). Species distribution model development begins with observing species, as they occur, within environmental variants that influence the types of habitat that may be suitable for the distribution of species. These types of models come in a variety of quantitative and rule-based scenarios and based on harmony of the predictors and the species in each model insights are provided into the habitat and environments a species might choose. This, in turn, allows for opportunities to make spatial predictions. This can be called '*Predictive mapping*,' Geographical extrapolation, using this type of model, can presumably predict what species will be living in a specified area from boundary to established boundary. Maps of any kind of ecological information, and any other useful information that is available, must be ready to use if any such predictive mapping is to occur (Franklin, 1995)

SDM (species distribution model) described as species niche model, ecological niche model or niche theory model where specie could potentially live, where it does live or where the specie might survive (Rotenberry et al., 2006). BIOCLIM was the climate niche modelling system which describes the climate of where the specie lived (Heikkinen et al., 2006) when predictors carry more information then simple climatic information, the models are made to answer the question about climate change. The maps which are resulted from the model may be called as predictions of species geographical range (Graham et al., 2004). SDMs are based on the understanding the correlation of species and its interaction with its surrounding abiotic and biotic environment. Other factors are observing for the purpose of learning about environmental interaction, and testing ecological or biogeographical theories concerning species range and types of habitation. Determining how pattern and scale can influence the abundance and distribution of the species (Scott et al., 2002). When testing phylogenitic and ecological hypothesis (Jones et al., 2007) the model describes species habitat relationship may be the result of interest and special prediction form the model may not be needed.

SDMs were used much in local and global scale conservation planes. Activities that require "biodiversity assessment," i.e., knowing the distribution of species, communities, species richness or other community attributes, on the landscape require (Kremen et al., 2008) such maps showing where species are distributed and where their habitats are found so that areas of peril or possible extinction may be targeted for a protected status and habitats may be set aside as 'nature reserves'. One impressive example was carried out by Australian scientists via state agencies. They developed SDMs for more than 4000 species. These SDMs were based 'on over a quarter of a million location records in a 100

000 km2 region, and made important conceptual and methodological advancements along the way' (Ferrier et al., 2002b, Ferrier et al., 2002a), modified from Ferrier (2002), this example shows how SDMs supports regional biodiversity

2.7-Generalized Additive Model

Generalized Additive Model (GAMs) are an useful approach used to identify and describe non-linear relationship among response and predictors and so when applied from a prospective they differ from the Generalized Linear Model (GLMs) with their ability to illustrate the nature of response function (Yee and Mitchell, 1991). GAMs are the non-parametric addition of GLMs (Guisan et al., 2002). GAMs like GLMs have distributions belong to the groups of distributions i.e. Gaussian, binomial, Poisson, negative binomial. The model can made spatial predictions by importing entire GIS datasets of all predictors in statistical software packages, predicting using existing software tools exporting the resulted GIS map. This approach can be adopted by any modelling technique whose ability depends on the software limits and size of datasets. An alternative way has developed "look-up table" which described response curves for each variable of reduced number of values. Then "look-up tables" are used in GIS for reclassification of predictors with respect to their contribution to model using map algebra or logical operators. GAMs have been applied in SDM using specialised software tools like GRASP (Generalized Regression Analysis and Spatial Prediction) (Lehmann et al., 2002).

GAMs were introduced to species distribution modelling by Yee and Mitchell's (1991) asserted that assumed the best-fitting response as the non-linear, if the data fitted to the parametric curve, then for carefulness, a non-parametric curve is preferred. These models are useful to characterise non-linear species response curves in exploratory and graphical way. Species response parameters like optimum/tolerance can't be calculated by GAMs as some of the others models can (Hirzel and Guisan, 2002). However GAMs are flexible and very powerful modelling approach (Wood, 2006) and have became extensively used in species distribution modelling (Brown, 1994, Frescino et al., 2001, Guisan et al., 2002, Lehmann et al., 2002). In comparison GAMs better then the GLMs and other models in the case of spices distribution modelling (Moisen et al., 2006, Austin, 2002, Meynard and Quinn, 2007). For the planning and conservation GAMs have been extensively used in species distribution modelling (Lassalle et al., 2008, Platts et al., 2008). Their use will be continued as one of the different or the only way in modelling the species distribution.

Chapter 3: Research methods

3.1- Study Area

Margalla Hills National Park at the Himalayan foothills located north east of the federal national capital, Islamabad, along with the adjacent areas of Shakarparian and Rawal Lake, spanning over an area of 17,386 hectares. The geographical coordinates of MHNP are 72°55' E to 34°43' N. The area has rugged topography, varying in elevation from 465m-1600m with numerous valleys and many steep slopes, where rock structure is basically limestone. It is the easiest accessible national park due to its close proximity with Islamabad. Tourist visiting spots are present like Damon-e-Koh and Monal along with associated hiking tracks. There are few villages situated at the margins and also within the boundaries of the park. There is a variety of vegetation diversity in the area, evergreen trees, and shrubs in majority than the deciduous trees in the southern slopes. In the north, stand Pines and groves of Oak. Fauna is Indo-Himalayan, the birds present are resident as well as the winter migrants of north high altitudes, spring and summer visitor for breeding. MHNP is at the far end of monsoon zone, in July and August heavy rainfall occurs with a monthly average of 269 mm and 309 mm respectively. The soil of the area is derived from wind, water laid deposits and sedimentary rocks. The average temperature of the area ranges from maximum 33.3° C to minimum 19.5° C (Jabeen et al., 2009). May and June are the hottest months when temperature may rise upon 42° C and December and January are the coldest months when it may drop to zero. Figure 3.1 gives a view of the study area.

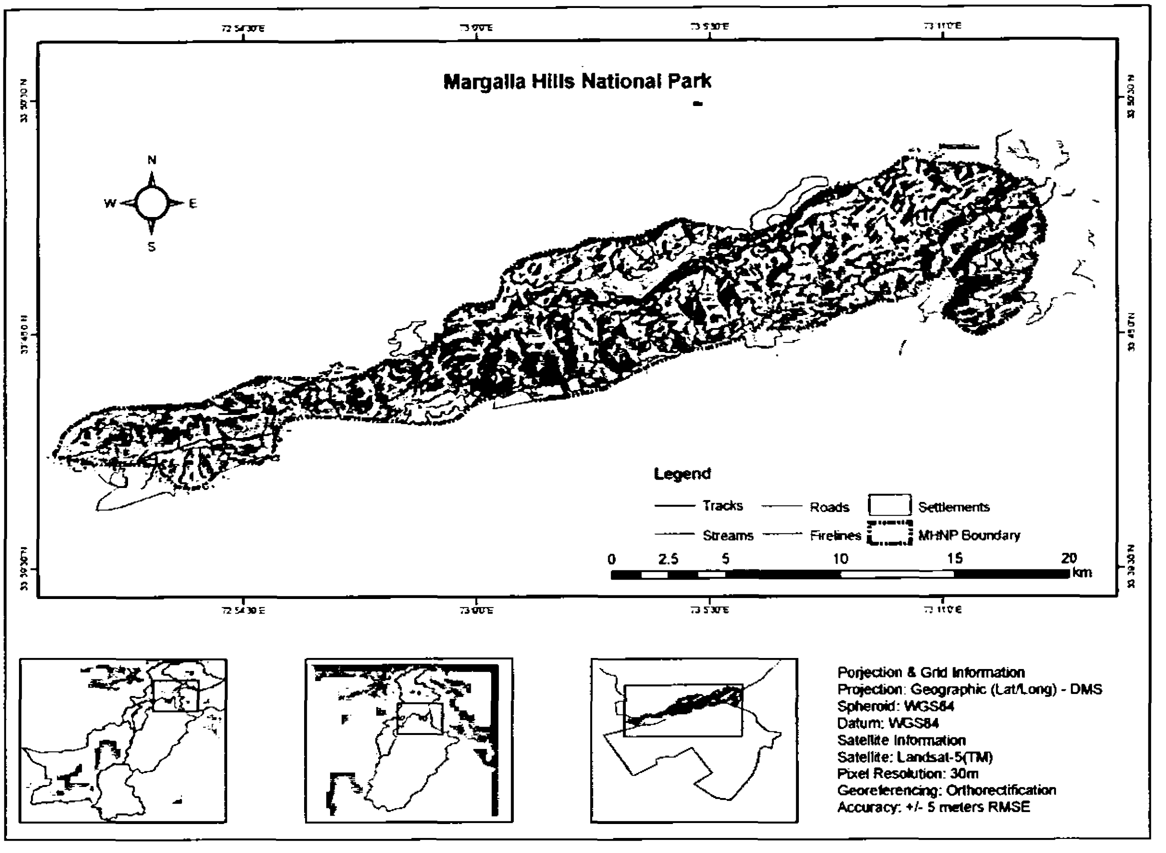


Figure 3.1: Margalla Hills National Park

3.2- Methodology

The present study aims at the analysis of *Dodonaea viscosa* extraction that is used as major fue lwood in the study area. For this purpose a socioeconomic investigation and detailed ecological survey were conducted in MHNP, which is explained in this chapter under the headings below. Figure 3.2 gives an overall view of methodology involved in data analysing process.

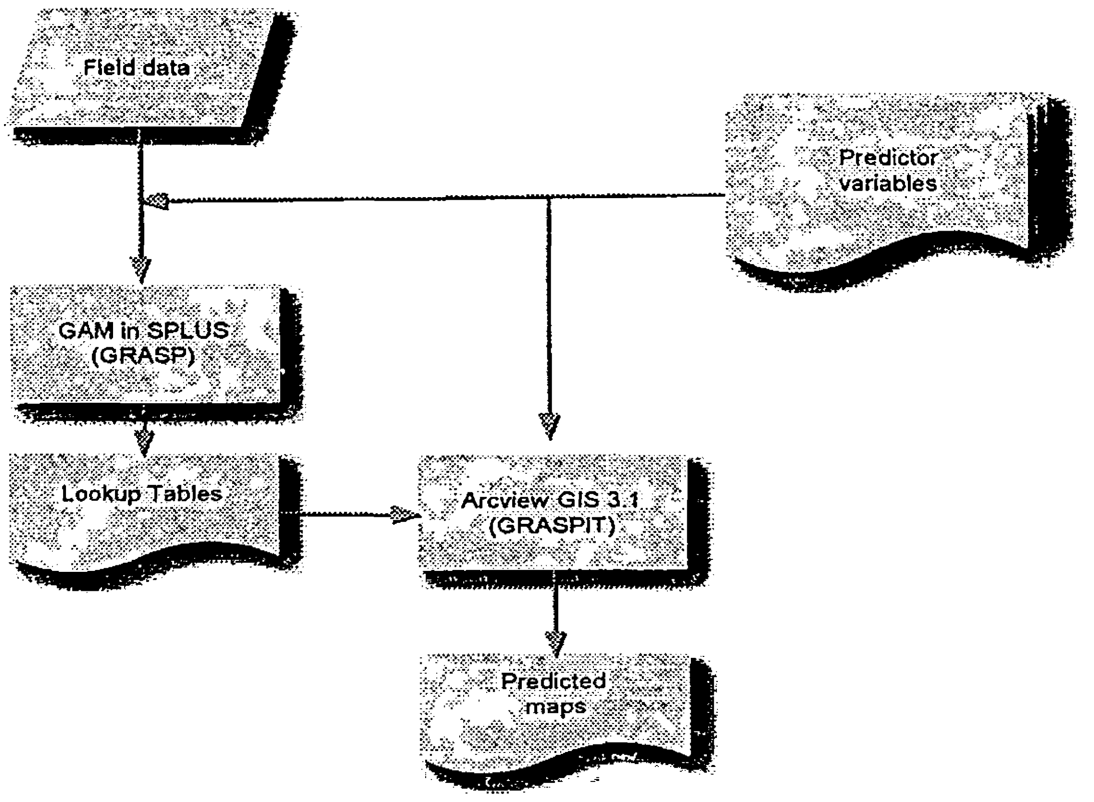


Figure 3.2: modelling process for predictive mapping of *Dodonaea viscosa.*

3.2.1- Preparation for study

To start with research work detailed analysis of the literature and consultation with experts was carried out concerning diverse aspects of the study. Similar studies from research papers were gathered to outline the aims and objectives of the study and conduction of research work. In order to gather data regarding fuel wood consumption discussions and interviews of inhabitants/ dependants of MHNP were made (Questions in Appendix-iv). Data collection sheet was also made to record the field sampling in the study area (Appendix-ii). Materials required for field sampling were

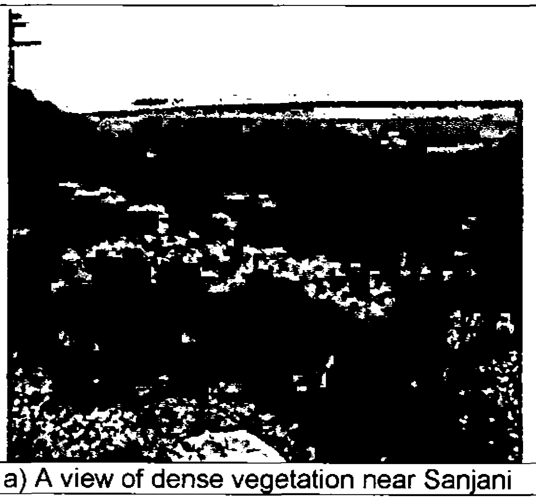
- Garmin® Etrex® GPS (Global Positioning System) handled receiver.
- Measuring tape of medium size
- Digital camera
- Map of MHNP showing boundaries

- Bamboo sticks
- Cutter for bushes
- Slate and writing material

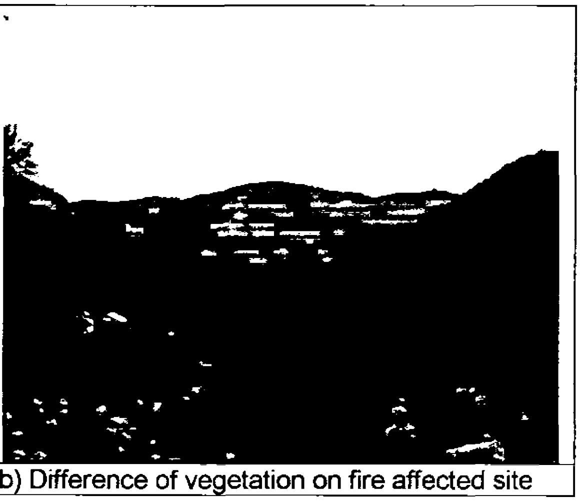
3.2.2-Field survey and data collection

Field visit and data collection was on personal. Field survey was carried out in April-May 2011 which covered almost all of 26 villages of the study area (Appendix-ii) focused on the investigation about fuel wood consumption patrons and field sampling. Park was approached by different roots and tracks by hike from

- Trail 5 to Choki
- Trail 3 to Choki
- Saidpur village to deep forest (towards north)
- Faisal mosque to Sinduri and adjacent areas
- Gandian and Sinyari to top hills
- Daman-kho to Choki and Malwar
- Quaid-Azam University to Rumli, Narias and Shadra
- Shadra to Subban, Mangwal and Baddo
- Shah Allah Dita to kathalla
- Forest near Jori Rajgan and khurram Paracha in Sanjani
- Gokina to Choki
- Bari Imam to pirsuhawa



a) A view of dense vegetation near Sanjani



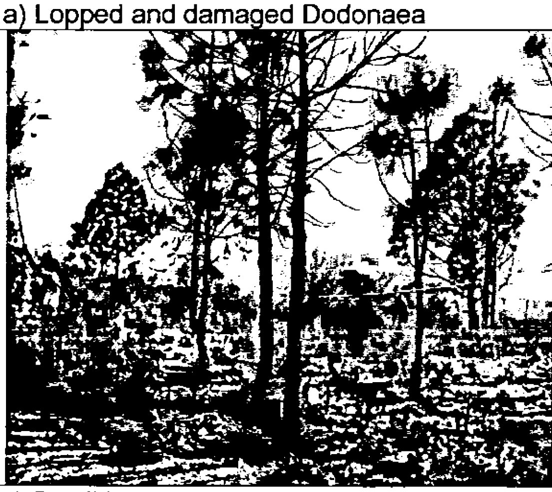
b) Difference of vegetation on fire affected site

a) and b) A site view in the study area

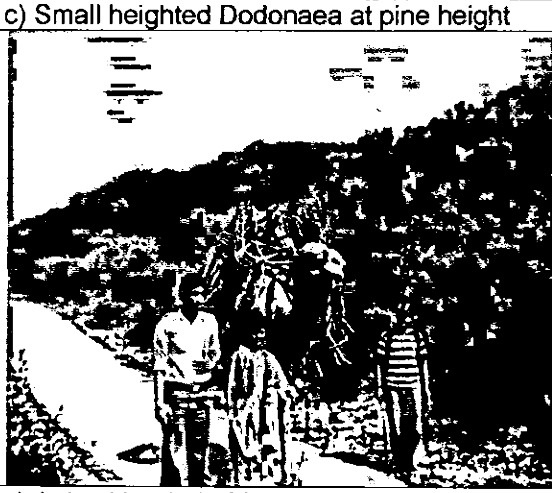
A View of fuel wood collection hotspots

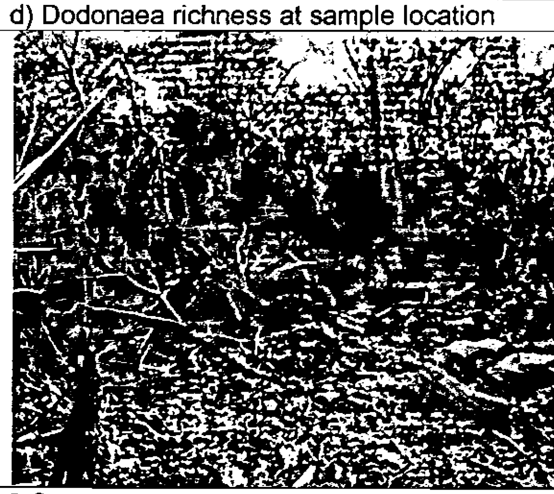

a) Lopped and damaged Dodonaea


b) Fuel wood collector 1-hour hike from Talhar


c) Small heighted Dodonaea at pine height


d) Dodonaea richness at sample location


e) Animal loaded of fuel wood near mangyal


f) Stumps and debris of cut wood

3.2.3- Sampling

Random sampling was carried out with total of 297 plots though out the study area (Fig.3.2). Size of each sampling plot was 100 m^2 (10mx 10m) which was based to record presence /absence of *Dodonaea viscosa* its density, height and visual estimation (Ringvall et al., 2005) of percentage cover. Bamboo sticks were used to point corners of the selected sampling plot area measured by the tape. Photographs of the sampled area were also taken with its sample number mentioned on the slate. The information about the lopped and fully damaged plants was also recorded on the indication of presence of wood debris, signs of lopped and presence of stumps. Numbers of lopped plants were counted out of total density. Location data for each plot is recorded by GPS (Global Positioning System) receiver.

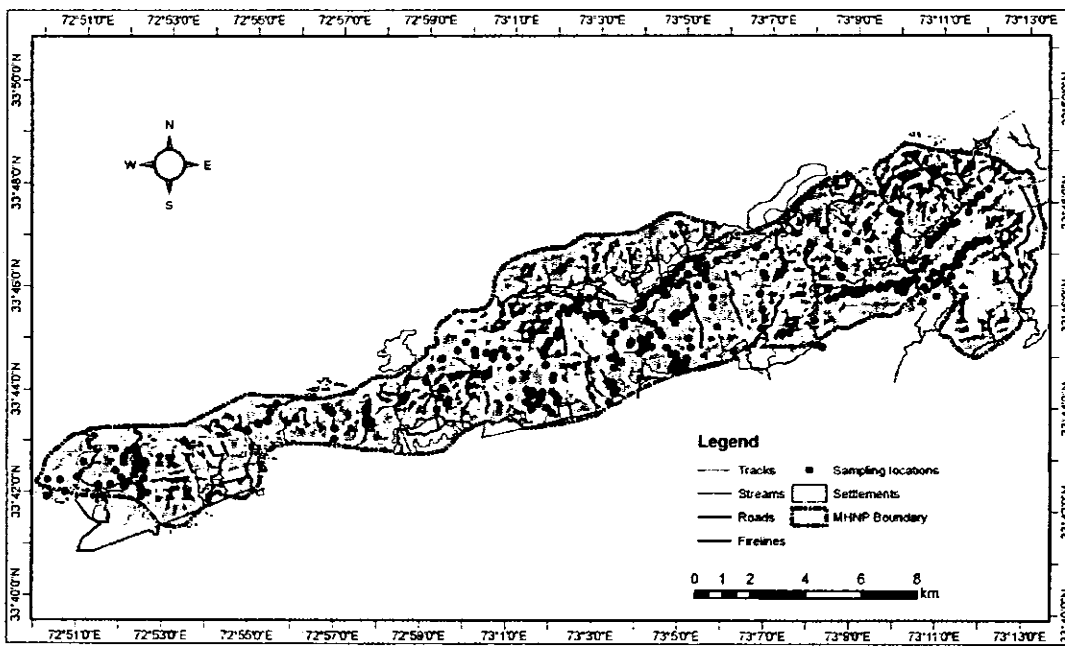


Figure 3.3: Sampling Locations in MHNP.

The cover of the species have given values on the bases of visual assessment to their percentage cover in the sampling plot, from which for analysis adopted the higher values of percentage to find percentage cover (Beck et al., 2005). Similarly the height was also given value on its overall variation in the sampling plot.

3.3-Remote sensing data

The main source of information extraction was through Satellite Remote Sensing (SRS). The LANDSAT satellite imagery was used as a source of SRS data for the current assessment. It was a good choice due to the fact that data is available since 1972 holding a largest data for monitoring the global environment. The data is available at no cost from America's National Space Agency (NASA) and can be searched using World Reference System (WRS) consisting of the Path and Row system for the entire globe. The study area falls within path 150 and row 37 of WRS-2. The SRS data for the current study comprised one Landsat TM (Thematic Mapper) image (2010-06-18). The image was obtained as L1G data, which is geo-referenced and radiometrically corrected.

The imagery has seven spectral bands including three visible (0.45-0.69 μm, TM bands 1, 2, and 3), one near infrared (0.76-0.90 μm, TM band 4), one short wave infrared (1.55-1.75 μm, TM band 5), one thermal infrared (10.40-12.50 μm, TM band 6), and one mid-wave infrared (2.08-2.35 μm, TM band 7) band with a spatial resolution of 30 metres, and a revisit time of 16 days(Ray et al., 1994).

3.4-GIS Data

Monitoring of land cover using SRS alone is not as powerful or accurate as when it is combined with ancillary GIS data (Green et al., 1994).The combination of SRS data with GIS layers (such as topography, property ownership, and forest stand management information), may result in data analysis with powerful and more reliable information capabilities. The GIS data used during the present study was extracted from Digital Terrain Model (DTM).

3.5-Predictor variables

The predictors are the physical variables consider likely to be useful for predicting the occurrence of vegetation species on the areas which have been cleared of native vegetation. Examples include climatic attributes, geology, soil attributes and topographic position (Cawsey et al., 2002). These needed to be available for both plots and spatial GIS layers. The variables used in the study (Table) are described below.

Table 3.1: Predictor Variables

S.NO	Predictor Variables	Data item	Unit	Resolution	GIS layer derivation	Significance
	Spectral					
1	ndmi	Normalized Difference Moisture Index	_	30m	Landsat bands(4&5)	moisture change (Goodwin, et al., 2008)
2	ndvi	Normalized Difference Vegetation Index	_	30m	VIS and NIR reflectance	Green vegitation indicator (Tuker,et al.,1999)
3	nbr	Normalized Bum Ratio	_	30m	Landsat bands(4&7)	Burn Extant (cocke et al.,2005)
	Topographic					
4	tpi	Topographic Position Index	_	30m	DTM	Relation in actual cell elevation (Riely, et al., 1999)
5	twi	Topographic Wtness Index	_	30m	DTM	Static soil moisture content (Goodwin, et al., 2008)
6	cti	Compound Topographic Index	_	30m	DTM	Slope and runoff (sakun,2003)
7	spi	Stream Power Index	_	30m	DTM	Soil decrease impact
8	rug	Topographic Ruggedness Index	_	30m	DTM	Differrence in grid elevation (Riely, et al., 1999)
	Terrain					
9	ele	Elevation	metre	30m	DTM	Point above the surface (Tuker, 2001)
10	slp	Slope	degree	30m	DTM	Change in altitude
11	dset	Distance to Settlements	metre	30m	Settlements vector layer	Disturbance indicator (Hannon & Bradshaw, 2000)
12	droad	Distance to Roads	metre	30m	Roads vector	Disturbance indicator (Geneletti, 2003)
13	dtrack	Distance to Tracks	metre	30m	Track vector	Disturbance indicator (Godefroid & Koedam, 2004)
14	dstr	Distance to Streams	metre	30m	Stream vector	Soil erosion (Haslam, 1987)
15	cosasp	Cos of Aspect	degree	30m	DTM	Northness

3.5.1-Spectral

3.5.1.1-Normalised Difference Moisture Index

Normalised Difference Moisture Index (NDMI) derived from Landsat spectral bands 4 and 5 (Fig. 3.4) and calculated using the following equation:

$$\mathrm{NDMI} = \frac{\mathrm{Band4} - \mathrm{Band5}}{\mathrm{Band4} + \mathrm{Band5}}$$

This index contrasts the near-infrared (NIR) band 4, which is sensitive to the reflectance of leaf chlorophyll content to the mid-infrared (MIR) band 5, which is sensitive to the absorbance of leaf moisture (Goodwin et al., 2008)

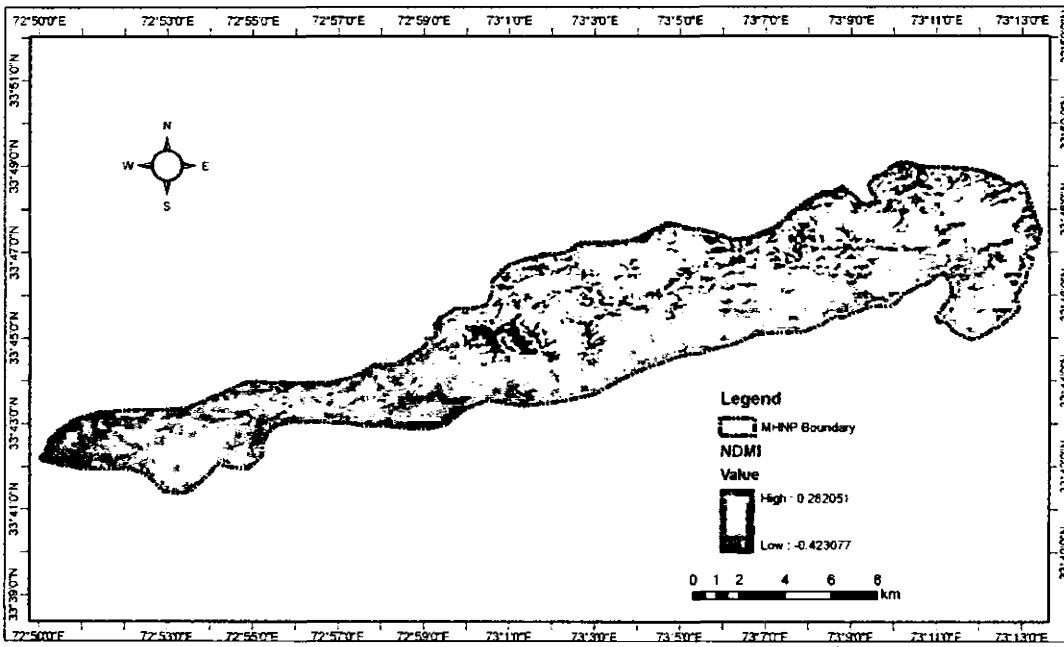


Figure 3.4: Normalize Difference Moisture index

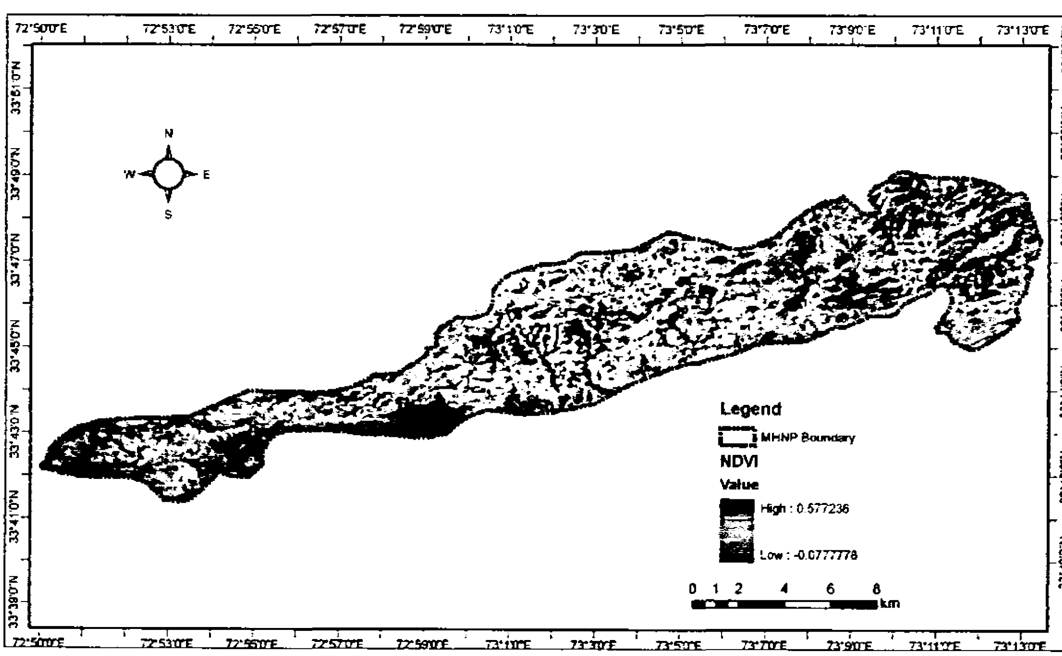


Figure 3.5: Normalize Difference Vegetation index

3.5.1.2-Normalised Difference Vegetation Index

The calculation for the Normalised Difference Vegetation Index (NDVI) is as (Fig 3.5) follows:

$$NDVI = \frac{(NIR-VIS)}{(NIR+VIS)}$$

Where VIS and NIR indicate the acquired spectral reflectance measurements in the respective visible (red) and near-infrared regions. The directive idea of NDVI is that the red-light region of the electromagnetic spectrum is Channel 1 in the red-light region of the electromagnetic spectrum. This is where the greatest amount of incoming sunlight is absorbed by chlorophyll; whereas, The greatest reflection comes from the moisture absorbing part of a plant's spongy mesophyll leaf structure and this is called 'Channel 2' in the near-infrared region of the spectrum (Tucker et al., 1991)

3.5.1.3-Normalised Burn Ratio

Highlighted and burned areas are defined by their severity using an index called The Normalised Burn Ratio (NBR). Landsat TM imagery is used to help index this (Fig. 3.6). The formula for the NBR is very like that of NDVI. The only difference is the use of near-infrared band 4 and the short-wave infrared band 7 (Cocke et al., 2005).

$$NBR = \frac{B4 - B6}{B4 + B6}$$

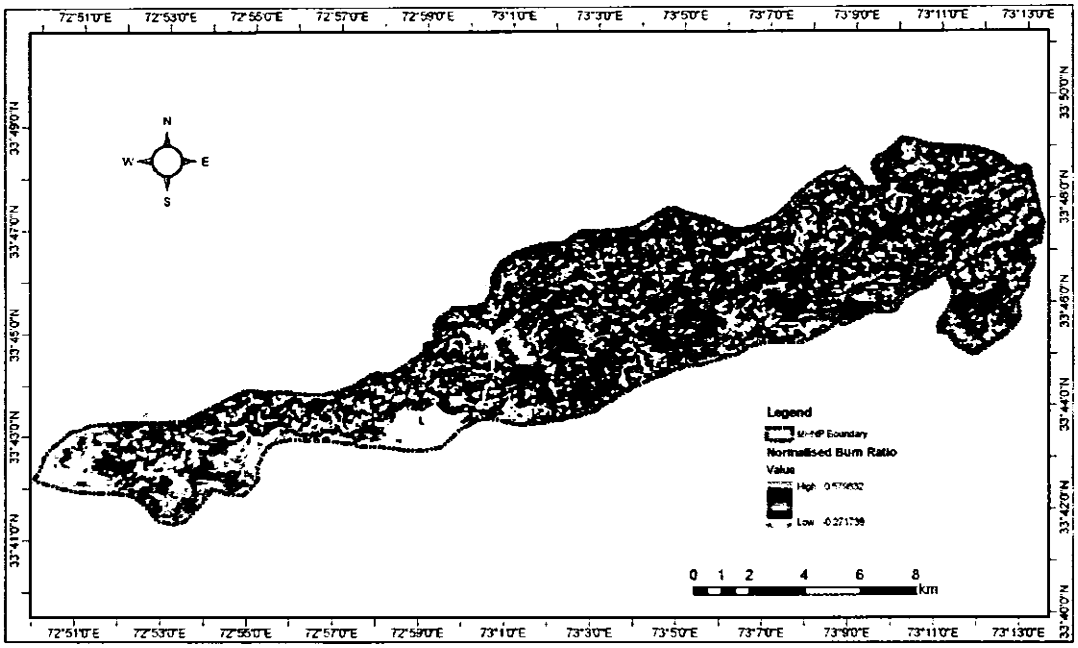


Figure 3.6: Normalize Burn Ratio

3.5.2-Topographic

3.5.2.1-Topographic Position Index

Quantitative representation regarding the relationship of the elevation of actual cell with neighbouring cells is termed 'Topographic Position Index' (TPI). The way in which land erodes or accumulates more land and the capacity of an area to do this depends on the TPI level of surrounding cells (Riley et al., 1999). Higher positioning of cells to neighbouring cells will lend a positive result. The result in the cell at a lower position will be in the negative. Results of flat areas with constant slope appear in almost zero value (Beasom et al., 1983).Figure 3.7 showed TPI for MHNP.

3.5.2.2-Topographic Wetness Index

Soil moisture conditions in a watershed are analyzed by the Topographic Wetness Index (TWI).the TWI is also used as the indicator for static soil moisture content. The TWI plays a significant role in the study of soil erosion. This Index is extracted from the Digital Elevation Model (DEM) which comes from the words 'distributed hydrological model' in a watershed area (Fig.3.8). There is a formula used to calculate the Topographic Wetness Index (TWI) is $w = ln\left(\frac{As}{tan\beta}\right)$. Here in the formula *As* has indicated specific catchment area, and tanβ is the local slope angle of the specific grid, used to approximate the local hydraulic gradient under steady state conditions (Goodwin et al., 2008).

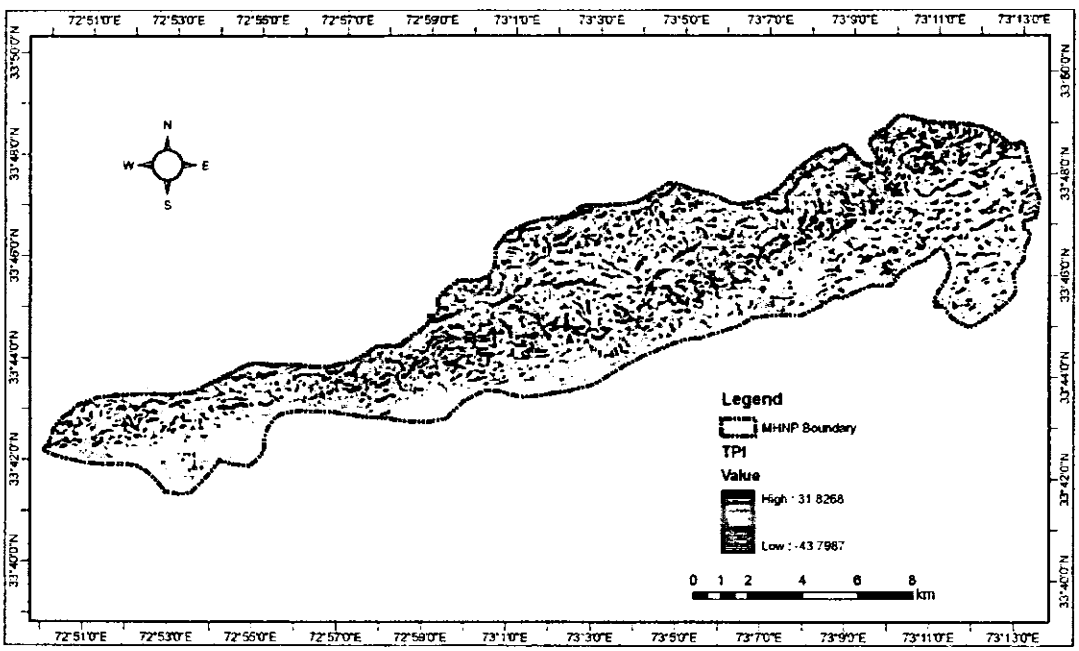


Figure 3.7: Topographic Position Index

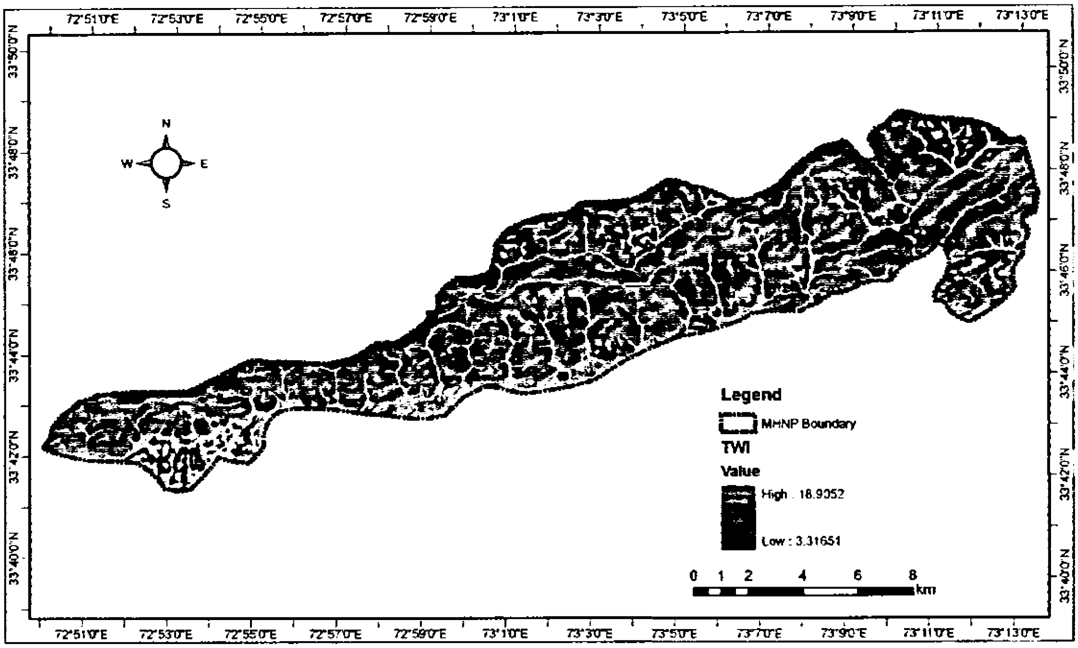


Figure 3.8: Topographic Wetness Index

3.5.2.3-Compound Topographic Index

The basic function of Hydrology (or catchment) can be modelled by the Compound Topographic Index (CTI) and by the relationship of slope and runoff (Fig 3.9). Its formula is $ln\left(\frac{\alpha}{tan\beta}\right)$ where α stands for catchment area per pixel, β is for slope. Large catchments (generally in due to steep slopes in hilly areas) result in high CTI values, while small catchment in plain areas show low CTI results (Skakun et al., 2003).

3.5.2.4-Stream Power Index

The combination of slope and catchment area is also known as Stream Power Index (SPI) which helps to identify the most efficacious areas where measures to conserve soil decrease impacts caused by concentrated surface runoff. Its formula is given as,

$$SPI = ln(CA \times \tan G)$$

Where CA stands for specific catchment area and G for slope steepness (Fig 3.10).

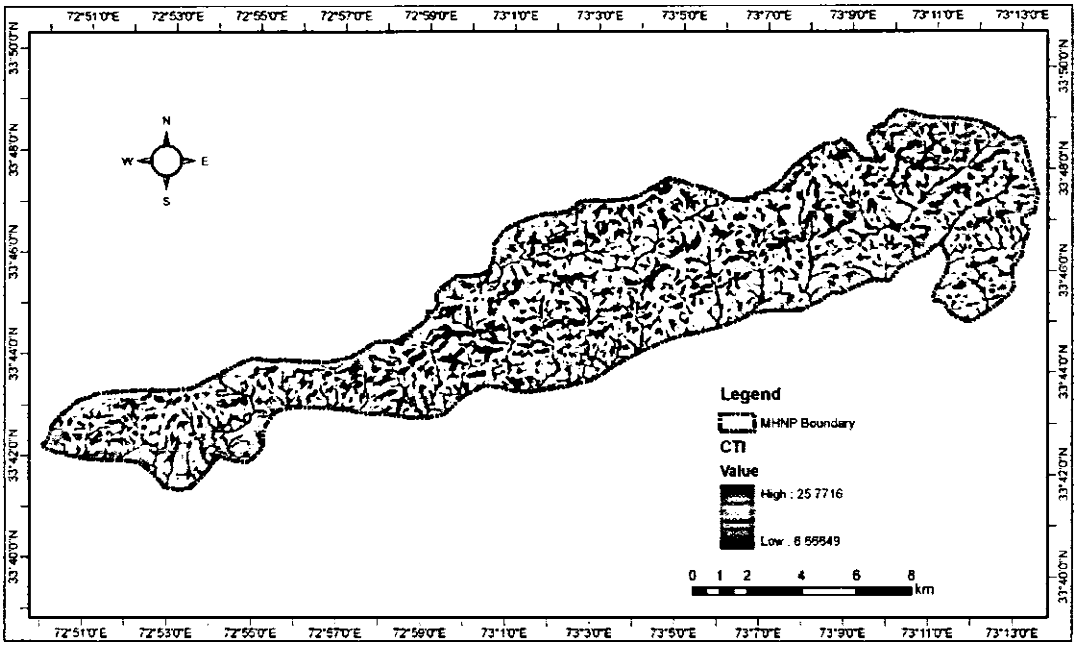


Figure 3.9: Compound Topographic Index

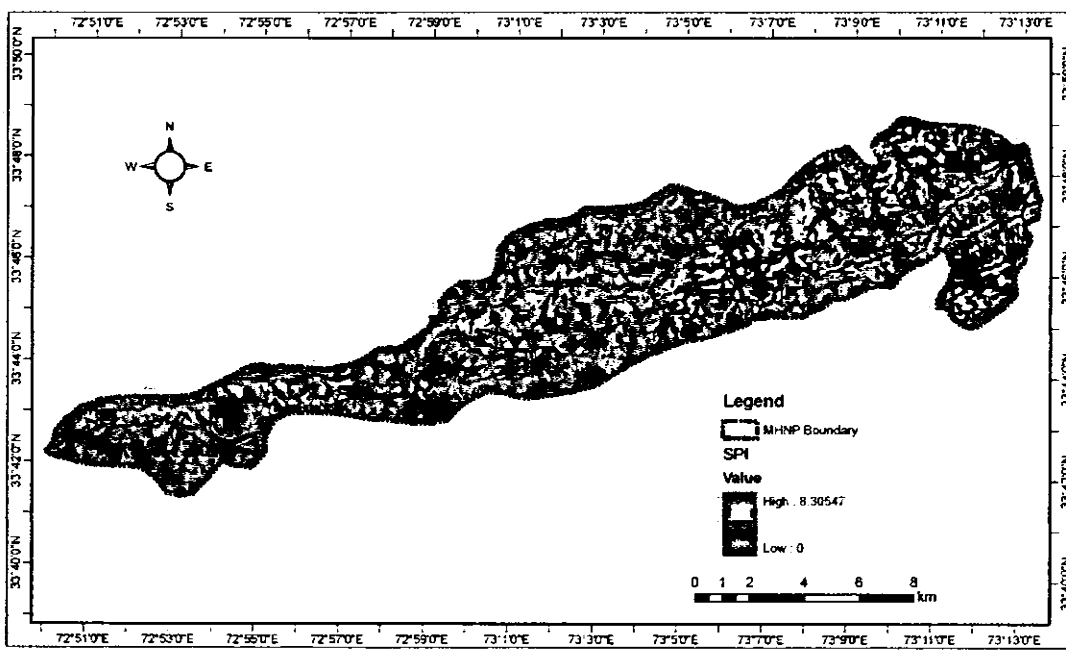


Figure 3.10: Stream Power Index

3.5.2.5-Topographic Ruggedness Index

The topographic ruggedness index (TRI) is a measurement developed by the TRI and illustrates the amount of difference in elevation, in a digital grid, between neighbouring cells (Fig 3.11). This calculation begins from comparing the difference in elevation values from a centre cell and the eight cells immediately surrounding it. Then it squares each of the eight elevation difference values to make them all positive and averages the squares. The TRI is calculated by taking the square root of this average, and corresponds to average elevation change between any point on a grid and its surrounding area (Riley et al., 1999).

A point may arrive in which the threshold for a habitat of any taxon makes life for that taxon untenable; therefore, quantification of ruggedness may be important when evaluating habitat quality or use.

3.5.3- Terrain

3.5.3.1-Elevation

A mathematical model of the Earth's sea level and any fixed point above that level is known as a 'Geoid'. Elevation, (or geometric height), referrs to any points on the Earth's *surface*, while altitude, (or geopotential height), is used for points *above the surface*, (such as an aircraft in flight or a spacecraft in orbit), and depth is used for points *below the surface*, (such as the location of a sea trench or a submarine.) Elevation in metre for MHNP has shown in Fig 3.12

3.5.3.2- Slope

The slope is (in the simplest of terms) the measurement of a line, and is defined as the ratio of the "rise" divided by the "run" between two points on a line, or in other words, the ratio of the altitude change to the horizontal distance between any two points on the line. Given two points ($x1, y1$) and ($x2, y2$) on a line, the slope m of the line is:

$$m = \frac{y2 - y1}{x2 - x1}$$

Figure 3.13 showed lower and higher slope values for MHNP.

3.5.3.3- Distance to settlements

Human habitation has rapidly affected most areas of vegetation and natural flora and fauna. The domestic animals kept by humans can have as huge an impact on the environment as the people do. The world's climate and ecosystems are currently greatly disturbed by changes made by human beings (Hannon and Bradshaw, 2000). Fig. 3.14 has shown areas of MHNP at varied distance from source of disturbance.

3.5.3.4- Distance to roads

Biodiversity of an area can be affected by roads and the pollution, from roads, directly as well as indirectly. Biomass and plant life suffer as a result of improvements in human infrastructure and the ability to transport anything from one place to another; this is a main reason for natural habitats to weaken both in quality and quantity (Geneletti, 2003) (Fig. 3.15)

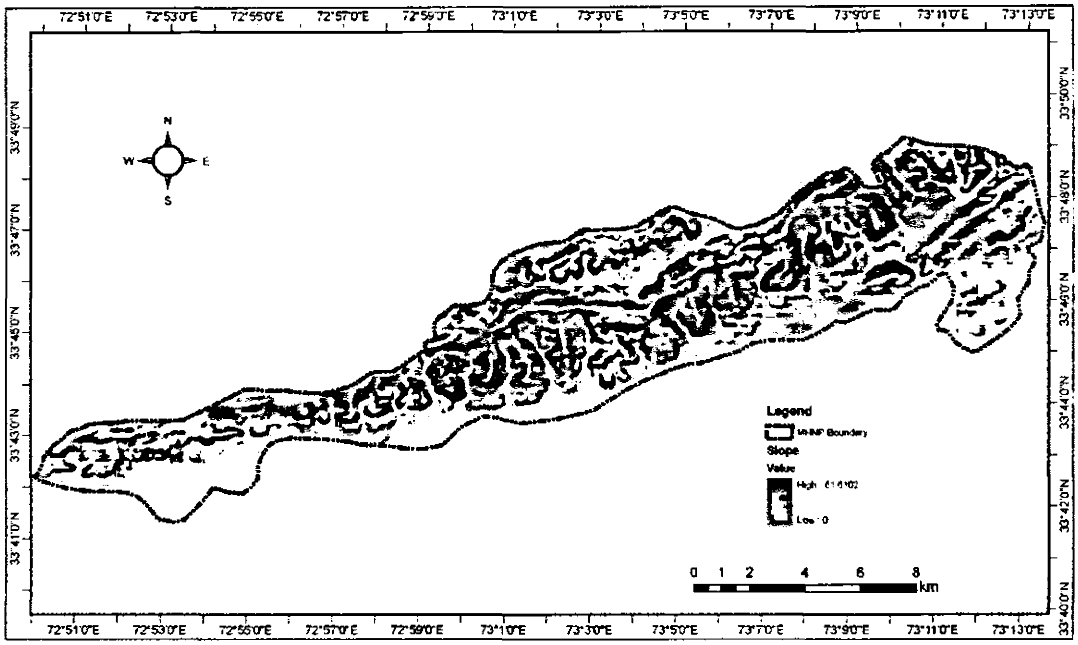


Figure 3.13: Slope

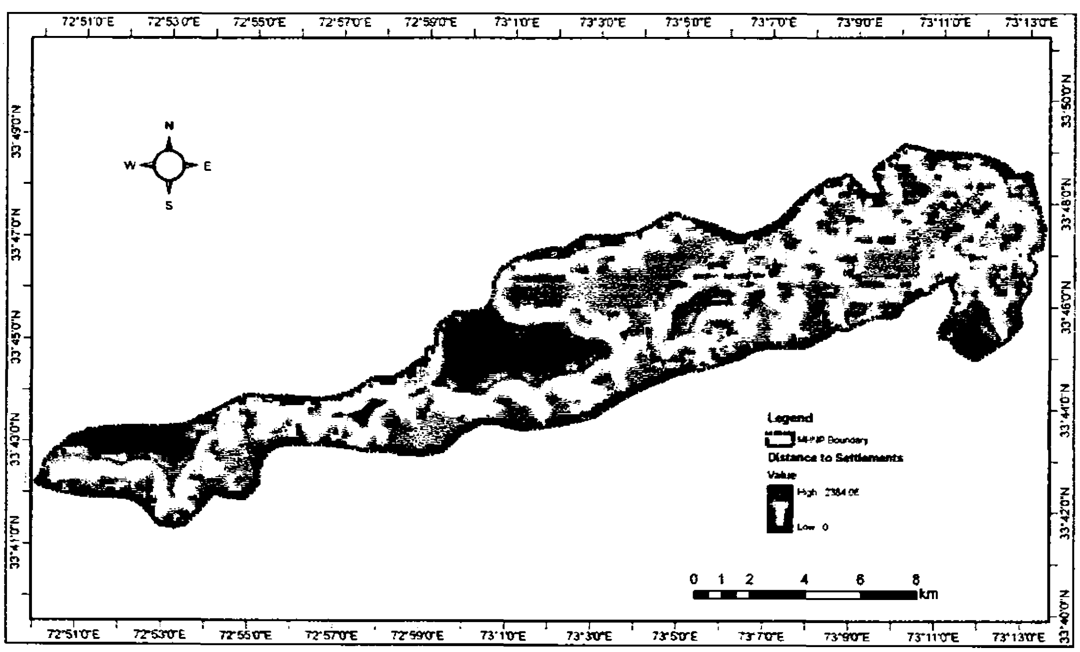


Figure 3.14: Distance to Settlements

3.5.3.5- Distance to tracks

Paths made by humans and animals influence the composition of surrounding plants species. The distance to the path and it's length are dependant on what the path (or track) is composed of and what type of plants and biomass are near it (Godefroid and Koedam, 2004). Fig. 3.16 showed the values for areas near and far from tracks.

3.5.3.6- Distance to streams

Habitats can be greatly disturbed by the soil erosion caused by water flow increases (such as floods). This will affect all plant life nearby although plants far enough away from the disturbance will remain stable in growth patterns. Distance from streams (Fig. 3.17) is thus an important variable in vegetation mapping and modelling (HASLAM, 1987)

3.5.3.7- Cos of Aspect

Aspect (or compass direction of a slope) can be transformed by trigonometric

functions (Fig. 3.18). The simplest way to do this is to create, "northness" as follows.

Northness = cos (aspect)

Northness will take values close to 1 if the aspect is generally northward, close to -1 if the aspect is southward, and close to 0 if the aspect is either east or west. The aspect would be eastwards if the value of the northness is lesser.

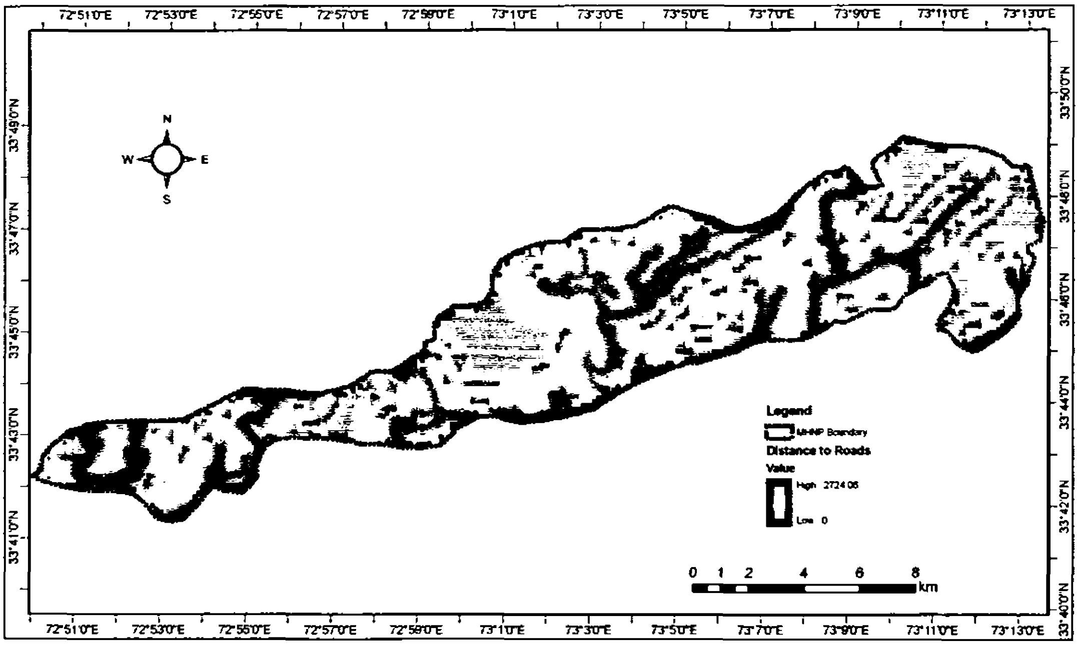


Figure 3.15: Distance to Roads

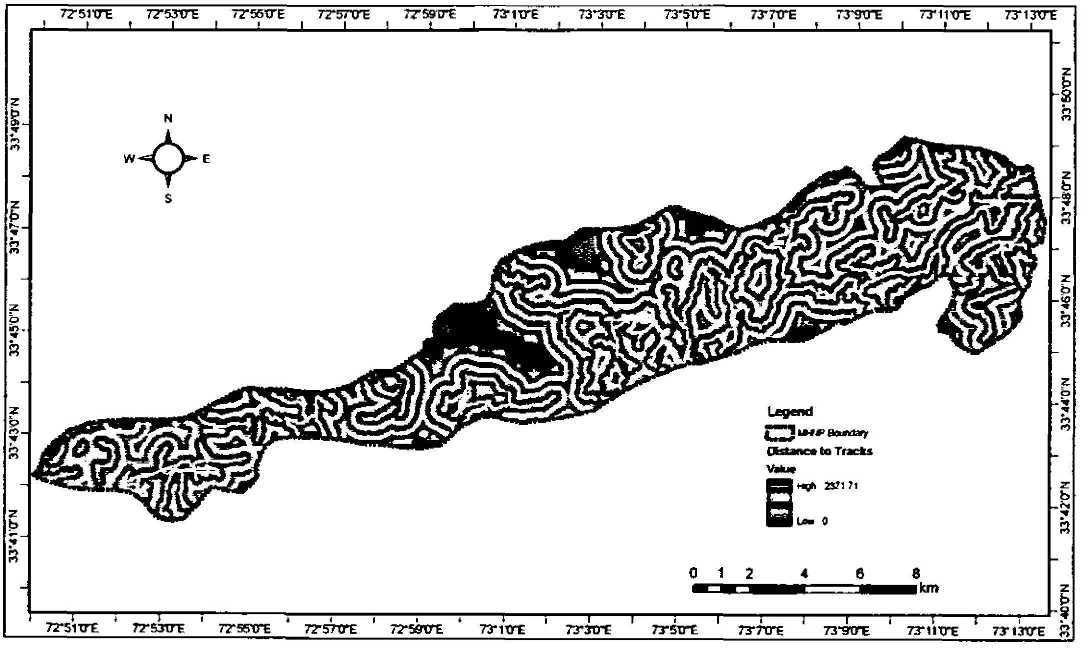


Figure 3.16: Distance to Tracks

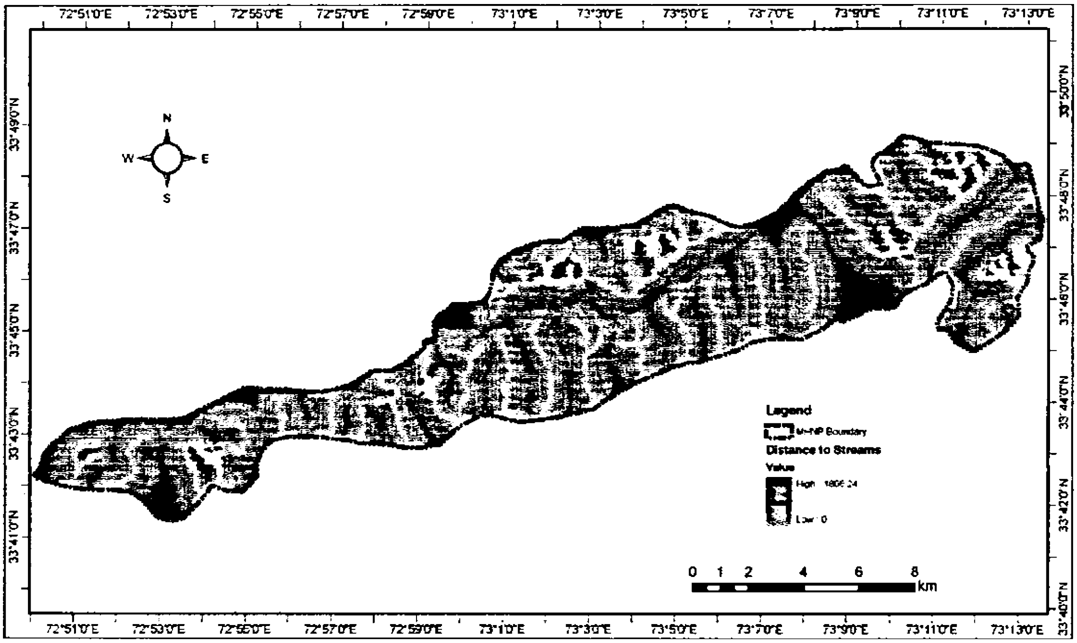


Figure 3.17: Distance to Streams

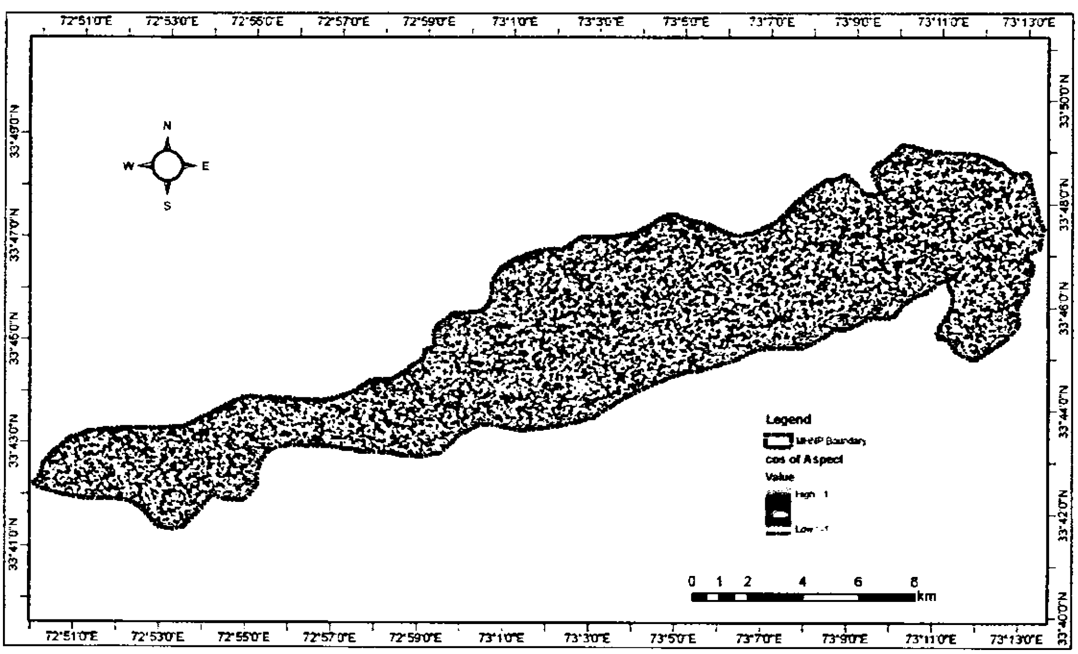


Figure 3.18: Cos of Aspect

3.6- Statistical Model

The Statistical modelling applied for required aspects of *Dodonaea viscosa* which are a) Distribution of *Dodonaea viscosa,* b) Density, c) Height d) Cover. In total four GAM were fitted to model aspects of *Dodonaea viscosa* which included first of the model which was binomial presence/absence based while the rest of the three, namely density, height and cover were of Gaussian distribution family.

3.7- Model Selection

The sampling data along with the data of the associated variables were imported to S-Plus ver. 8 (insightful Corp.2007) where GAM was applied with generalised Regression Analysis and Spatial Prediction (GRASP) package. Results were found by modelling four different response variables of *Dodonaea viscosa* against predictor variables. Each model runs through a stepwise procedure for backward selection of fitted variables to give final outcome on the basis of change in deviance tested at 5% level. The dropping terms were analysed by ANOVA; CHI-sq test (analysis of variance) to verify their effect. The response variables in the model were shortly denoted by "padod" for presence absence, "dedod" for density, "htdod" for height and "abnd.dod" for the cover of Dodonaea viscosa. The abbreviations/symbols used for the predictor variables were NDMI(ndmi), = normalised difference moisture indexNDVI(ndvi) = normalised difference vegetation index, nbr = normalised burn ratio, ELE(ele) = elevation, slp =slope, cosasp = cos of aspect, TPI = topographic position index, CTI = compound topographic index, SPI = Stream power index, TWI = Topographic wetness index, rugg = ruggedness, dset = distance to settlements, dtrack = distance to tracks, dstr = distance to streams, droad = distance to roads.

Chapter 4: Results

The outcomes of the socioeconomic investigations from the MHNP residents are shown under following charts. The residents were mainly dependent on the fuel wood obtained from the forest which is 94 percent where as only 6 percent acquired from market.

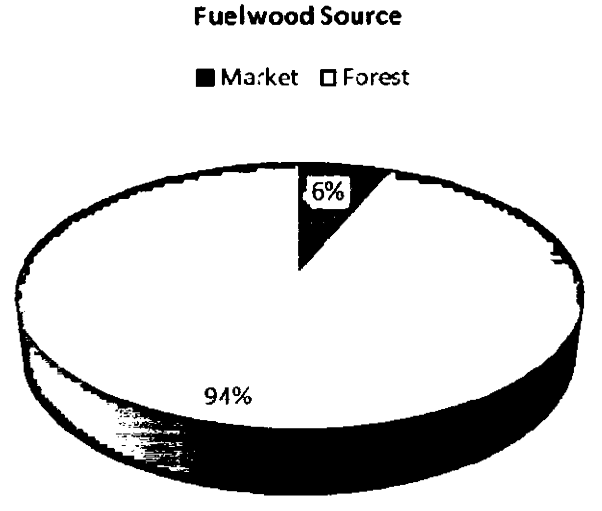


Chart 4.1: shows forest as main source of fuel wood in MHNP

Dodonaea viscosa is the most preferred species among the forest resources used for the fuel which constituted approximately 44 percent of the total fuel wood used from the area.

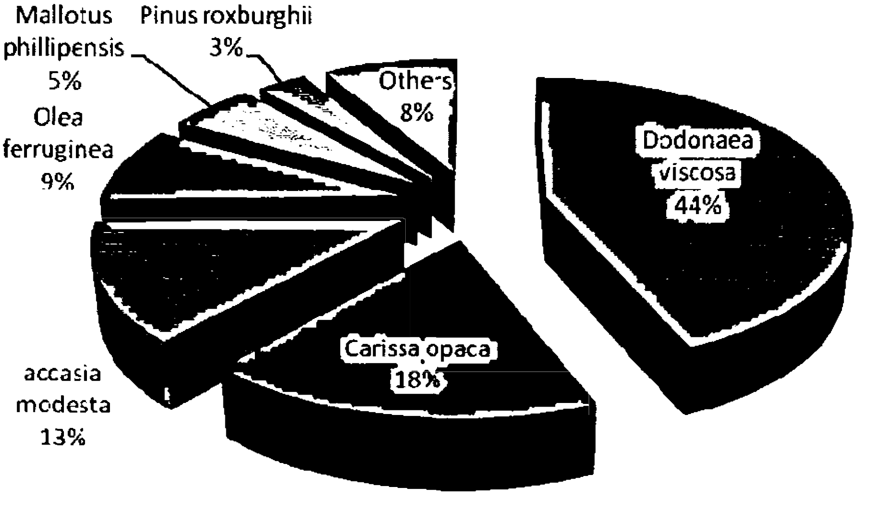


Chart 4.2: Percentage of preferred fuel wood species used in MHNP

4.1-Presence /Absence of *Dodonaea viscosa*

***Predictor's Space*:**

The predictor's space occupied by Presence absence *Dodonaea viscosa* (padod) shown as histograms and scattergrams of predictors vs. response in Figures 4.1 and 4.2.

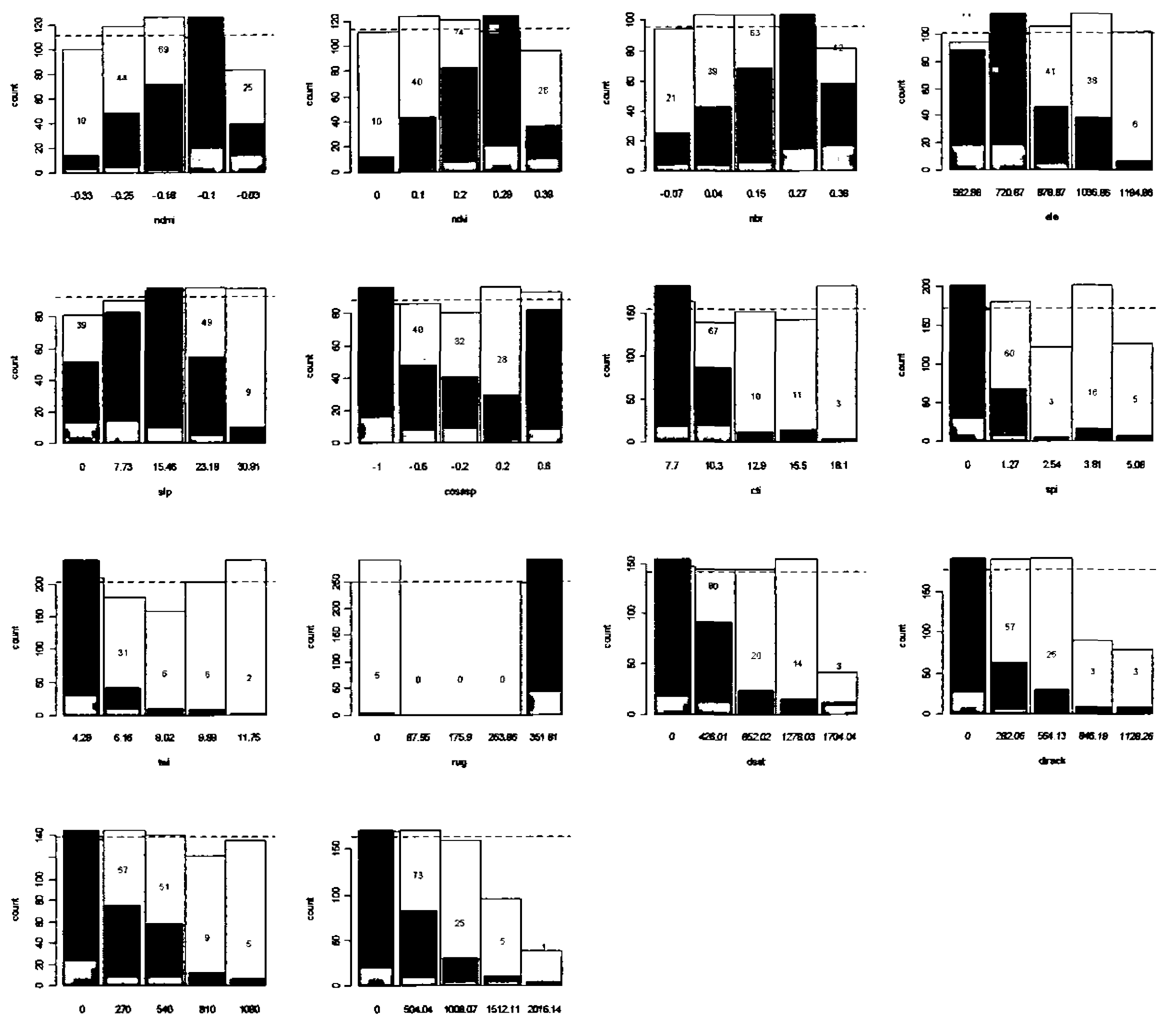


Figure 4.1: Histograms of presence/absence of *Dodonaea viscosa* against predictor variables

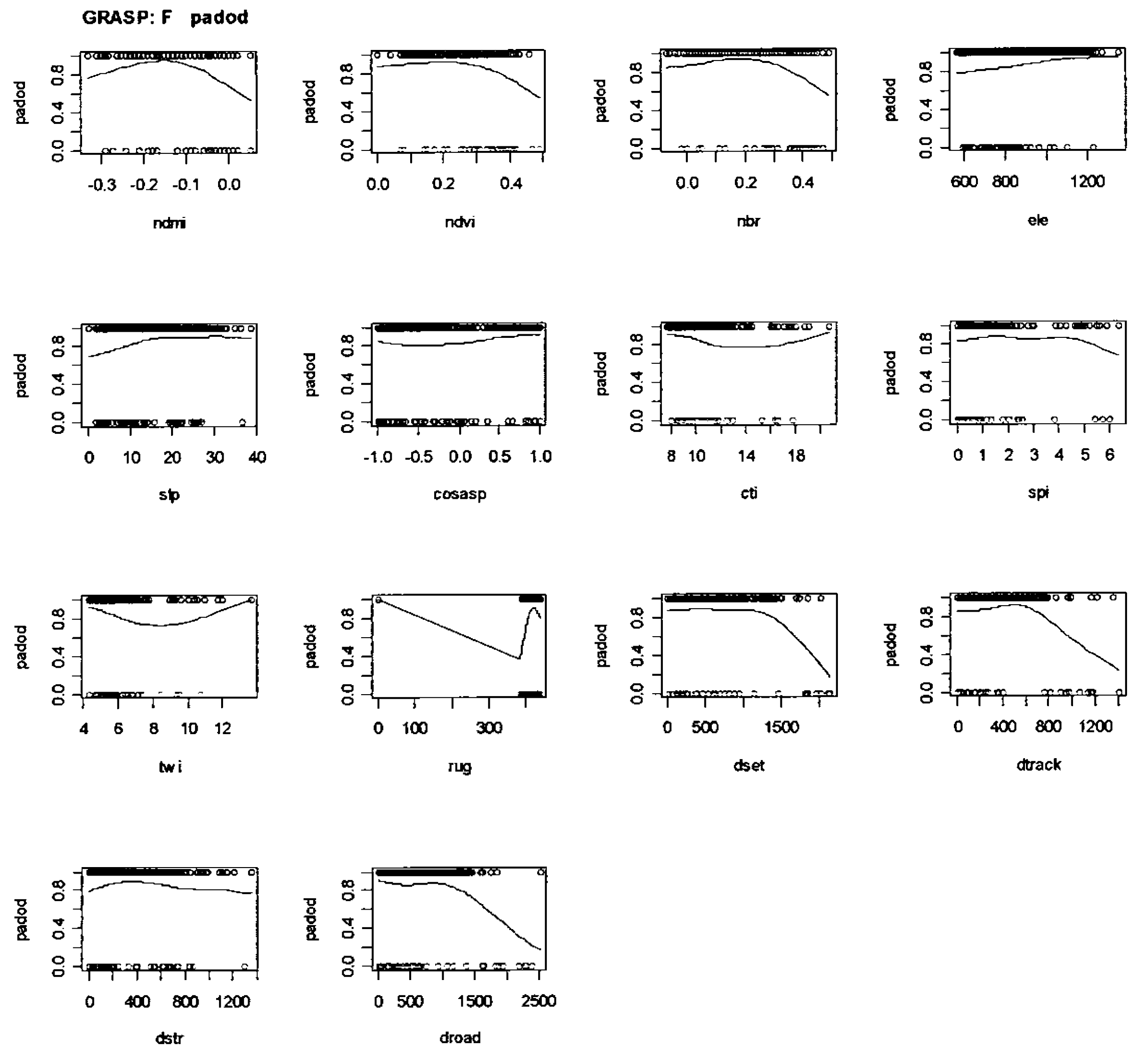


Figure 4.1: Scattergrams of presence/absence of *Dodonaea viscosa* against predictor variables

Model selection:

Out of a total 297 observation points presence of Dodonaea viscosa was present in 254 points and absent in rest of 43 points (prevalence = 85%). The stepwise selection of the variables resulted into the final model with Null Deviance 245.64 and Explained Deviance 102.66. The D^2 (pseudo quotient) was 0.4179 and correlation value was 0.67. The initial and final models with stepwise selection of significant terms are as follows:

Initial Model:

padod = s(ndmi, 4) + s(ndvi, 4) + s(nbr, 4) + s(ele, 4) + s(slp, 4) + s(cosasp, 4) + s(cti, 4) + s(spi, 4) + s(twi, 4) + s(rug, 4)+ s(dset, 4) + s(dtrack, 4) + s(dstr, 4) + s(droad, 4)

Final Model:

padod = s(nbr, 4) + s(ele, 4) + s(spi, 4) + s(rug, 4) + s(dset, 4)

(Where "padod" is presence absence of *Dodonaea viscosa.*)

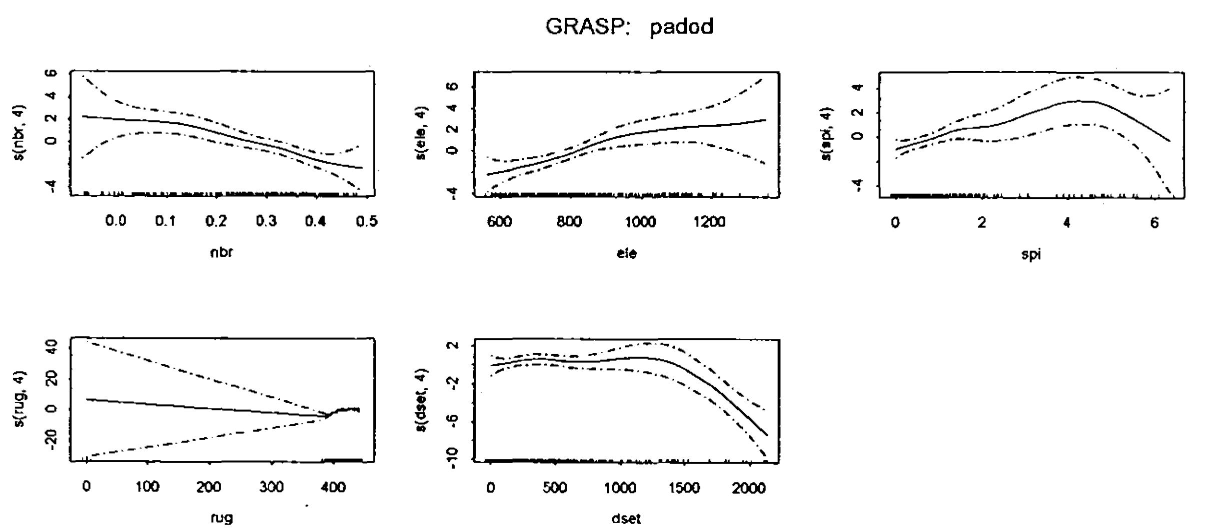


Figure 4.3: Partial response of padod against final selected predictor variables

Predictor's Contribution:

The contribution of dropping variables from the model shown change in residual deviance has been presented as table 4.1.

Table 4.1: Analysis of deviance for dropping of terms in presence/absence model

	From To	Df	Deviance	Resid.Df	Resid.Dev	P-value
1				240.76	104.96	0.05
2	s(twi,4)	4.00	0.37	244.76	105.34	0.98
3	s(cti,4)	3.80	1.40	248.56	106.74	0.82
4	s(ndmi,4)	3.91	1.49	252.47	108.22	0.82
5	s(ndvi,4)	3.85	5.05	256.32	113.27	0.26
6	s(slp,4)	3.94	4.09	260.27	117.36	0.39
7	s(cosasp,4)	3.92	4.78	264.19	122.14	0.30
8	s(droad,4)	4.10	7.43	268.29	129.57	0.12
9	s(dtrack,4)	4.14	6.82	272.42	136.39	0.16
10	s(dstr,4)	3.80	6.59	276.22	142.99	0.14

ANOVA (analysis of variance) for selected terms in model are shown as Table 4.2

Table 4.2: ANOVA for selected terms in model for Presence/Absence *Dodonaea viscosa*

	Test	Df	Deviance	Pr(Chi)
[1,]	-s(nbr,4)	-4.34	-30.99	0.00
[2,]	-s(ele,4)	-4.19	-23.41	0.00
[3,]	-s(spi, 4)	-4.24	-15.06	0.01
[4,]	-s(rug,4)	-4.39	-22.52	0.00
[5,]	-s(dset,4)	-4.25	-37.81	0.00

The predictor's contribution in terms of drop, model and alone has shown in Table 4.3.

Table 4.3: Drop contribution for selected terms in model for Presence/Absence

	drop	alone	model
s(nbr, 4)	30.99	18.73	4.50
s(ele, 4)	23.41	6.62	5.15
s(spi, 4)	15.06	6.27	4.02
s(rug, 4)	22.52	27.00	10.25
s(dset,4)	37.81	26.22	8.12

Model validation:

The validation parameters for presence/absence Dodonaea are as follows (Figure 4.4):

cv ROC auc: 0.83

cv COR: 0.577

ROC auc: 0.889

COR: 0.67

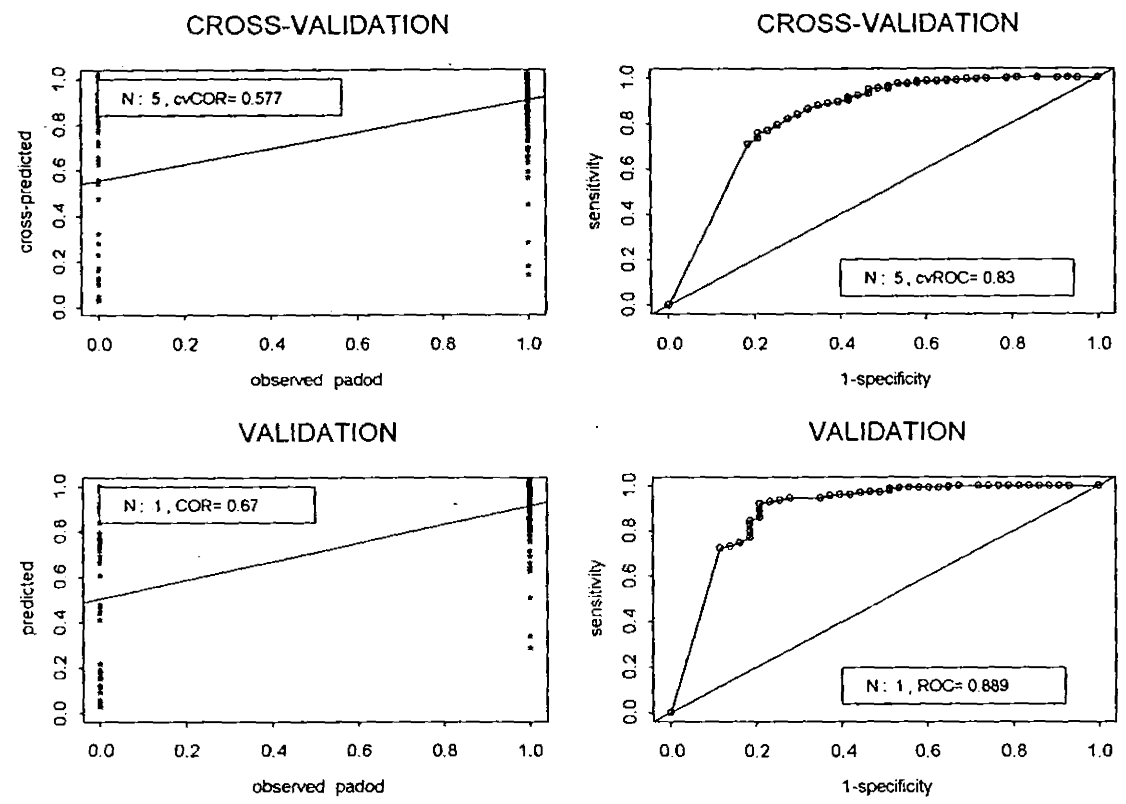


Figure 4.4: Cross-validation of predictive model for padod.

4.2-Density of *Dodonaea viscosa*

Predictor's Space:

The predictor's space occupied by *Dodonaea viscosa* density (dedod) shown as histograms and scattergrams of predictors vs. response in Figures 4.5 and 4.6.

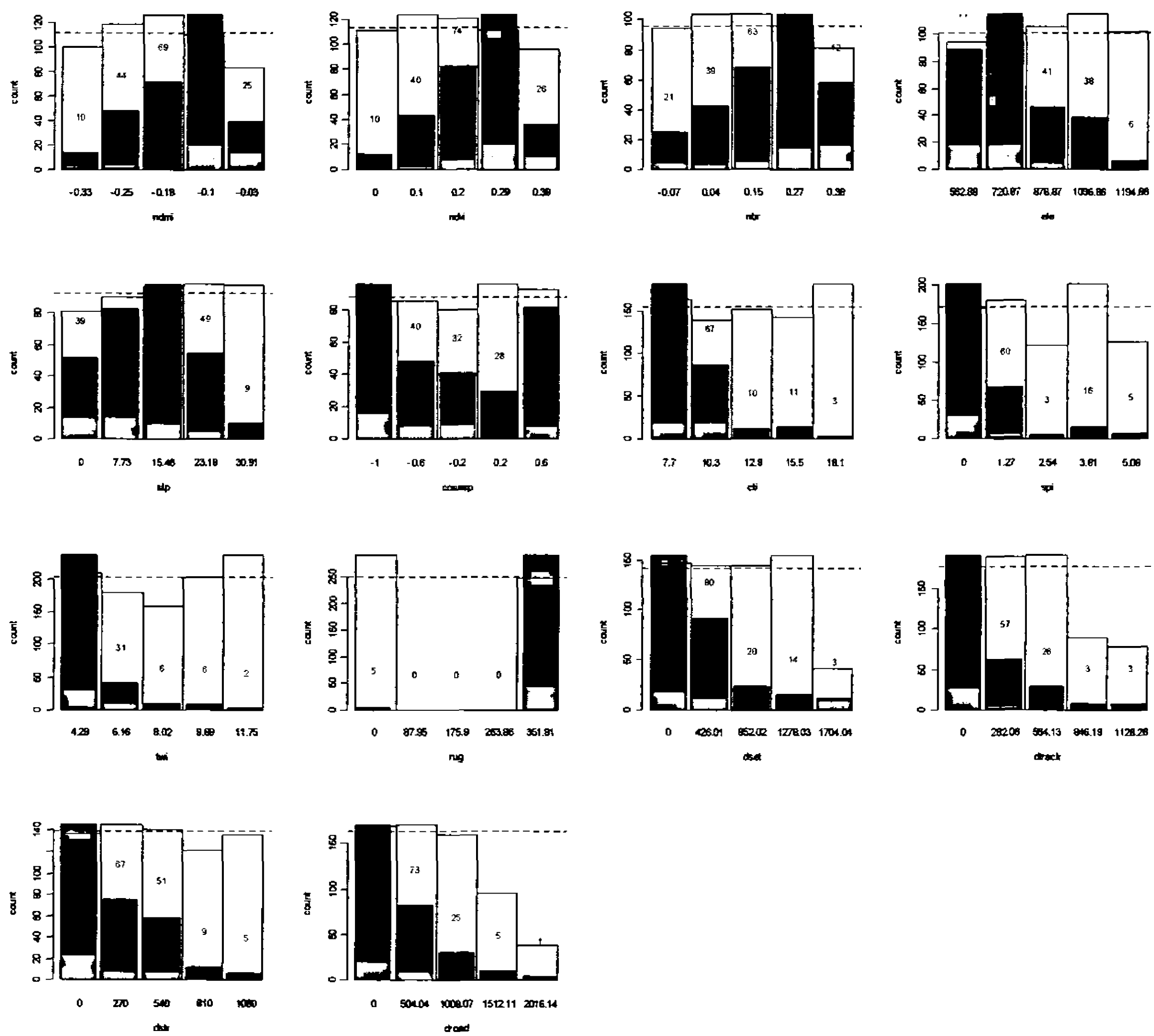


Figure 4.5: Histograms of *Dodonaea viscosa* density against predictor variables

Model selection:

The number of observations used to model density was 297. The step wise selection of the variables resulted into the final model with Null Deviance 44370.24 and Explained Deviance 11688.12. The D^2 (pseudo quotient) was 0.263 and correlation value was 0.51. The initial and final models with stepwise selection of significant terms are as follows:

Initial Model:

dedod = s(ndmi, 4) + s(ndvi, 4) + s(nbr, 4) + s(ele, 4) + s(slp, 4) + s(cosasp, 4) + s(cti, 4) + s(spi, 4) + s(twi, 4) + s(rug, 4)+ s(dset,4) + s(dtrack, 4) + s(dstr, 4) + s(droad, 4)

Final Model:

dedod = s(nbr, 4) + s(rug, 4) + s(dset, 4) + s(dstr, 4)

(Where "dedod" is the density of *Dodonaea viscosa*)

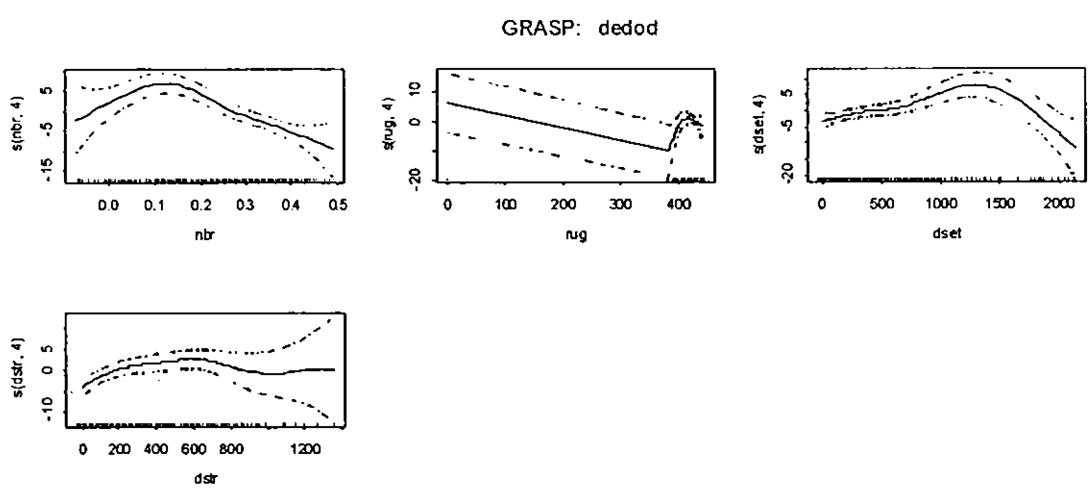


Figure 4.7: Partial response of dedod against final predictor variables

Predictor's Contribution:

The contribution of dropping variables from the model shown change in residual deviance has been presented as table 4.4.

Table 4.4: Analysis of deviance for dropping of terms in *Dodonaea viscosa* density model

	From To	Df	Deviance	Resid.Df	Resid.Dev	AIC
1				240.00	28680.28	42306.17
2	s(twi, 4)	4.00	89.68	243.99	28769.95	41440.22
3	s(cti, 4)	4.00	201.25	247.99	28971.20	40684.45
4	s(cosasp,4)	4.00	258.67	252.00	29229.87	39986.91
5	s(spi, 4)	4.00	307.59	256.00	29537.45	39338.15
6	s(ndvi, 4)	4.00	340.71	260.00	29878.17	38722.70
7	s(dtrack,4)	4.00	401.88	264.00	30280.05	38168.54
8	s(ndmi, 4)	4.00	387.89	267.99	30667.94	37600.52
9	s(ele, 4)	4.00	544.32	271.99	31212.26	37189.04
10	s(slp, 4)	4.00	633.81	276.00	31846.07	36866.31
11	s(droad, 4)	4.00	836.05	280.00	32682.13	36745.81

Analysis of variance for the selected terms in the model are shown as Table 4.5

Table 4.5: ANOVA for selected terms in *Dodonaea viscosa* density model

	Test	Df	Deviance	Pr(Chi)
[1,]	-s(nbr, 4)	-4.00	-5431.98	0.00
[2,]	-s(rug, 4)	-4.00	-1052.87	0.00
[3,]	-s(dset, 4)	-4.00	-3215.99	0.00
[4,]	-s(dstr, 4)	-4.00	-1281.45	0.00

The contribution of the predictors in terms of drop, alone and model contribution has been documented in Table 4.6.

Table 4.6: Drop contribution of selected terms in *Dodonaea viscosa* density model

	drop	alone	model
s(nbr, 4)	5431.98	5989.58	16.42
s(rug, 4)	1052.87	1392.41	16.10
s(dset, 4)	3215.99	3211.52	19.81
s(dstr, 4)	1281.45	1236.20	6.47

<u>Model validation</u>:

The validation parameters for *Dodonaea viscosa* density (dedod) are as follows

(Figure 4.8):

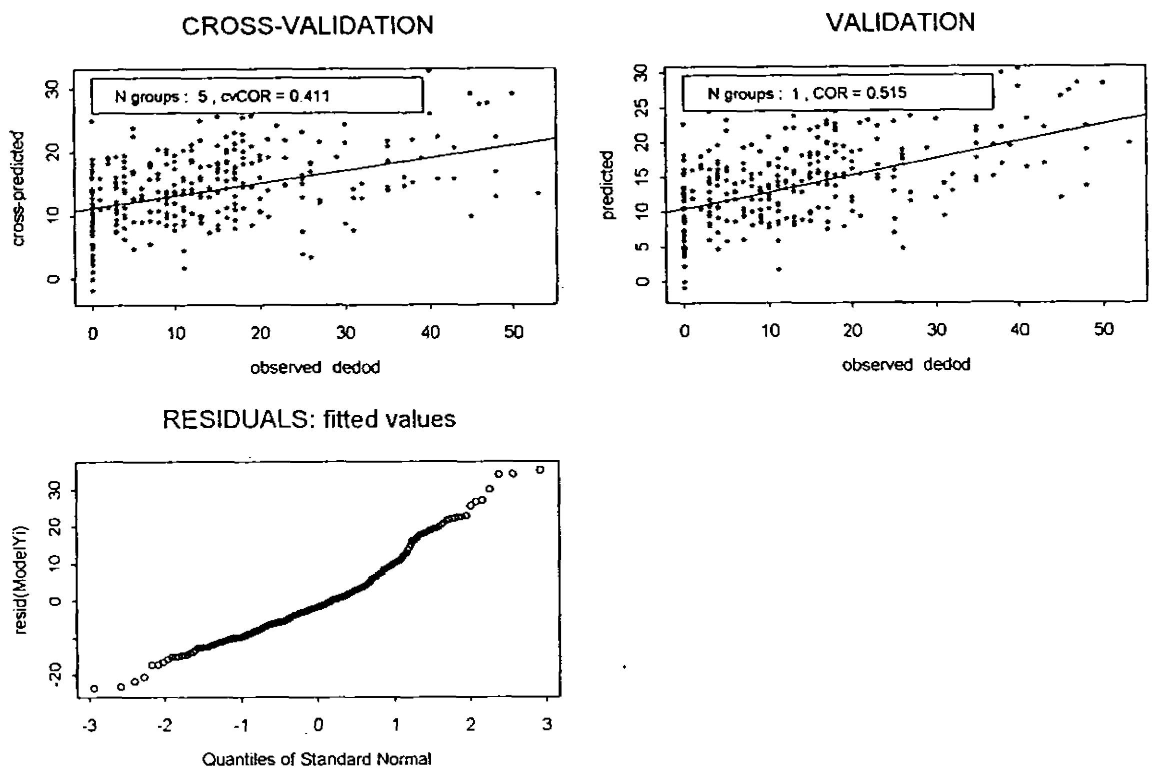


Figure 4.8: Cross-validation of predictive model of dedod

4.3- Height *Dodonaea viscosa*

Predictor's Space:

The predictor's space occupied by *Dodonaea viscosa* height (htdod) shown as histograms and scattergrams of predictors vs. response in Figures 4.9 and 4.10.

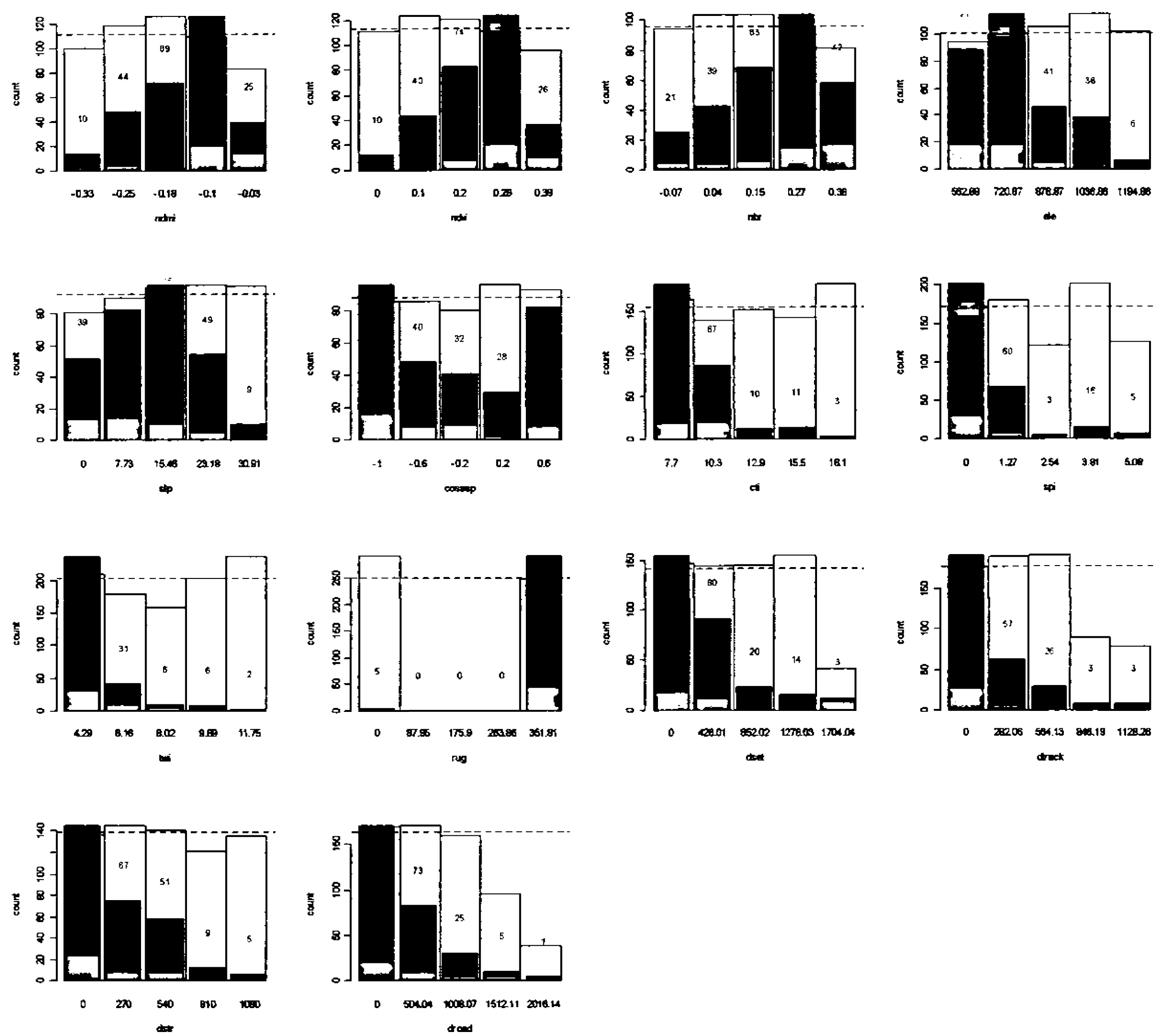


Figure 4.9: Histograms of htdod against predictor variables

Model Selection:

The number of observations used to model density was 297. The stepwise selection of the variables resulted into the final model with Null Deviance 179.51 and Explained Deviance 51.146. The D^2 (pseudo quotient) was 0.284 and correlation value was 0.53. The initial and final models with stepwise selection of significant terms are as follows:

Initial Model:

htdod = s(ndmi, 4) + s(ndvi, 4) + s(nbr, 4) + s(ele, 4) + s(slp, 4) + s(cosasp, 4) + s(cti, 4) + s(spi, 4) + s(twi, 4) + s(rug, 4) + s(dset,4) + s(dtrack, 4) + s(dstr, 4) + s(droad, 4)

Final Model:

htdod = s(nbr, 4) + s(ele, 4) + s(rug, 4) + s(dset, 4) + s(droad, 4)

(Where "htdod" is the height of *Dodonaea viscosa*)

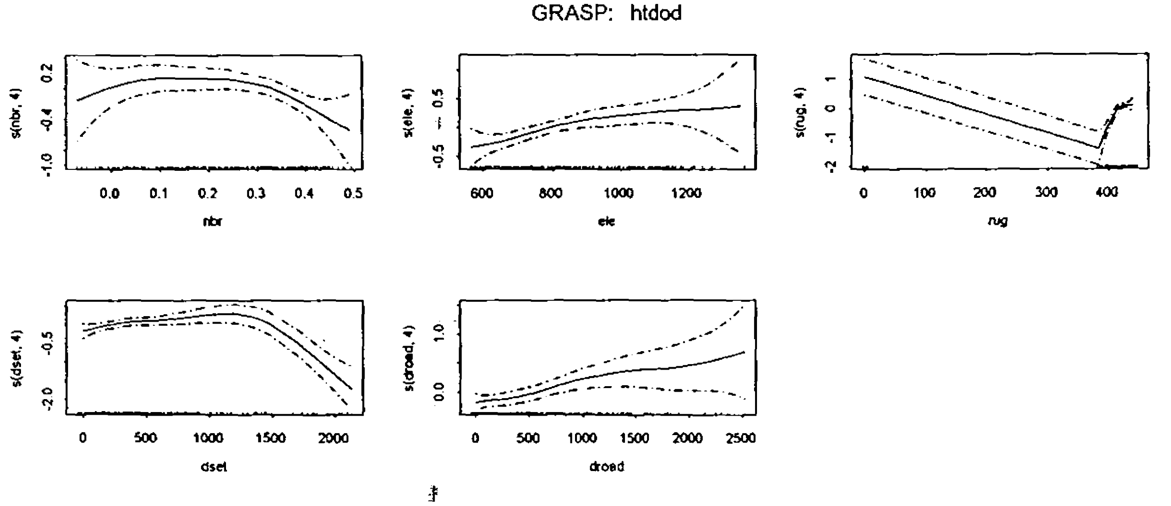


Figure 4.11: Partial response of htdod against final predictor variables

Predictor's Contribution:

The contribution of dropping variables from the model shown change in residual deviance has been presented as table 4.7.

Table 4.7: analysis of deviance for dropping of terms in *Dodonaea viscosa* height model

	From To	Df	Deviance	Resid.Df	Resid.Dev	AIC
1				239.99	116.62	172.02
2	s(cti, 4)	4.00	0.49	243.99	117.11	168.62
3	s(ndmi, 4)	4.00	0.53	247.99	117.64	165.26
4	s(twi, 4)	4.00	0.63	251.99	118.27	162.01
5	s(spi, 4)	4.00	0.72	255.99	118.99	158.84
6	s(ndvi, 4)	4.00	1.05	259.99	120.04	156.01
7	s(dstr, 4)	4.00	1.39	263.99	121.43	153.51
8	s(dtrack, 4)	4.00	1.71	267.99	123.14	151.33
9	s(cosasp, 4)	4.00	2.34	271.99	125.48	149.78
10	s(slp, 4)	4.00	2.89	275.99	128.37	148.78

Table 4.8 represents ANOVA for selected terms of the model.

Table 4.8: ANOVA for the selected terms in *Dodonaea viscosa* height model

	Test	Df	Deviance	Pr(Chi)
[1,]	-s(nbr, 4)	-4.00	-6.47	0.17
[2,]	-s(ele, 4)	-4.00	-6.67	0.15
[3,]	-s(rug, 4)	-4.00	-19.48	0.00
[4,]	-s(dset, 4)	-4.00	-11.32	0.02
[5,]	-s(droad, 4)	-4.00	-6.50	0.17

The predictor's contributions in terms of drop, model and alone has shown in table 4.9.

Table 4.9: Drop contribution for selected terms in model for *Dodonaea viscosa* height

	drop	alone	model
s(nbr, 4)	6.47	8.48	0.68
s(ele, 4)	6.67	3.61	0.71
s(rug, 4)	19.48	18.95	2.47
s(dset, 4)	11.32	15.70	2.01
s(droad, 4)	6.50	13.21	0.87

<u>*Model validation*</u>:

The validation parameters for *Dodonaea viscosa* height (htdod) are as follows (Figure 4.12):

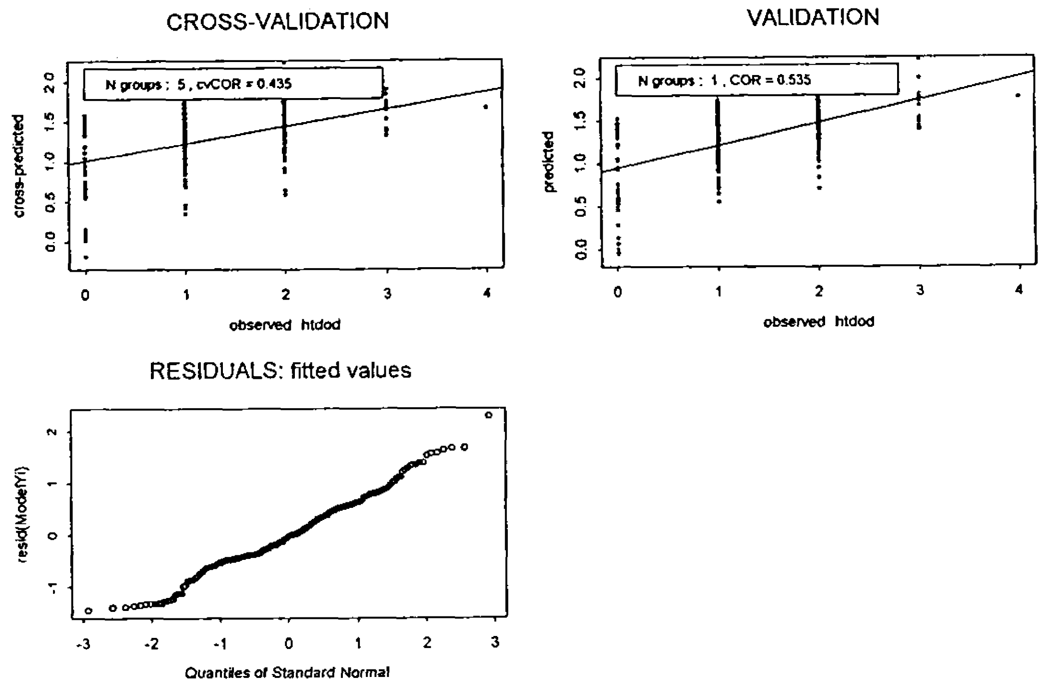


Figure 4.12: Cross-validation of predictive model of htdod

4.4- Cover of *Dodonaea viscosa*

Predictor's Space:

The predictor's space occupied by *Dodonaea viscosa* cover/abundance (abnd.dod) shown as histograms and scattergrams of predictors vs. response in Figures 4.13 and 4.14.

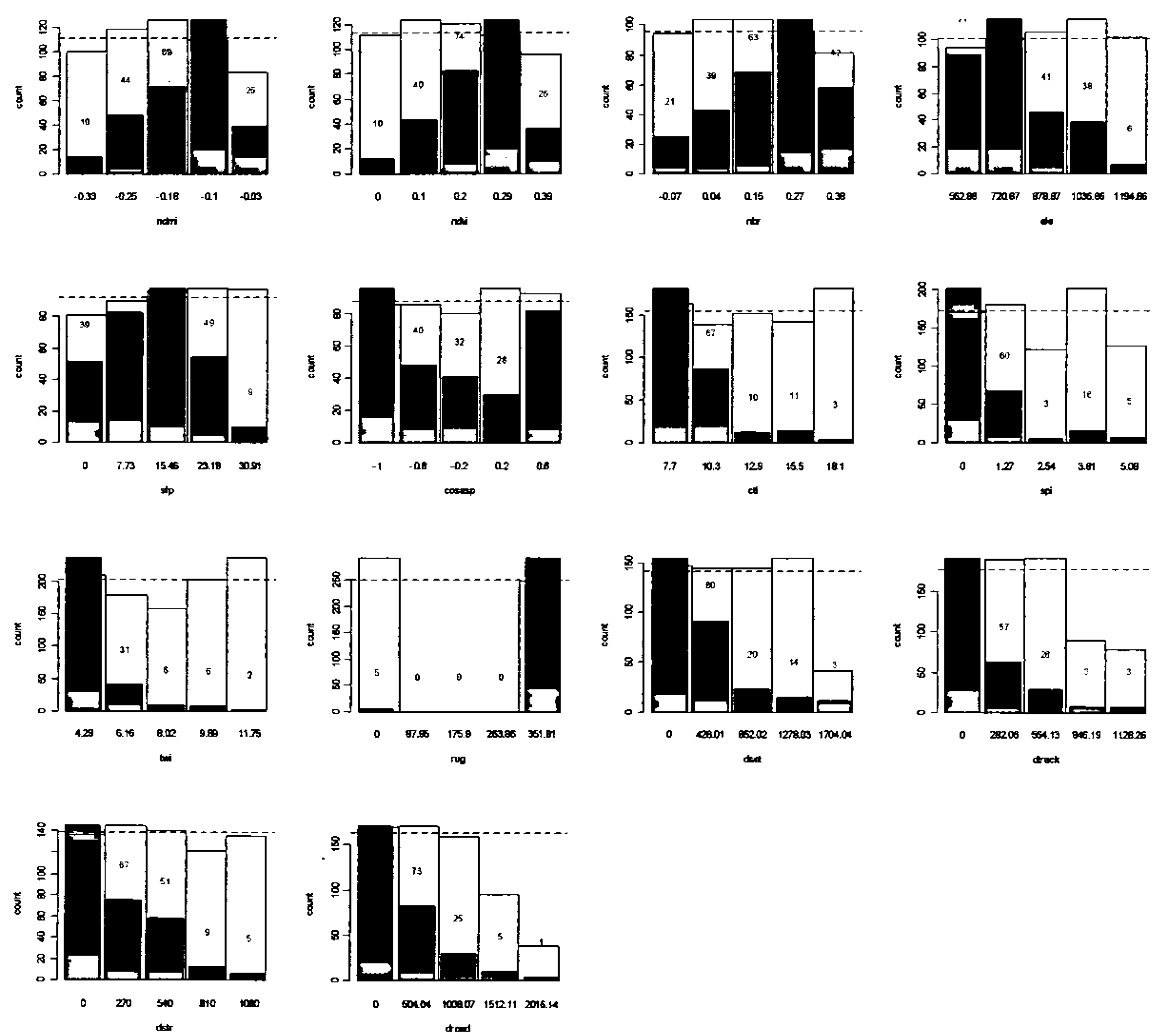


Figure 4.13: Histograms of *Dodonaea viscosa* cover against predictor variables

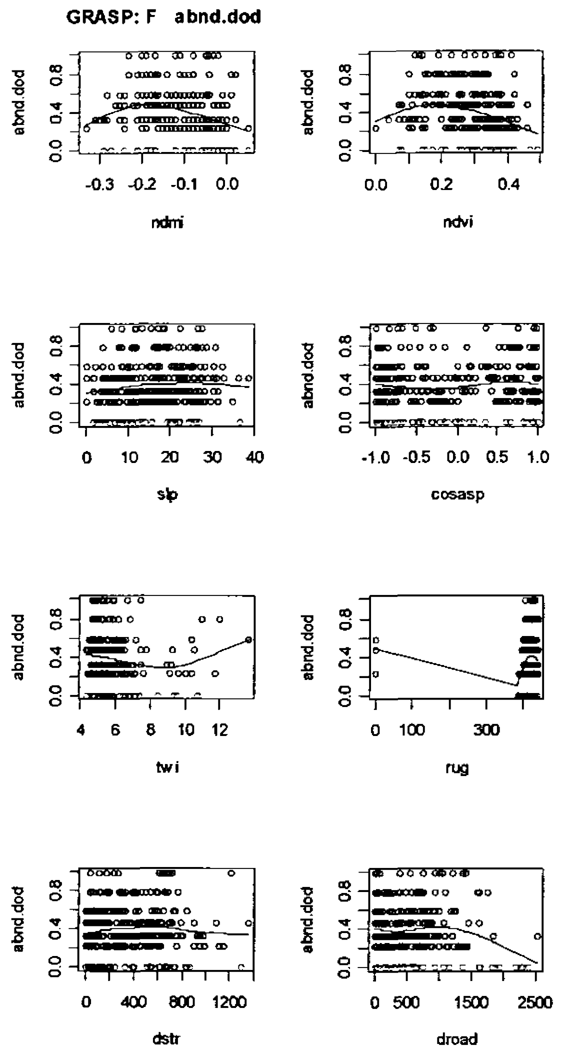


Figure 4.14: Scattergrams of *Dodonaea viscosa* cover against predictor variables

<u>*Model selection*</u>:

The number of observations used to model cover was 297. The stepwise selection of the variables resulted into the final model with Null Deviance 18.896 and Explained Deviance 6.384. The D^2 (pseudo quotient) was 0.40 and correlation value was 0.58. The initial and final models with stepwise selection of significant terms are as follows:

Initial Model:

abnd.dod = s(ndmi, 4) + s(ndvi, 4) + s(nbr, 4) + s(ele, 4) + s(slp, 4) + s(asp, 4) + s(cosasp, 4) + s(cti, 4) + s(spi, 4) + s(twi,4) +s(rug, 4) + s(dset, 4) + s(dtrack, 4) + s(dstr, 4) + s(droad, 4)

Final Model:

abnd.dod = s(nbr, 4) + s(ele, 4) + s(asp, 4) + s(rug, 4) + s(dset, 4) + s(dtrack, 4)

(Where "abnd.dod" is the abundance/cover of *Dodonaea viscosa*)

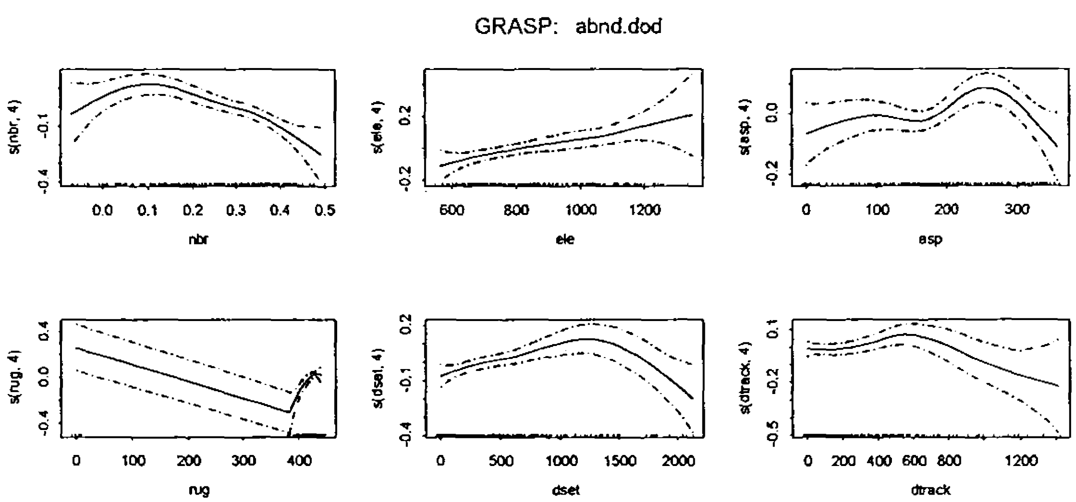


Figure 4.15: Response of abnd.dod against predictor variables

Predictor's Contribution:

Table 4.10: Analysis of deviance for dropping of terms in *Dodonaea viscosa* cover model

	From To	Df	Deviance	Resid.Df	Resid.Dev	AIC
1				235.99	11.20	16.98
2	s(twi, 4)	4.00	0.05	239.99	11.24	16.65
3	s(ndmi, 4)	4.00	0.08	243.99	11.32	16.35
4	s(cti, 4)	4.00	0.08	247.99	11.40	16.05
5	s(ndvi, 4)	4.00	0.14	251.99	11.54	15.81
6	s(spi, 4)	4.00	0.15	255.99	11.69	15.58
7	s(dstr, 4)	4.00	0.16	259.99	11.86	15.37
8	s(droad, 4)	4.00	0.19	263.99	12.04	15.18
9	s(slp, 4)	4.00	0.23	267.99	12.28	15.03
10	s(cosasp, 4)	4.00	0.23	272.00	12.51	14.88

Table 4.11 represents the ANOVA for selected terms in model

Table 4.11: ANOVA for the selected terms in *Dodonaea viscosa* cover model

	Test	Df	Deviance	Pr(Chi)
[1,]	-s(nbr, 4)	-4.00	-1.73	0.79
[2,]	-s(ele, 4)	-4.00	-0.65	0.96
[3,]	-s(asp, 4)	-4.00	-0.90	0.92
[4,]	-s(rug, 4)	-4.00	-0.94	0.92
[5,]	-s(dset, 4)	-4.00	-0.77	0.94
[6,]	-s(dtrack, 4)	-4.00	-0.40	0.98

Predictor's contribution in terms of drop, model and alone has been shown in table 4.12.

Table 4.12: Drop contribution for selected terms in model for *Dodonaea viscosa* cover

	drop	alone	model
s(nbr, 4)	1.73	1.96	0.38
s(ele, 4)	0.65	0.12	0.32
s(asp, 4)	0.90	1.11	0.20
s(rug, 4)	0.94	1.35	0.57
s(dset, 4)	0.77	1.37	0.33
s(dtrack, 4)	0.40	1.73	0.30

Model validation:

The validation parameters for *Dodonaea viscosa* cover (abnd.dod) are as follows (Figure 4.16):

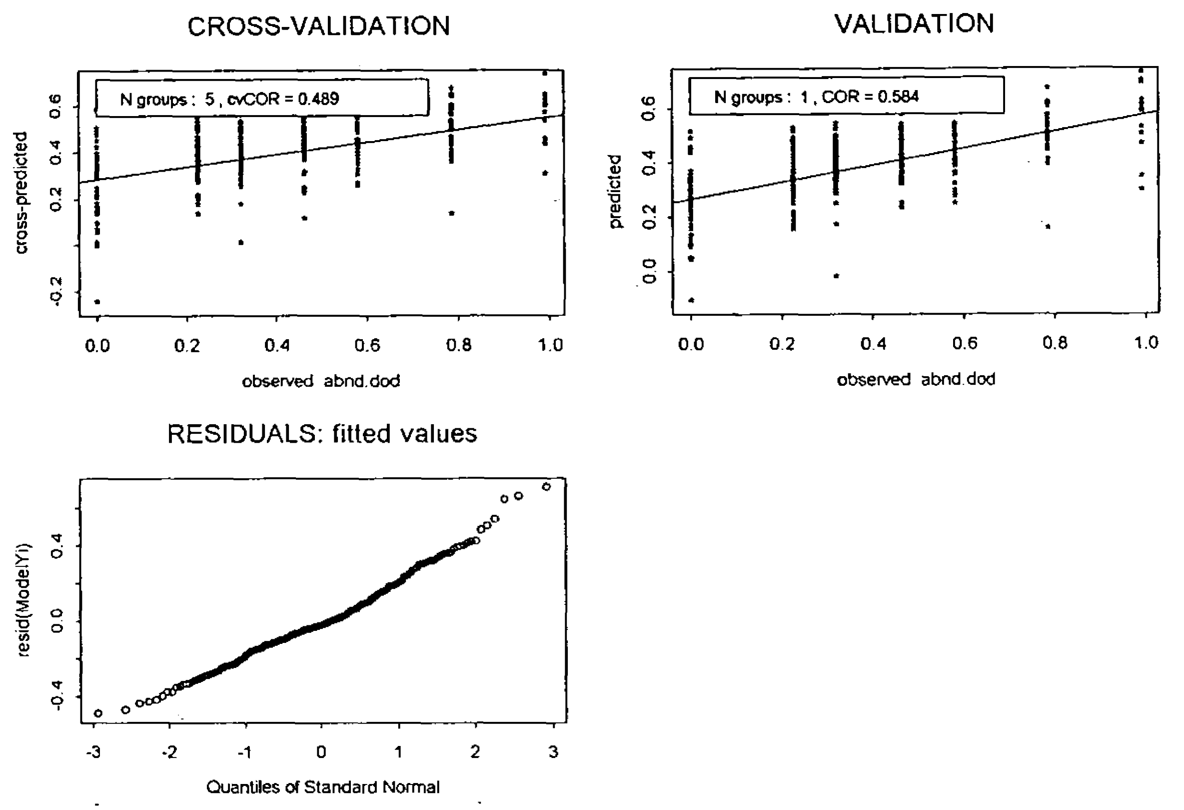


Figure 4.16: Cross-validation of predictive model of abnd.dod

4.5-Model predictions

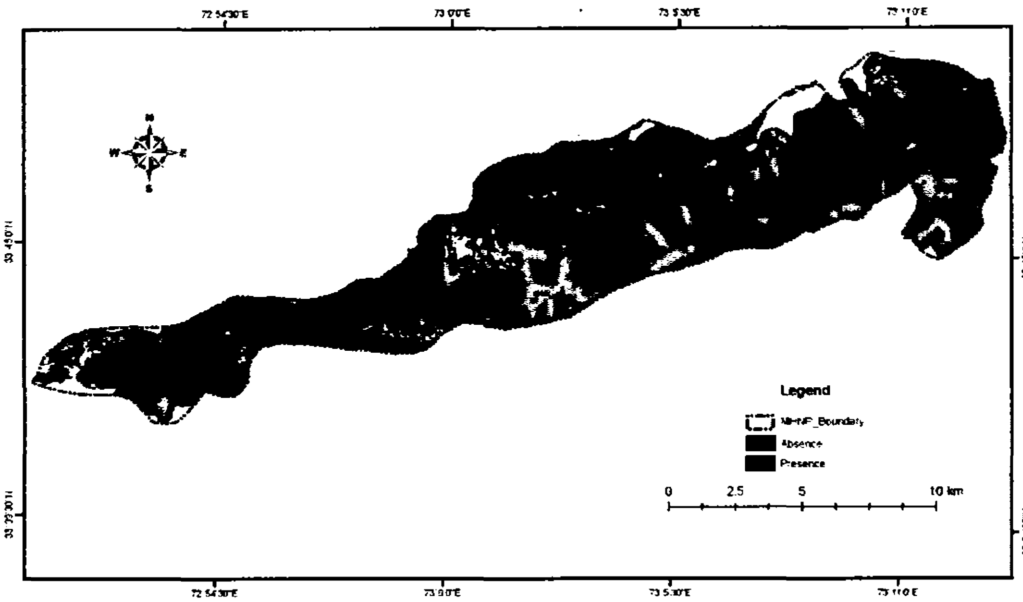


Figure 4.17: Potential distribution of *Dodonaea viscosa* in MHNP

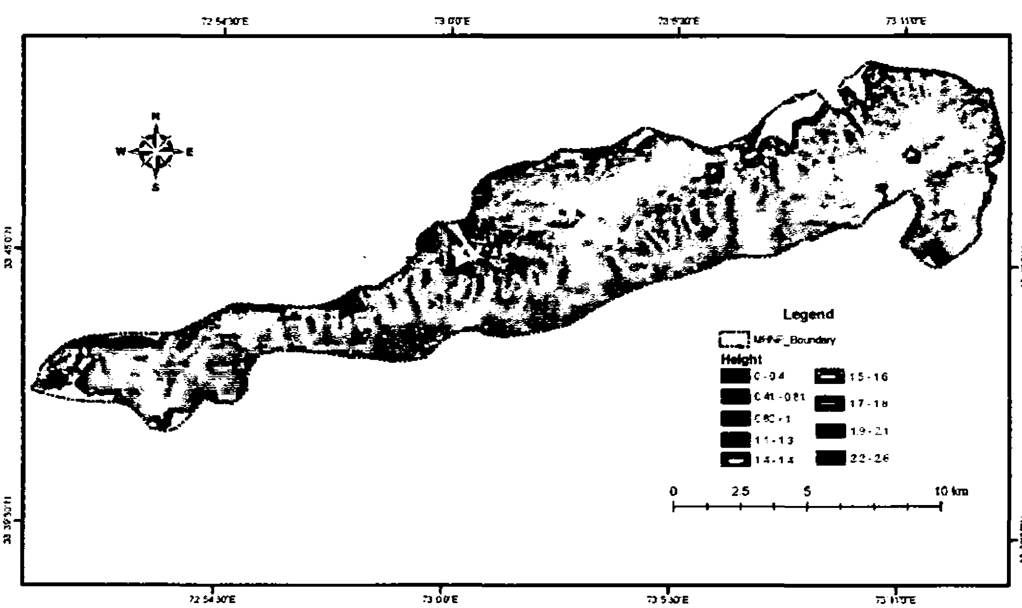


Figure 4.18: predicted height variability of *Dodonaea viscosa*

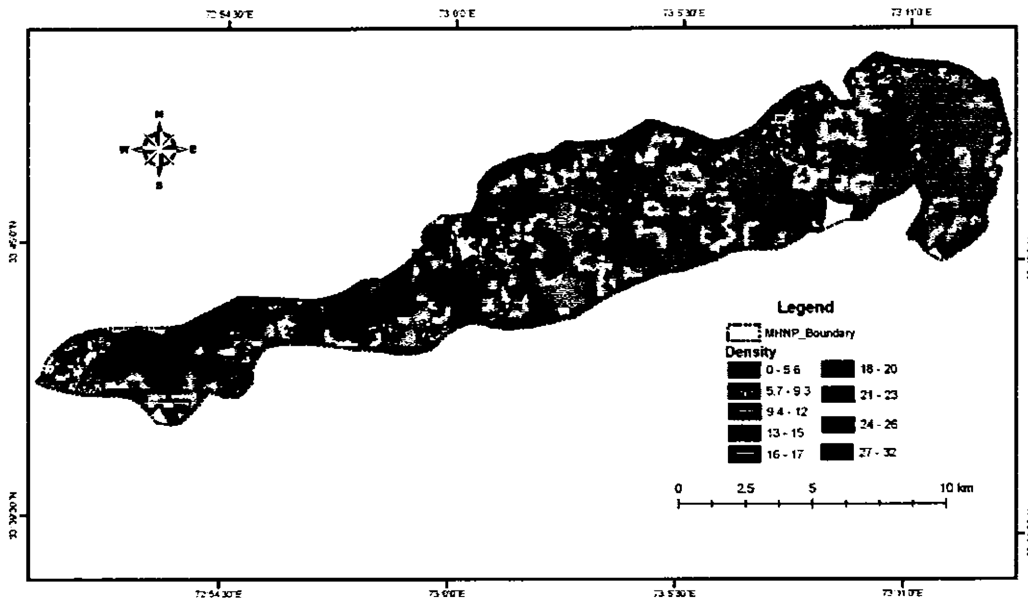


Figure 4.19: Density occurrence of *Dodonaea viscosa*

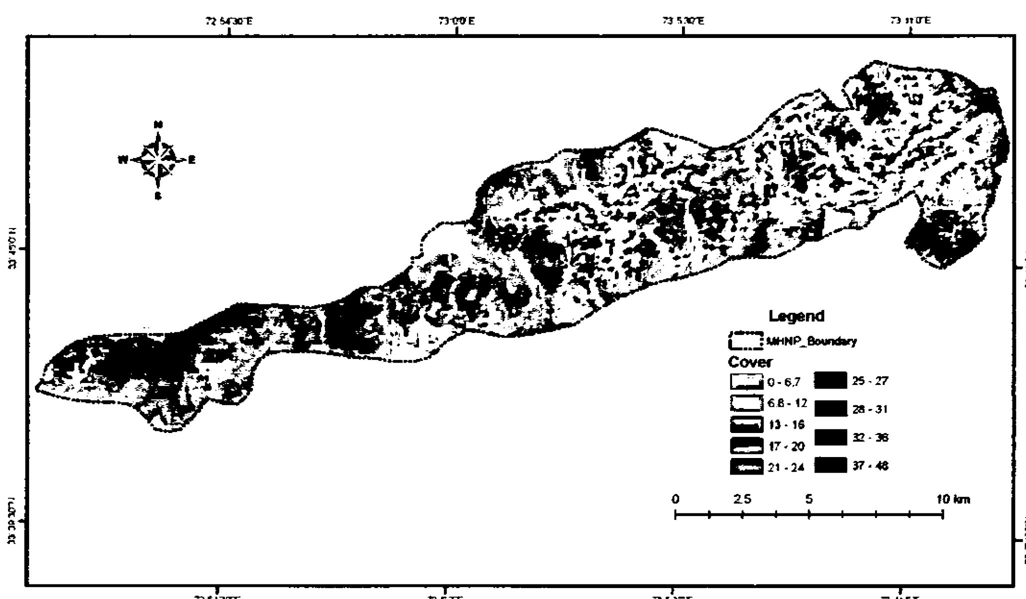


Figure 4.20: Cover of *Dodonaea viscosa*

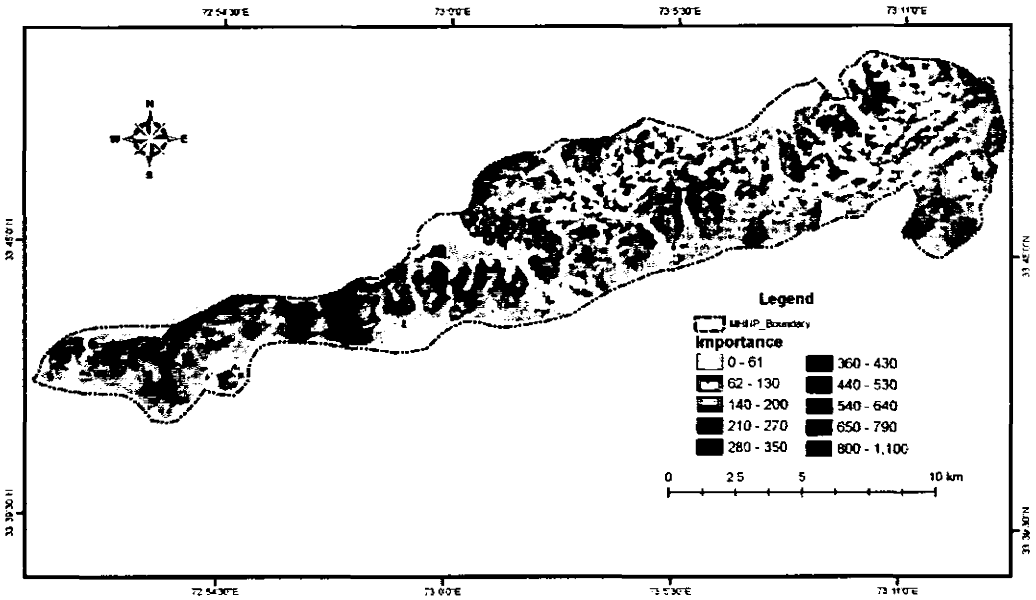


Figure 4.21: Importance resulted by cover, density and height.

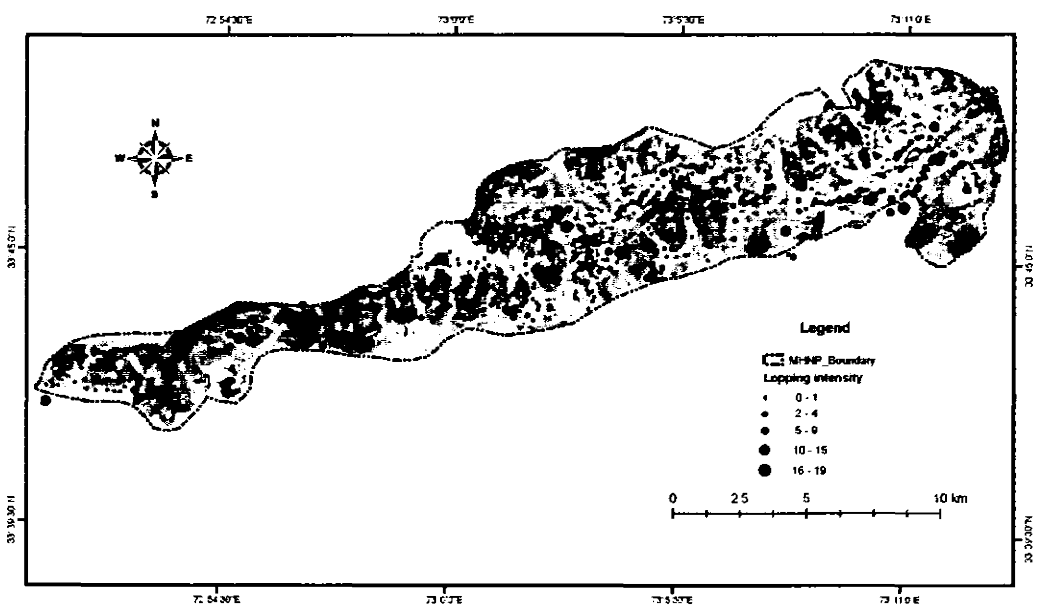


Figure 4.22: Lopping intensity at different locations.

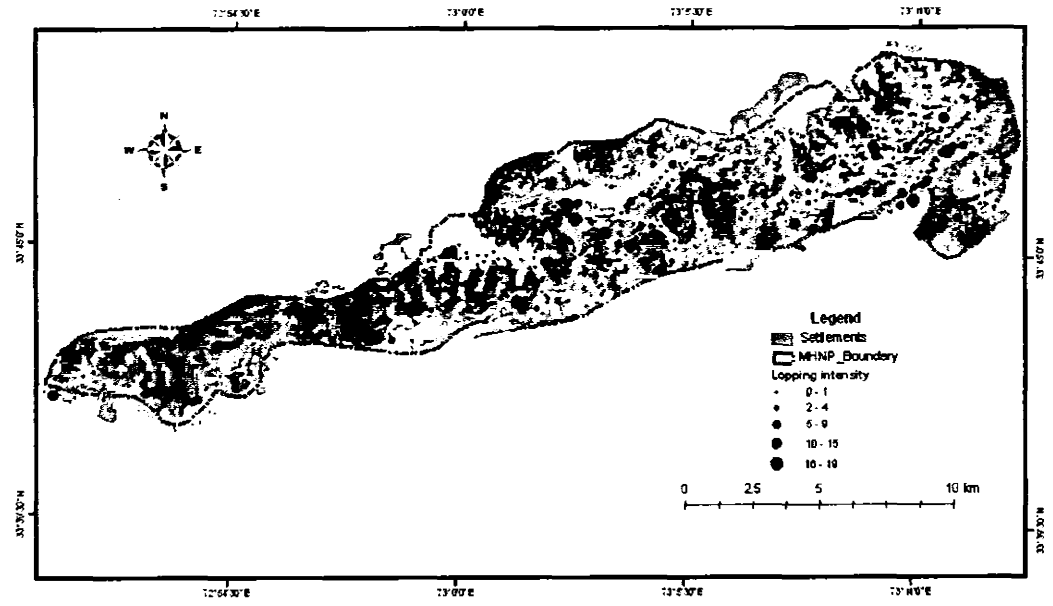


Figure 4.23: Settlements and Lopping intensity on Importance map.

The GAM resulted in the prediction of potential distribution of *Dodonaea viscosa* on the basis of its presence absence Fig. 4.17. The potential height, density and cover of the species are in Fig. 4.18, Fig. 4.19 and 4.20 respectively. Importance resulted by multiplication of height, cover and density quantified the *Dodonaea viscosa* in the study area Fig. 4.21. Lopping intensity observed in Fig 4.22 by comparing lopping data to the importance map. The map calculations predicted that *Dodonaea viscosa* is present in 13894.55 hectares of the study area which is 79% of the total area of the park where as 896.69 hectares of the park is covered by human settlements. The lower vales (e.g.0-16) of *Dodonaea viscosa* presence mostly occur in areas (Fig.4.21) that are near to the human settlements (Fig.4.22) and higher values of loping intensity (16-19) are adjacent to human settlements.

Chapter 5: Discussion

The current research is the first ever attempt to map fuel wood in MHNP. The study mapped status of the *Dodonaea viscosa* used as most important fuel wood species in the area. Only a survey based study focused on the contribution of *Bari Imam* shrine in fuel wood extraction from MHNP revealed *Dodonaea viscosa* as a major extraction out of total 15.16 tons of annual shrine fuel wood consumption (Shinwari and Shinwari, 2011) matching with the outcomes of socioeconomic investigations during current study regarding fuel wood/Dodonaea use, which covered almost all of the villages of the study area. But this information might not be sufficient for future management of this selective fuel wood species in/and MHNP which would require its overall presence in the area and its vulnerable locales. The advantages and uses of statistical techniques and GIS tools for such analysis are well known (Guisan and Zimmermann, 2000a), especially for the conservation purpose (Franklin, 2010). The modelling approach used during the assessment was presence/absence (binomial) and height, cover, density (Gaussian) based GAMs. The GAMs are used significantly in predictive modelling for their strong and statistical foundation and ability to realistically model ecological relationships (Guisan and Zimmermann, 2000b). These models are not parametric, data define smoother to fit non-linear functions (Yee and Mitchell, 1991). Encouraging results have been achieved from other studies using predictive mapping (Maggini et al., 2006) with respect to fitting and stability of the models as well as accuracy of the prediction at varying spatial resolutions.

The results showed that fitness of the predictive models of all types varied as shown by D^2 statistics which was 0.341. The statistics represents the deviance explained and its low value is likely to be result of missing possible predictors (Miller and Franklin, 2002). The values further suggest that the model was not over fit by an excess of predictors (Hastie et al., 2001). The D^2 values are often very low in large binomial data sets during the present exercise to predict and map spatial distribution of *Dodonaea viscosa* in the study area, GAM can be identified as the robust method, which is an arrangement with many previous studies using GAMs (Zaniewski et al., 2002).

Nevertheless, there is always some disagreement of actual and predicted values whenever are the statistic tools used for modelling. Validations of the model and error assessment are essential part of this modelling process that can be done by variety of available approaches. The prediction errors are categorised into 'biotic' and 'algorithmic'(Fielding and Bell, 1997). The biotic errors are due the lack of information on biotic controls within a predictor data set that might be leading to low D^2. The ROC (Receiver Operating Characteristics) depicts the predictability and stability of the model developed (Maggini et al., 2006). An ROC statistics of 0.5 crosspond to random comparison between presence/absence and predicted probabilities (Lehmann et al., 2002) and ROC statistics greater then 0.7 are considered good with values over then 0.9 are considered very good (Michel et al., 2010). The simple and cross validation has some difference in AUC-values which suggest that there was good model stability. The accuracy level achieved by the GRASP methodology applied in the present study can be regarded as very good (cross-validation with 0.88 ROC for presence/absence of *Dodonaea viscosa* and 49 – 60% of correlation in the models), directly related to the amount of information used to define the relationships between the components (predictors) in the models and response variables of *Dodonaea viscosa* (presence/absence, height, density, cover).

The study results shown the lower values of *Dodonaea viscosa* presence (0-61) or (62-130) and higher values of lopping intensities are in those sites which are adjacently located to community settlements of the area. Same has the case with roads and tracks where higher values of presence are at a distance which reflected the people active contribution in *Dodonaea viscosa* extraction. The mid and near mid elevations (500-750m) seemed to be less disturbed carrying more of this species which are naturally difficult to excess by the people.

Chapter 6: Conclusion and Recommendations

6.1- Conclusion

Vegetation mapping has now become the fundamental pre-requisite for ecosystem conservation, planning and management. Statistical modelling is gaining a significant popularity and becoming a key component in vegetation mapping and modelling offering an explicit, consistent, repeatable and economic method for extending vegetation mapping (Accad and Neil, 2006). The modelling approach deployed in this study applies an integrated suite of such techniques in a geomorphically and ecologically complex environment, successfully predicting the distribution of *Dodonaea viscosa* in the Margalla Hills National Park. To achieve this prediction at high accuracy, data integration that includes numbers of terrain and spectral based variables; along with the location and presence/absence data is required. Expert knowledge of a system, along with the use of Satellite Remote Sensing Data (SRS Data) plays a very important role in this kind of research. It helps us in establishing a focused sampling design in order to record the greatest amount of possible variations. In contrast with common remote-sensing classification procedures (non-supervised and supervised classification), in this methodology we do not assign each pixel to individual class (thus our expression of hard-classification, where a pixel can belong to one class only per image treatment, but each pixel has a value assigned to each different layer, giving us the possibility to map the subtle variations of the components. GAMs and GRASP are computer tools that demand high processor performance and large memory capacity when used over large areas at high resolution (several million pixels). For applications over greater areas, the option could be the use of Landsat 5 TM imagery (30×30 m pixel resolution), since covering such areas with high resolution imagery would be very costly. Nevertheless, if money for such investment (imagery and computers) is not a main constraint, the computing power of the latest generation of processors and current memory capacity has reached the point where the size of the data files is becoming less important.

As a conclusion we can state that the methodology implemented here, incorporating habitat characterisation and topology, remote sensing techniques, and spatial prediction (GRASP) is an effective, useful and reliable way to map extensive *Dodonaea viscosa* areas with relatively small investment in field surveys. Combining this GRASP application with time series of community assessment in selected areas, we could implement a forecast of *Dodonaea viscosa* condition and analyse changes of its components over time. As this methodology is fully compatible with GIS, new layers of related information could be added as they become available, and they may improve prediction accuracy and stability of our initial models.

6.2-Recommendations

MHNP is an area where no gas or any other alternate fuel source for inhabitants of more then 26 villages, which are within and adjacent to the boundaries of the park. Their soul dependence is on the national park's resources in this regard. Socio-economic assessments showed that a majority of the people in the area have low income and they would not go for the any other fuel options like LPG, furnace oil etc. Specific species like *Dodonaea* faced pressure for selection and collection as fuel in the area. Other fuel wood species can also be used in from the area or grown for fuel as an alternative, a study from Nairobi Kenya suggested the planted growth of *Eucalyptus* for fuel (Furukawa et al., 2011) but that need to be tested its suitability specifically for MHNP. Plantation and regrowth of the Dodonaea can also be introduced on selective sites where it is vulnerable or by its capacity of regeneration the fuel wood pressure should not be concentrated on specific site e.g. near settlements.

Involvement of locals/stake holders in the management and for the purpose of reducing pressure on the fuel wood/Dodonaea can be a good practice. Wakeel argued that the areas under public supervision are more vulnerable in term of change in forest cover then those which are under institutional/governmental supervision (Wakeel et al., 2005) while Jawad exposed it to be the institutional mismanagement (Ali et al., 2005) lead us to no sustainable use of any forest. The park management authority, in collaboration with the inhabitants should make a comprehensive plan which carry out the demands fuel wood as well as reduce pressure on *Dodonaea viscosa* and other native species exploited. The GIS based tools are recommended for the planning and regular monitoring of the fuel wood resources in future and also for monitoring other conservation threats in the region. Studies focused on fuel wood status and correlation of these native fuel wood species like *Dodonaea viscosa* with the accelerated invasion of exotic species recommended research direction for MHNP in future.

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Appendices

Appendix-i:

Sheet Used for Field Documentation of The Data

Plot No.	Species	No.Species	Length	Cover	Lopped	Damaged	Elevation	Longitude	Latitude	Date/time	Remarks

Appendix-ii:
Village Settlements in MHNP

Villages	Latitude	Longitude
Badho	33.80523	73.15478
Bari Imam	33.74952	73.10541
Dhok Saraa	33.77977	73.11155
Gandhiyan	33.72881	73.02156
Gokina Kalan	33.77569	73.0764
Gokina Khurd	33.76896	73.06468
Golra	33.69309	72.97512
Jori Rajgan	33.71669	72.86386
Kenthalan	33.73335	72.93993
Khurram Paracha	33.7151	72.87183
Malwar	33.78116	73.0996
Mandala	33.76501	73.17505
Mangiyal	33.78967	73.20391
Nariyas	33.79047	73.14209
Pari	33.75374	73.13653
Pir Sohawa	33.78525	73.11032
Raja Mehbub di Dhok	33.71491	72.8673
Rumli	33.7702	73.13537
Saduri	33.74625	72.97876
Saidpur	33.74444	73.0683
Sangjani	33.69711	72.8552
Shah Allah Ditta	33.71524	72.92031
Shahdara	33.77992	73.16669
Sinyari	33.726	72.99114
Subban	33.76842	73.18226
Talhar	33.76705	73.04764

Appendix-iii

IUCN Categories of Protected Areas.

Category	Name	Description
Category I (a)	Strict Nature Reserve	Area of land and/or sea, possessing some outstanding or representative ecosystems, geological or physiological features and/or species, available primarily for scientific research and/or environmental monitoring. features and/or species, available primarily for scientific research and/or environmental monitoring.
Category I (b)	Wilderness Area	Large area of unmodified or slightly modified land, and/or sea, retaining its natural character and influence, without permanent or significant habitation, which is protected and managed so as to preserve its natural condition.
Category II	National Park	Natural area of land and/or sea, designated to (a) protect the ecological integrity of one or more ecosystems for present and future generations, (b) exclude exploitation or occupation inimical to the purposes of designation of the area and (c) provide a foundation for spiritual, scientific, educational, recreational and visitor opportunities, all of which must be environmentally and culturally compatible.
Category III	Natural Monument	Area containing one or more, specific natural or natural/cultural feature which is of outstanding or unique value because of its inherent rarity, representative or aesthetic qualities or cultural significance.
Category IV	Habitat/Species Management Area	An area of land and/or sea subject to active intervention for management purposes so as to ensure the maintenance of habitats and/or to meet the requirements of specific species.
Category V	Protected Landscape/Seascape	Area of land, with coast and sea as appropriate, where the interaction of people and nature over time has produced an area of distinct character with significant aesthetic, ecological and/or cultural value, and often with high biological diversity.
Category VI	Managed Resource Protected Area	An area containing predominantly unmodified natural systems, managed to ensure long term protection and maintenance of biological diversity, while providing at the same time a sustainable flow of natural products and services to meet community needs.

Appendix-iv:

Questionnaire for Socio-Economic Survey and Fuel wood Use in MHNP Villages.

Village Name: ____________________

Dated________ **Location; N**______ **E**_______

Q1.what short of fuel is used for cooking and heating?

a. Fuel wood b. LPG c. other

____
____
____

Q2. If fuel wood is mostly used as fuel, then what is its source?

a. Forest b. Market c. other

____
____
____

Q3. Who usually go for cutting the Trees/fuel wood?

a. Male b. Female

____
____
____

Q4. Who collects the cut wood?

a. Male b. Female

____
____
____

Q5. Which are the preferred fuel wood species?

a.________ b.________ c________ d________

____
____
____

Q6. What are the reasons of preference?

____
____
____

Q7. How much distance is usually covered while bringing the fuel wood?

a. 0-1 hourb. 1-2 hours c. 2-3 hours d. 3-4 hours

____
____
____

Q8. What is the average household size?

a. <5 b. >5 c. >10 d. >15

Children: ____

Females:____Males:___
____

Q9. What are the sources of income of village residents?

____
____
____

Q10. What is the average income of village residents?

____
____
____

Q11. What are the causes of forest fire?

a. Human driven b. Natural

____
____
____

Q13. During which season, most of the forest fire happens?

a. Winter b. Summer

Q14. Is fire good for vegetation?

a. Yes b. No

____
____
____

Q15. What role do the villagers play during a fire event?

____
____
____

Q16. What actions do the forest committees take during a fire event?

____
____
____

Q17. Do fire lines help in fire control?

a. Yes   b. No

____
____
____

Q18. During which season fuel wood is used the most?

a. Winter   b. Summer

____
____
____

Q19. What is the total population of the village? ____________________________