Analysis of factors related to the distribution of Red deer (*Cervus elephus* L.) in Hustai National Park, Mongolia

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February 2008

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by

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Thesis submitted to the International Institute for Geo-information Science and Earth Observation in partial fulfilment of the requirements for the degree of Master of Science in Geo-information Science and Earth Observation, Specialisation: Geo-information for Biodiversity Conservation.

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Dedicated to my Guru
Dr. Jan de leeuw

Jan, you have been the light of my inspiration

Disclaimer

Abstract

The effect of livestock grazing on distribution of wildlife is a key issue in conservation management. The aim of this study is to explore and analyze the spatial distribution of red deer (*Cervus elephus* L.) in relation to livestock grazing. 301 species' point records (15*15 m) for cow, horse, deer, sheep/goat and gazelle based on dung (pellets) counts and 30 environmental predictors were prepared in GIS environment. After screening these predictors, logistic regression model was further used to produce probability map of spatial distribution of deer in Hustai National Park, Mongolia.

Chi Square illustrates significant association of park management (buffer and core zones) and distribution of the deer pellets as well as the distribution of marmots burrows. Our study of livestock and red deer association demonstrated significant negative association with abundance of sheep/goat pellets and negative association with cow dung abundance. However, positive association was observed with horse dung abundance. Logistic model (Nagelkerke R^2=.752, AUC=.956, AIC=209.3) shows higher probability of deer distribution with increasing elevation, higher slope steepness, nearer to the river and farther away from the roads. Elevation (Nagelkerke R^2=.654, AUC=.929, AIC=169.9) alone explains deer distribution similar to our final model.

Further analysis of elevation related factors was carried and this confirms human-induced threats (e.g. livestock guarding dogs, hunting, antlers collection etc.) and livestock grazing in the lower elevation might be causative factor governing occurrence of red deer in the higher elevation.

Keywords: Red deer, Hustai National Park, Mongolia, GIS, modelling spatial distribution, logistic regression model, elevation

Acknowledgements

I owe my heartfelt gratitude and honour to my first supervisor **Dr. Jan de Leeuw**, for his perpetual advice, continuous guidance and invaluable inspiration throughout the study period. I have learned because of you Jan, to conduct the research in the scientific framework. The knowledge of statistics and research methodology you shared with me all are valuable assets to the research. Finally, I am thankful for your support in guiding me in the field with full of encouragement and enthusiasm. You are excellent teacher and I always find your door open to me and your welcoming behaviour makes me work hard to come up with this research and you will be always remain great source of inspiration to me.

I am thankful to my second supervisor **Dr. Hein Van Gils**, for his valuable guidance, comments and suggestions during the study period. Your helpful suggestions during the final stage helped me a lot for shaping the thesis. I want to express my gratitude and admiration to **Drs. Henk Kloosterman**, for his guidance, correction of the proposal and thanks for your continuous support including meeting with Piet Wit. **Dr. Yousif Hussin** has encouraged and helped me for initiation of field work, so for this endeavours, he is also praiseworthy. I am extremely thankful to my program director **Dr. Michael Weir** for being supportive during my research period.

I am thankful to all the staffs of **NGIC**, Mongolia and my special thanks goes to **Mrs. Davaa Narantuya** and **Mr. Turtogtoh Ankhbayar** for their help and logistic support during research period. I want to express my thanks to **Hustai National Park Trust** for permitting me to carry out this genuine work. Also my vote of thanks goes to biologist from trust Ms. Dejid Nandintsetseg and researcher Mr. Dorj Usukhjargal. I want to thank my filed assistants Mr. Sainaa for his great help, tireless support and company during field visit.

I would like to express my sincere gratitude to **PRDS** family for making me able to pursue this course. My gratitude goes to my friend Kusumakar Bhusal and Dipak Neupane for support and Kalyan Karki for his encouragement. I am highly delighted to express my heartfelt thanks to my esteemed brother **Raju Sapkota** for his caring behaviour in each step of ITC and going through thesis with comments and suggestions. Also, **Hari Pokharel** (Kaka) is an asset for my thesis; regular chatting with poems and gazals makes me feel good to forget my worries far away from home (unlai ni tha cha, gahr kata, lol). I am equally thankful to my friend **Punna P. Sapkota**, for his company during stay at ITC and going through each and every words (lovely the) of thesis. I also convey vote of thanks to elder brother, **Sanjaya Devkota** for his help and guidance with special tea at the end of the day in his room.

I am also grateful to my friend **Ram K. Deo** and **Ashim R. Bajracharya** for their company during the stay. Madhu sir, Kamal sir, Nilam Kayastha (didi), Shreekamal Sir, Badri sir, and Ajay B. Mathema (dai) are also great source of inspiration in the ITC, for this I am also grateful to them. I am thankful to family of Reena didi for home environment during the stay in Enschede. I would like to thank, **Mamdooh Alamiri** for remote sensing techniques and his helpful behaviour in thesis time. Also, I am grateful to **Tarun Ghawana** for his friendship, special food and for proof reading the thesis. Many thanks to **Hamisi Manyenye,** my only class mate for being cooperative and helpful.

Last but not least, I would like to extend my thanks to all my international friends especially to Kiama, Nagya, Mthuthuzeli (baba), Edward (topology), Eugene, Mutumwa, Kingston, Tuan (professor), Oyundari, Poling, Yirgalem, Elias, Margaret, Wilber, Miza, Vivian, Satish, Arik.

Finally, I pay my deepest respect and love to my family members (buba, mummy, anu didi (kali), amrita and nisu) for making me able to do this genuine work by providing education and inspiration.

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1. Introduction

1.1. Background

The variability of the flora and fauna in the level of genes, species and ecosystem is widely defined as the biological diversity (biodiversity). Conservation of biodiversity is considered as the wealth of the country, not only regarding scientific aspects but also directly linked to nation's economy (Noss, 1990). Therefore, the biodiversity conservation and management has been the major concerns worldwide. Biodiversity loss occurs because of the competition within/between the population or because of negative human activity like logging, livestock grazing, mining etc.

Biodiversity loss is more critical in the areas like Mongolia, where land has to be utilized for wildlife and also for livestock grazing (Yoshihara et al., 2007). Grazing either facilitates the natural ecosystem or may degrade the system because of overgrazing. Grazing alters the composition of the plant community, increase the nutritive quality of forage, increase productive of selected species and increase diversity that finally alters the natural structure (Vavra, 2005).

In the steppe region, the plant growth is limited due to frequent droughts and low precipitation. Plant growth is highly related to amount of rainfall because there is strong correlation between average mean rainfall and average productivity. Also, there is the greater variation in climate between summer and winter in the steppe region, which greatly alters the food resources availability. The food availability is high in summer and decreases subsequently in the winter that makes the scarcity of the resources during this period (Staalduinen, 2005).

The period of drought frequently occurs in the growing season. Relatively shorter autumn season causes the plants to desiccate and freeze (dries the vegetation). This leads to less food resources availability in the winter season (Staalduinen, 2005). Wild ungulates compete with livestock, either due to limited food availability or because of food preference overlap (Yoshihara et al., 2007). Overgrazing causes the excessive defoliation and grass nutrient loss, this not only degrades the pastures but also reduces the animal production (Numata et al., 2007).

Increase in human population ultimately increases the number of livestock's in country like Mongolia, where most of people depend on livestock's for demand of wool and meat production. Overgrazing affect the grasslands because of selective grazing and also due to high stocking rate (Retzer, 2007). Mongolia consists of a total of 42 numbers of special protected areas (Enebish and Myagmarsuren, 2000). Among them, Hustai National Park is of major concern because of the Przewalski horse (15 horses in 2002 to 150 in 2007) is considered as one of the most successful reintroduction project worldwide (Hovens and Tungalaktuja, 2005). Hustai also holds considerable amounts of the marmots (>20,000), red deer (about 500), Mongolian gazelle (50-100) and predators like fox and wolves (Bhandi and Wit, 2000). The population of the deer and the wolf are fluctuating in the park, but the exact number, and distribution is unknown (Usukhjargal, 2006).

Red deer population is rapidly declining in Mongolia. The assessment of the red deer population in 1986 by government reported approximately 130,000 deer inhabiting 115,000 square km (Wingard and Zahler, 2006). Population assessment in 2004 confirm about (8000 to 10,000) red deer in Mongolia. There was 92 percent decline in the population between these years. The decrease in the population is mainly due to hunting because international buyers are looking for red deer shed and blood antlers, genitals, tails, and fetuses etc. Further, report on illegal wildlife trade by Wingard and Zahler (2006) suggests that decreasing population and increasing demand is main cause for the increase in price of wildlife in recent years. The price have increased for wolf, red and corsac fox, red deer parts, saiga antelope horns, and marmot skins and meat. Red deer and gray wolf both have multiple trade purposes. Red deer are sold to international trophy hunters and harvested for the medicinal properties of their antlers, genitalia, and tail. The estimated numbers of the hunters according to the report are 5,000 in 2004 and primary product is for medicinal purpose. Red deer trophy and subsistence hunting was banned in Mongolia in the year 2000. But this report showed that deer antlers, genitalia, and tails from Mongolia are still sold at shops along the border in China.

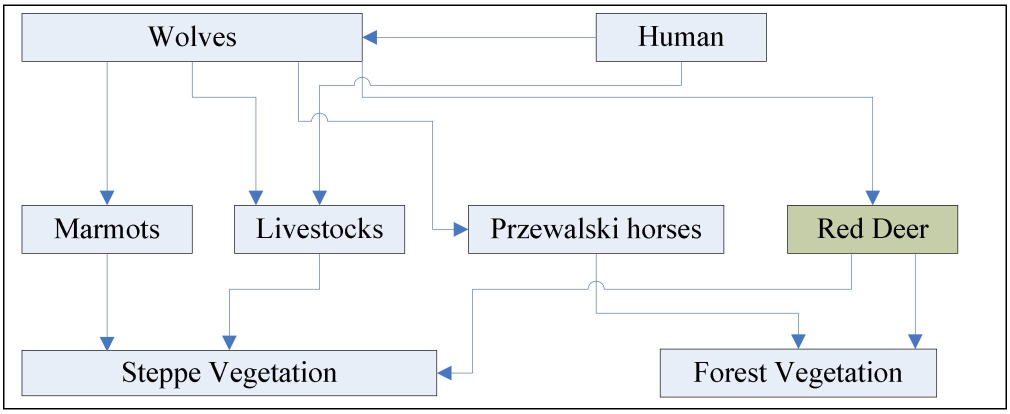


Figure 1-1. Simplified tritrophic system of the Hustai National Park ,from (Radersma, 2005)

1.1.1. Species-environment relationship

Study of species–environment relationships is an important in biodiversity conservation. The multi-scale investigations of these relationships are an important tool in ecological research (Cushman and McGarigal, 2004). Thus, analysis of this relationship is needed to guide the conservation of many declining species (Grand and Cushman, 2003). Mostly, statistical modelling predicts the distribution of species. Less concern is given to understand the functional relationship between species and environment (Guisan and Zimmermann, 2000). Therefore, ecological knowledge is often neglected during statistical modelling of species in ecology and conservation planning.

The other factor that needs consideration is to incorporate the environmental variables at multiple spatial scales since species response to environment varies with the scale of the observation (Cushman and McGarigal, 2004). Furthermore, habitats are subjected to continuous change. Absence/presence of particular species does not necessarily mean that environmental factors prevent its occurrence in the particular moment (Mezquita et al., 2005). Ecological relationships are complex, with each species occupying a multidimensional niche. Further, the distribution of single species depends on different environmental variables. Thus, understanding this complex process needs in-depth knowledge on species as well as different environmental factors.

Biomass alone is not adequate predictor of the species richness but the species richness is determined by the complex of different factors (Schuster and Diekmann, 2005). Species richness can be explained as a function of distinct variables. First process that defines the species presence is the location-specific variables related to resource requirement and secondly approach consists of variables that can be quantified over large spatial scales from topographical variables. The second approach is efficient and accompanied cheaply because this uses the variables derived by using remotely sensed data and geographic information system (Mac Nally et al., 2003).

1.1.2. Modelling fauna with GIS and remote sensing

Remote sensing techniques has been widely used for the study of the grassland types, structure because these approaches are cheaper and can be accompanied in the short time period without extensive field visits (Xu et al., 2007). GIS and remote sensing modelling has been widely used for the study of animal habitats in relation to forage species availability. The mapping and modelling of the plants species is relatively easier by using GIS and remote sensing because of their static nature. However, the mapping of the animal species using RS and GIS technologies is difficult and time consuming because of the dynamic behaviour of animals' movements. They keep moving in a large area travelling long distances and thus occupying a large spatially distributed habitat. This makes difficulties in modelling the animal species. The combination of satellite image and the different environmental factors is widely used for the prediction of the species occurrence in a particular area. Study by Stefanov and Netzband (2005) suggests that the MODIS data are useful for regional assessments of vegetation pattern and time-series analysis and further suggests that the higher temporal and spatial resolution is better for climatic, ecological and hydrologic studies.

The plant oriented diversity study is based on the characteristics of spectral reflectance feature of the plant species. Thus, the approaches and the method of remote sensing and GIS used for the plants species study cannot be used for animal study. The use of ancillary data such as climate, terrain, soils, human infrastructure and footprint, access to water etc. have been extensively used in geographic information systems for habitat and distribution of different species (Leyequien et al., 2007).

DEM (digital elevation model) is used for the modelling of the species, in relation to the environmental variables in GIS environment. The study done by the Jelaska et al (2003) suggests that the model could be improved significantly by the inclusion of other more complex DEM-based environmental predictors such as solar irradiation, exposure to wind etc. They further suggest that the high-resolution data from the DEM will be inappropriate for mapping complete floristic assemblage of larger area. Thus, there is need of optimal spatial resolution required for the complete flora mapping which will vary according to the different study objectives.

1.1.3. Habitat selection by red deer (*Cervus elephus* L.)

Red Deer (*Cervus elaphus* L.) are among the largest species of deer, distributed in the Asia, Europe and United States (Deer Specialist Group, 1996). This species were native to Eurasia and then introduced in the North and South America, New Zealand and Australia. The management of red deer is important as they are the game animals and many studies suggest that they also alter the forest regeneration (Borkowski, 2004; Gedir and Hudson, 2000; Palmer and Truscott, 2003; Patthey, 2003; Renaud et al., 2003; Schutz et al., 2003; Stankovski et al., 1998; Vospernik, 2006).

Home range of these species greatly differs from summer to winter and they migrate among these seasons to wider distance (Deer Specialist Group, 1996). The species are under complex interaction of the climatic variables, inter/intra species competition and thus alters habitat. Red deer's distribution is widely related to human disturbance (Patthey, 2003) and also by the availability of food resources (Stankovski et al., 1998). They share habitat including natural forests, planted forests, range/grasslands, shrubland, tundra etc. (Deer Specialist Group, 1996).

Red deer species are increasing in some part of the world, which has affected the natural ecosystem. Isolation and fragmentation of natural habitat causes problem to the growing population of red deer's habitat (Putman et al., 2005). Species of deer's also causes negative effect to the forest ecosystem either by damaging the sapling or stripping the tree barks (Renaud et al., 2003; Vospernik, 2006). Red deer species according to Renaud, et al. (2003) are the selective herbivorous and their food selection is not associated with taste and quality but also cost of obtaining it.

Red deer are grazers as well as browsers and they prefer the grassland with forest patches in summer and forested areas in winter season. Study done by Achermann (2000) in the Swiss National Park suggests that there exists the strong relation between the presence of the red deer with the phosphorus contents in soil and the vegetation units containing species like Acontium., Deschapsia, Trisetum, and Festuca. Also, Schutz et al., (2003) found that the presence of phosphorus in the topsoil is strongly preferred grazing sites by red deer. A number of factors are likely to affect the response of plant communities to deer grazing. Red deer prefer productive grassland mainly *Agrostis–Festuca* (Virtanen et al., 2002). Further, Virtanen et al., (2002) suggest that the red deer grazing sustains the plant diversity of productive grasslands but reduced deer grazing leads to the loss of plants species in these communities.

Red deer diet is mainly composed of the size of the grasses and the plant items rich in soluble cell containing forbs, seeds, fruits and cultivated forbs. Grazing by red deer changes the natural vegetation rapidly. Plant succession has proceeded faster in the preferred grazing areas (Virtanen et al., 2002). Deer also affects the natural ecosystem by browsing which causes difficulties in regeneration of Scots pine (*Pinus sylvestris*) (Palmer and Truscott, 2003).

1.2. Research approach

The use of remote sensing integrated with the different microclimate and physical factors can be used for the species distribution modelling as shown below in Figure 1-2.

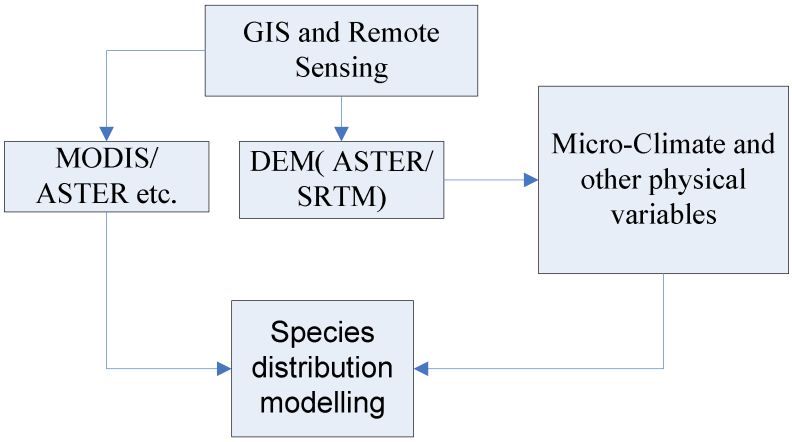


Figure 1-2. Research Approach

1.3. Problem Statement and Justification

Threats to natural ecosystem is global concern and major threats to biodiversity including hunting, logging, grazing, tourism etc. (Batsukh and Belokurov, 2005). Human activities causes negative influence to self regulating natural system (Debeljak et al., 2001; Stankovski et al., 1998). Forest ecosystems are changed not only by human activities but are greatly altered by different animal activities such as browsing, fraying and stripping activities by the ungulates (Vospernik, 2006). These activities when combined with the isolation of species (some ecological barriers) aided by increase in the numbers of species causes habitat problem to the species like red deer.

In recent years, the fluctuation in the deer population has been noticed in the HNP (Usukhjargal, 2006). The study also suggests red deer are migrating towards the northern Bogdh Khan area and the deer population greatly varies in Hustai National Park. Many studies been conducted in past for Takhi horse, wolf and marmots in these steppe. But the study to explore the spatial distribution of red deer in Hustai National Park has not been done yet. Over 150 Przewalski horse and around 20,000 Bobac marmots inhabit the park but the red deer population is fluctuating with around 500 red deer in Hustai with the population concentrated in the core zone of the park (Hovens and Tungalaktuja, 2005). This is creating a problem for the animals itself as more deer's are competing over the same resources in a limited area i.e. core area of the park. This is not good for the wildlife conservation objectives in the long run as intra-species and inter-species competition will create problems of existence of these animals. This study aims to address the question like, why the deer population is concentrated in core zone of the park. Thus, there is necessity of research, on the deer distribution to explore this underlying process.

1.4. Research objectives

The main objective of the research is to model the distribution of red deer in the Hustai National Park, Mongolia. The specific objectives are:

- To examine potential of satellite imagery and ancillary environmental variables for modelling red deer distribution.
- To identify suitable area for red deer based on different vegetation attributes and ground based information.

1.5. Research questions

- Does deer pellet size differ from the pellet size of sheep/goats and gazelle?
- Does the land management (conservation status) effect the distribution of red deer and marmots?
  - ✓ Does the distribution of red deer differ between different management zones?
  - ✓ Does the distribution of marmots differ between different management zones?
- Does livestock in and around the park effect the distribution of red deer?
  - ✓ Is there any association between the dung pellets of sheep/goats and dung pellets of red deer?
  - ✓ Is there any association between the cow dung and pellets of red deer?
  - ✓ Is there any association between the distribution of horse dung and pellets of red deer?
- How well does the physical environment (elevation, radiation, slope, precipitation, soils, geology, etc.) predict the distribution of red deer?

1.6. Research hypothesis

- There is no difference in length or width of pellets between gazelle, red deer and sheep/goat.
- There is no association between management zone (core, buffer) and abundance of deer pellets.
- There is no association between park management (core, buffer) and abundance of marmots burrows.
- There is no association between the distribution of deer and livestock pellets in park.
- The predictor’s variables predict the distribution of red deer better then by chance alone.

2. Methods and Material

2.1. Study area

The study was carried in Hustai National Park, Mongolia (87° 47’ -119° 57’ E - 41° 35’ -52° 06’ N), 100 km away from the capital, Ulaanbaatar. Nationally protected areas in Mongolia encompass 20.5 million hectares roughly 13.1% of the country’s territory. Also, 115 areas encompassing 1.13 million hectares are under local protection. According to a scientific survey, about 40% of the area, home for threatened and endangered wildlife and plant species, has been taken under state special protection (Batsukh and Belokurov, 2005). There are 55 protected areas including 19 national parks in Mongolia. Hustai National Park support nomadic life and world’s endangered flora and fauna including the Przewalski horse.

Table 2-1. Area of HNP

Category	Area (ha.)
Total	778,000
Core area(s)	50,000
Buffer zone(s)	350,000
Transition area(s)	378,000

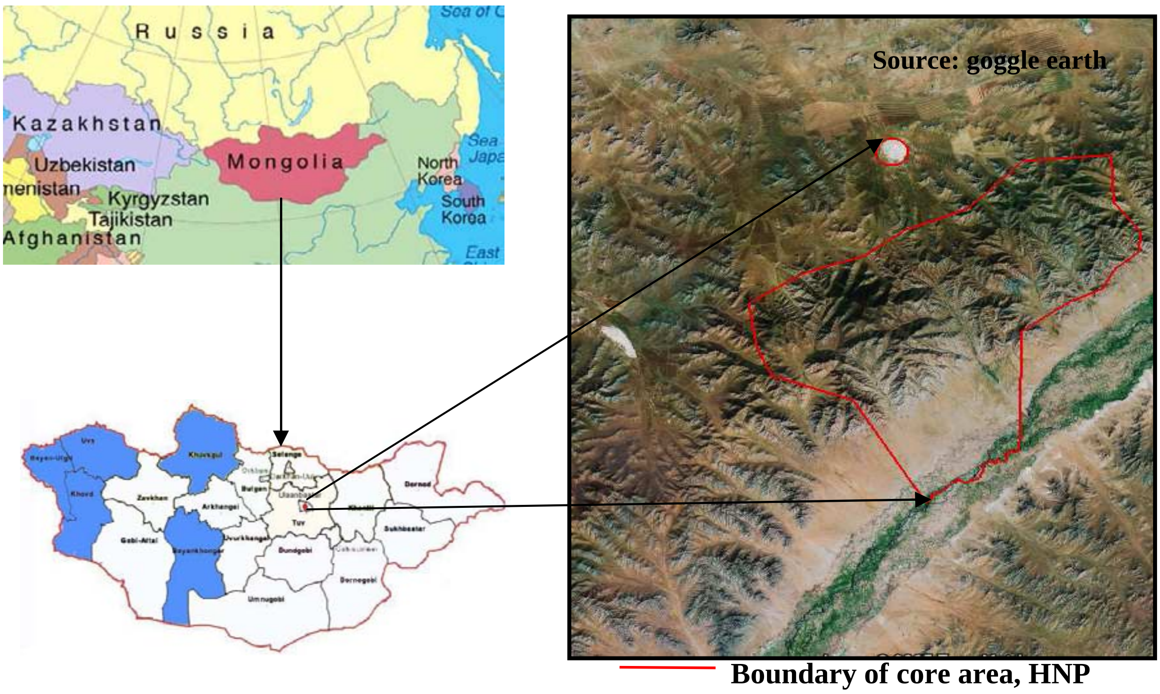


Figure 2-1. Location of Hustai National Park, Mongolia

2.1.1. Climate and Vegetation

Hustai national park (HNP) has continental climate, with the annual average temperature 0.2 ℃. The average annual rainfall is 270mm and 80% of that falls in growing season (May till September). Heavy wind in spring causes wind erosion of the top soil. The National park is classified as a mountain steppe region and about 450 vascular plant species can be found in Hustai national park. Sand dunes, shrubs, steppe, meadows, tussock grasslands and woodlands in the mountain steppe region and riverine forests are major vegetation communities (MNE Mongolia, 2002). About 2.080 ha. of HNP is dominated by Birch and Poplar forest (Bhandi and Wit, 2000).

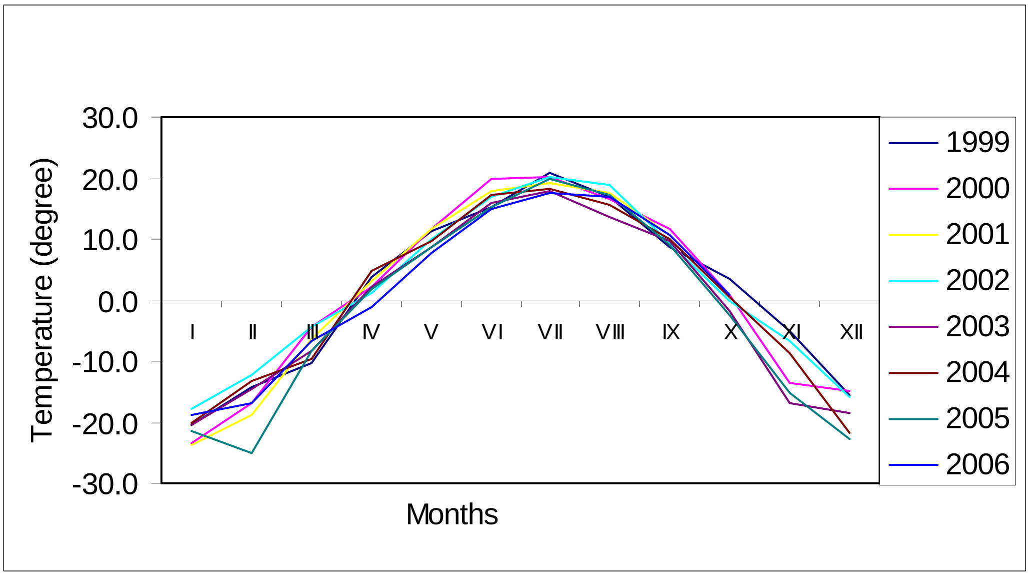


Figure 2-2. Monthly average temperature of Hustai National Park, Mongolia

2.1.2. Local human settlement around Hustai

More than 10,800 nomadic people including 175,000 animals (sheep, goat, horse and cattle) inhabits surrounding area of the park (MNE Mongolia, 2002). The buffer zone of the HNP covers an area of 350,000 ha. There is significant impact of livestock grazing in these areas that reduces grasslands area creating competition with wildlife. About 50-75% of herder families in the buffer zone are considered as poor. So, there is the buffer zone project in the park which focuses on increasing the livelihood of the local people by the introduction of project like "Development of sustainable livelihoods in the buffer zone of Hustai national park" in 2003 (MNE Mongolia, 2002).

Figure 2-3. a) Sheep grazing in HNP, 2007 b) Male and female red deer in HNP, 2007

2.1.3. Faunal distribution of HNP

Hustai national park is of world-wide importance supporting distribution of the wild horse (Przewalski horse) and species like the Mongolian gazelle, wolf, Corsac fox, Manul cat etc. (MNE Mongolia, 2002). Mongolia comprise huge number of wildlife biodiversity (including commercially-exploited and rare species such as Musk deer (*Moschus moschiferus*), Mongolian gazelle (*Procapra sibirica*), Red deer (*Cervus elaphus L.*), Roe deer (*Capreolus pygargus*), Black tailed gazelle (*Gazella* *subgutturosa*), Mongolian saiga (*Saiga tatarica*), Marmot (*Marmota baibacina*, *Marmota sibirica*) etc. (Batsukh and Belokurov, 2005). Altogether 46 types of mammals that has been recorded in HNP including 150 wild horses, 50-100 Mongolian gazelle and over 20,000 of the Bobac marmots.

Red deer is included in the list of rare species of Mongolia as stated by (Batsukh and Bolorama, 1998). About 500 red deer inhabit this area and they are greatly dependent on the grassland with patches of forest (MNE Mongolia, 2002). The mating period, or rutting season, starts in late-September. In Hustai national park's, they feed on grass, shrubs, trees etc. and their main predators are wolf (estimated 25 to 30 individuals).

2.2. Research method

2.2.1. Acquisition and satellite image processing

ASTER (Advanced Space borne Thermal Emission and Reflection Radiometer) scenes were acquired form the march 2005 as this is the recent and the cloud free data available. ASTER scene covers an area of 60 km by 60 km. The three visible and near infrared (VNIR) part of the spectrum have a 15m resolution, six short wave (SWIR) have a 30m resolution and the five thermal bands (TIR) a 90m resolution. The study area was in the transition zone of the two scenes thus the each of the scene was geometrically corrected to the common projection system (UTM, WGS84, 48N). These scenes were joined in ERDAS® Imagine 8.7 using the mosaic tool to get the total coverage to the study area. The boundary data of HNP was used to clip the study area in Arc Map® 9.1 with the extract by sample tool. Then all the other maps were corrected to the common projection system.

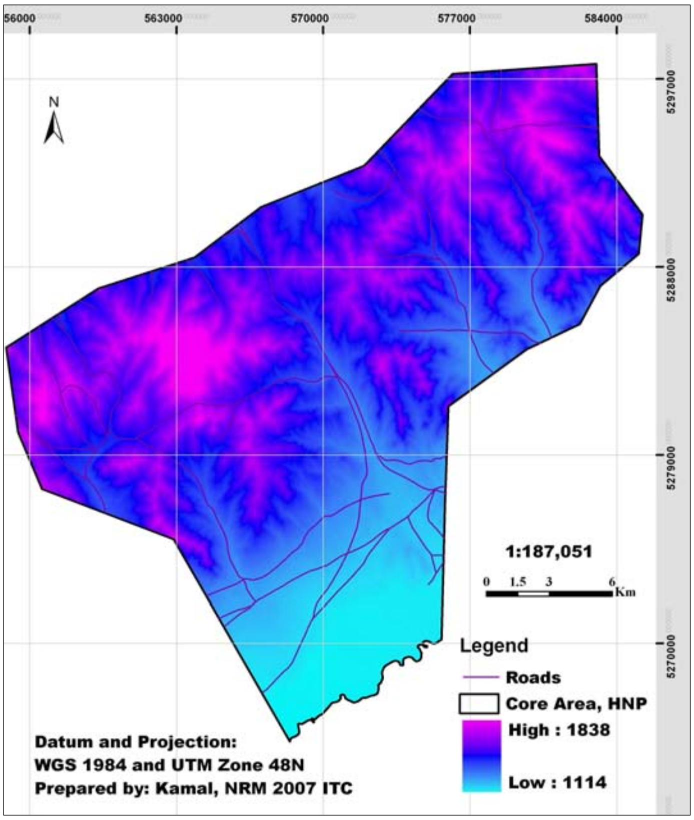


Figure 2-4. ASTER DEM HNP, Mongolia

Similarly, the SRTM (Shuttle Radiometer Topographic Mission) DEM (digital elevation model) were downloaded and processed. Bad values were removed in the ENVI software. ASTER DEM was also collected form ITC, Lab. Then the accuracy for both the DEM (ASTER and SRTM) was calculated and the accurate DEM matching with field data was finally used for further analysis.

2.2.2. Field survey and direct observation

Fieldwork was carried out from the 10th of September to the 6th of the October 2007. Pre-fieldwork preparations including route selection, collection and review of existing data were done. The secondary data available including reports, literatures, maps and relevant data for study were collected from available sources and reviewed. Two sampling techniques were followed; clustered random sampling and transect sampling. The clustered random sampling was done prior to transect. Prior to the field visit the random points were generated by using Hawth's tool extension in ArcMap® 9.1.

The random points focused on collecting the different types of vegetation attributes and the presence/absence of the deer pellet. Then after that the regular transect of 200 meters with walking distance was carried out covering the different landform and management zones. Line transect is considered important in the study of the animals as they are not stationary and thus larger area should be covered to gathered the necessary information (Patthey, 2003). 301 observation points with square plot with dimension (15*15) m (Patthey, 2003) were observed in the field. All the observation points are shown in Figure 2-5. The data for vegetation attributes like height and cover of herbs, shrubs and trees were collected in each plot. Similarly, the data on pellet presence/absence for the red deer, gazelle, sheep/goat and dung of the horse and cow noted for further analysis. Marmot's holes in the plot were counted, as marmots are also considered as the agent of change in the Hustai natural system.

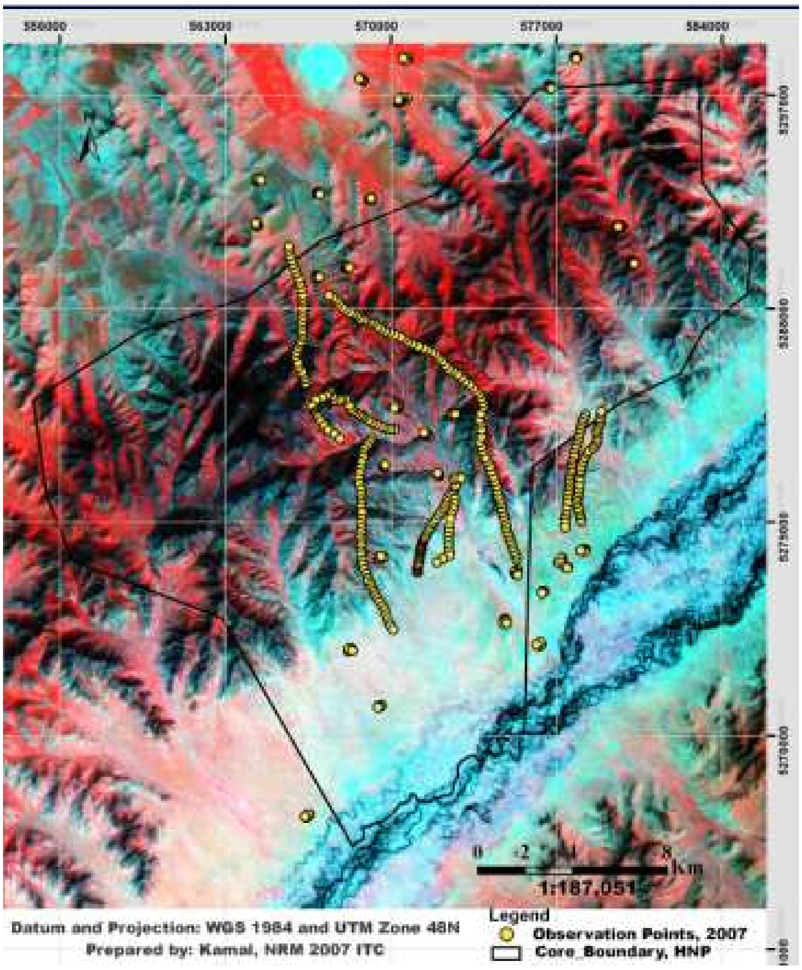


Figure 2-5. Field observation points, 2007

In addition, some observation on the deer inhabited places to know more about the distribution of deer and to collect information of governing factors regarding distribution. The observation points in Figure 2-5 and the data collection sheet is shown in the appendix 7.4. Some key informant's like park staffs, nature guides were interviewed to know more about the ecology and the distribution of red deer in the park.

2.2.3. Derivation of predictor's variables

In total, we selected 30 environmental predictors, which were considered potential to influence the distribution of red deer based on literature and author's hypothesis. These predictors were classified into 5 classes, (1) topographical variables,(Debeljak et al., 2001; Patthey, 2003) (2) variables related to vegetation (Achermann, 2000; Schutz et al., 2003) , (3) climatic variables, (Guisan and Zimmermann, 2000; Hovens and Tungalaktuja, 2005), (4) Other variables important for red deer, (Patthey, 2003; Virtanen et al., 2002) and (5) Grazing, (Palmer and Truscott, 2003; Renaud et al., 2003). These predictors are described in more detail below.

2.2.3.1. Topographical variables

The DEM at a resolution of 90m, was derived from CGIAR-CSI (is able to provide SRTM 90m digital elevation data for the entire world). Scene (Zone 3 in North and Zone 58 in East) was downloaded for the study area with datum WGS84 for zone 47N. Data was projected to UTM zone 48 N, and clipped to the study area. Altitude, slope angle and slope aspect were created from the same data. The potential direct solar radiation (Wh/m^2) was calculated from the DEM using solar analyst, an extension in ArcMap® 9.1. The radiation was calculated for every 30 minutes and summed up for a year.

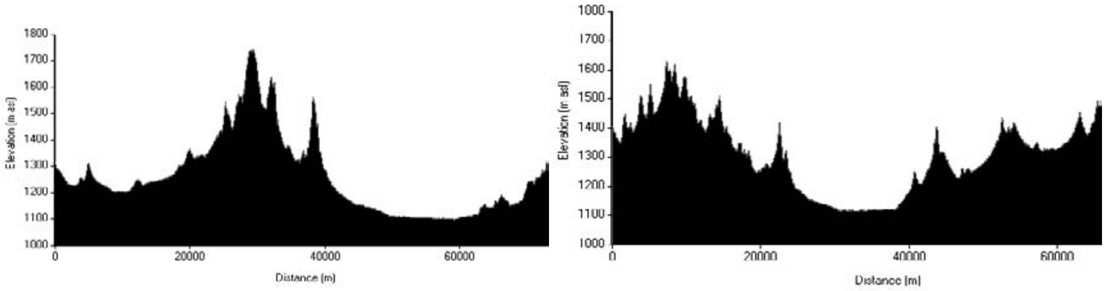


Figure 2-6. Profiles Derived from DEM (Right: North-South, Left: East-West)

2.2.3.2. Vegetation variables

Height and cover of herbs, shrubs and grass in each plot (301) were measure using a measuring tape (mm). Cover was computed, first observing bare ground then the total cover of herb, shrub and grasses summing to 100 percent. We also used vegetation map of the national park (NGIC Mongolia, 2007). The vegetation map was clipped with the study area after projecting it to UTM zone 48 N.

$$\mathrm{NDVI} = \frac{\mathrm{NIR - red}}{\mathrm{NIR + red}} = \frac{\mathrm{Band3 - Band2}}{\mathrm{Band3 + Band2}} \qquad \textbf{Equation 1}$$

Variety of the grasslands attribute may determine the suitability for grazing. These attributes may include the height, biomass, cover, percentage of annuals and perennial grasses available, percentage of the grass, herbs and shrubs available etc. Several of these grasslands attributes has been mapped using remote sensing. The vegetation monitoring from satellite imagery is advancing with use of high-resolution data's and with the advancement in remote sensing technology. Different vegetation indices including NDVI, SAVI, TSAVI, and MSAVI etc are used to monitor the state of the vegetation (Nakaji et al., 2008). The unique spectral signature of green vegetation in NIR and RED part of spectrum is the basis of vegetation indices. NDVI is based on the spectral properties contrasting with its soil background, which is a type of ratio-based indices. Our analysis is based on ASTER remote sensing data. The NDVI was calculated using ASTER sensor bands 3 and 2.

Table 2-2. The list of the predictor's variables

Category	Variables	Data type	Source
Topography	Altitude (m)	Categorical	Field and
	Slope angle (°)	Categorical	DEM
	Slope aspect	Categorical	SRTM NASA
	Radiation (kJ/m^2) (annual average)	Categorical	SRTM NASA
			SRTM NASA
Vegetation variables	NDVI	Continuous	ASTER-2005
	Grass Cover and Height (%, cm)	Continuous	Field, 2007
	Herb Cover and Height(%, cm)	Continuous	Field, 2007
	Shrubs Cover and Height (%, cm)	Continuous	Field, 2007
	Distance to forest (m)	Continuous	Hustai NP
	Vegetation cover types (7 classes)	Categorical	Hustai NP
Climatic	Annual or seasonal minimum temperature (°C)	Continuous	WorldClim
	Annual or seasonal maximum temperature	Continuous	WorldClim
	(°C)	Continuous	WorldClim
	Annual or seasonal mean precipitation (mm)		
Others	Soil types (5 class)	Categorical	Hustai NP
	Conservation status (3 zones)	Categorical	Hustai NP
	Distance to main road (m)	Continuous	Hustai NP
	Distance to main and small roads (m)	Continuous	Hustai NP
	Distance to gers (m)	Continuous	Hustai NP
	Distance to rocks (m)	Continuous	Hustai NP
	Distance to river and streams(m)	Continuous	Hustai NP
Animals	Horse dung class	Categorical	Field, 2007
	Cow dung class	Categorical	Field, 2007
	Goat /sheep class	Categorical	Field, 2007
	Gazelle class	Categorical	Field, 2007
	Marmots burrow class	Categorical	Field, 2007
	Deer pellet	Binary	Field, 2007
	Deer distribution (2002-07)	Continuous	Hustai NP

2.2.3.3. Climate variables

The data related to precipitation, maximum temperature and minimum temperature were derived form the WorldClim database (WORLDCLIM, 2006) in ESRI grid format at a resolution of 1km (30 arc~seconds).The annual precipitation was calculated from the precipitation data of 12 months. Similarly, the minimum and maximum temperature was calculated. Finally, both of precipitation and temperature data were projected and clipped with the study area.

2.2.3.4. Animal distribution data

Data was collected on the field with the simple random sampling and transect for the dung and pellets of horse, deer, sheep/goat, and gazelle. The marmot's holes were counted and grouped in four categories; absence, low, medium and high. In addition, the data regarding the distribution of the other animals were grouped according to the absence and the presence groups (Low, minimum and high; refer appendix 7.6).

Figure 2-7. a) Marmots burrows in HNP, 2007 b) Przewalski horse (Takhi) in HNP, 2007

Fresh (just after dropping) pellets of animals were collected to make it possible to ensure best identification for those of gazelle and sheep/goats. Deer stay farther from human settlement and they remain isolated from human beings (Patthey, 2003). Thus the fresh pellets of deer were difficult to collect, for this the wildlife experts from the park were consulted for identification of the deer pellets. We consulted a local wildlife expert and field guide to ensure that we correctly classified red deer pellets.

2.2.3.5. Other important variables

Road data was obtained from the Hustai National Park. The soil map, rock distance map, rivers distance map, gear distance map and conservation status map were created from the existing map of the national park. Euclidean distance tool in ArcMap® 9.1 was used to calculated distance map with the output cell size of 30m. All the maps were finally clipped with the study area.

2.2.4. ANOVA (Analysis of variance)

ANOVA was used to test whether it was possible to distinguish the pellets of different species based on the length and width. ANOVA can be used to test the hypothesis that means among two or more groups are equal. ANOVA test is based on these assumptions, firstly the standard deviations (SD) of the populations for all groups should me more or less equal and secondly, the samples should be randomly selected from the population. Our data doesn't meet the first criteria but as suggested by Moore and McCabe (2003) difference up to a factor two are allowed and careful judgment of p value and higher F value should allow reliable inference in case of higher variation in standard deviation.

ANOVA tells that there is difference between the means but does not tell which combination of species differed from each other. A post hoc comparison test can answer, if there is significant difference among group means following an ANOVA. Thus post-hoc, Bonferroni test was conducted to know which combination differed (Moore and McCabe, 2003).

2.2.5. Habitat association analysis

Chi square test (X^2) is widely used for habitat association study. We used X^2 to test the association between the distributions of animals with the management zones. This test provides a method for testing the association between the row and column variables in a two-way table. Chi square test was used to test the null hypothesis that there is no association between the variables. The lower P value ($P<0.05$) and high chi square value indicates that some association between the variables is present (Moore and McCabe, 2003).

The chi-square test statistic is computed as:

$$X^2 = \sum \frac{(\text{observed} - \text{expected})^2}{\text{expected}}$$ **Equation 2**

Where, the square of the differences between the observed and expected values in each cell divided by the expected value are added across all of the cells in the table.

Association between the distribution of animals with management zones as well as the association of cattle's with red deer was computed with the help of 301 independent observations.

2.2.6. Logistic model

Logistic model has been used widely in the study of the distribution of animals with presence/absence data. This model has also been widely used to models habitat of birds(Hashimoto et al., 2005); to model the spatial distribution for brown bear, to determine critical area for protection with the aim of increasing their probabilities of survival or connection of isolated population (Garcia et al., 2007) and to model the distribution of grizzly bear mortalities based on local landscape attributes, demographic status, seasons, and mortality type by Nielsen, et al (2004).

The statistical model for the logistic regression is:

$$\text{Log}\,(P / 1\text{-}P) = \beta_0 + \beta_1 X$$ **Equation 3**

Where P is a binomial proportion and X is the explanatory variable. The parameters of the logistic model are β_0 and β_1.

Logistic model and multiple logistic regression technique can be related to the presence/absence of the red deer (dependent variable) in relation to the previously described thematic layers (independent variables).The red deer presence and absence data was calculated based on pellet counts and can further be used to develop statistical models. These models can be used to predict the distribution of the deer occurrence in the study area. The distribution of the red deer and potential variables that influence the deer distribution were modelled and analyzed with logistic regression model in statistical computing software, SPSS® 11.0.5.

Logistic regression is valid for hypothesis testing with specified power but there is not any method that suggests the sample requirement for the stable estimates (UCLA, 2008). Long (1997) suggest that the sample size less than 100 is not sufficient but more than 500 is sufficient in any case. Five predictor in model and one-tailed test with alpha =.05 provides the power of 0.90 for 235 samples (UCLA, 2008). Thus, we assume that 301 independent samples are adequate in this study.

2.2.7. Model validation

Goodness of fit for logistic model is measured using either the maximized likelihood deviance or R^2 which follow an asymptotic chi-squared and F-distribution, respectively. R^2 described the percentage of the variance explained but the variance of the categorical dependent variables depends on the frequency distribution of that variable. Thus, R^2 could not be used for the determination of goodness of fit but can be used to measures the strength of association (Garson, 2008).

The likelihood ratio is a function of log likelihood, which can be used for assessing the significance of the logistic regression model. This is also called goodness of fit, deviance chi-square, scaled deviance, deviation chi-square or L-square (Garson, 2008). The lower the value of log likelihood ratio, the better is the performance of the model. Furthermore, forward conditional logistic model starts with the constant only model and adding variables one at a time until the variables in the model is significant with certain cut-off level(Chan, 2004). The stepwise method does not identify the final model. The best model is that which does not improve the model performance significantly with the addition of another variable and has lowest value of Akaike Information Criterion (AIC). In which, the value of AIC is calculated by using the following formula (Dick, 2004).

$$AIC = -2 \times \text{log-likelihood} + 2 \times K$$ **Equation 4**

Where, K is the number of parameters

Similarly, the ROC (Receiver operating characteristics) curve is also used to assess the accuracy of the model. The area under the curve, which ranges from 0 to 1 is used to assess the model discrimination (Chan, 2004). The sensitivity (true positive fraction) and specificity (true negative fraction) depends on the threshold provided by the user and represented as:

$$\text{Sensitivity} = \frac{\text{True positives}}{\text{Total positives}} \qquad \text{Specificity} = \frac{\text{True negatives}}{\text{Total negatives}}$$

There is no statistical test of the area under an ROC curve; as a rule of thumb, the area under the curve (AUC) can be “graded” as an academic grade on 0-10 scale: 6 is “passing” (model is at least somewhat useful), 7 is ‘good”, 8 is “very good” and 9 is “excellent”(Rossiter and Loza, 2008).

3. Results

3.1. Pellet identification

Figure 3-1. a) Pellets: sheep/goats in HNP, 2007 b) Pellets: red deer in HNP, 2007

Figure 3-2 reveals that the pellet length and width differed between red deer, sheep/goat and gazelle. ANOVA confirmed that there was a significant difference between these three species in pellets length (ANOVA, $F=336.595$, $df=2, 57$, $P<0.001$) and pellets width (ANOVA, $F=170.8$, $df=2, 57$, $P<0.001$). (Refer annex 7.10)

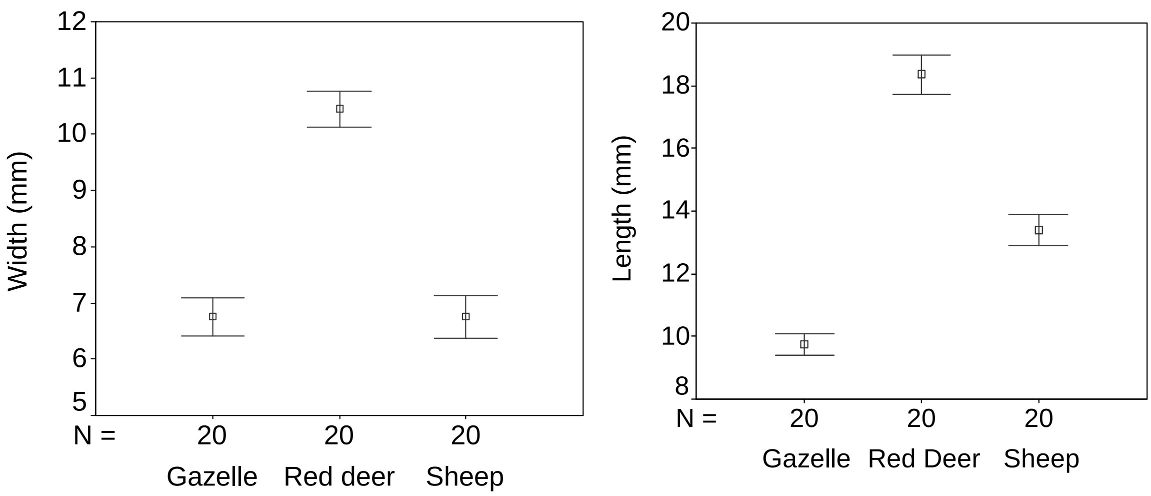


Figure 3-2. Pellets (width and length) of gazelle, red deer and sheep/goats.

The ANOVA does however not reveal which combination of species differed from each other. Further post-hoc Bonferroni test indicated that pellets diameter differed between red deer on the one hand and sheep/goats or Mongolian gazelle on the other ($P<0.05$). However, pellet diameter of sheep/goats and gazelle were not significantly different ($P>0.05$). Similarly the post-hoc Bonferroni test revealed that pellet length differed between each of the species of red deer, sheep/goats and gazelle ($P<0.05$).

3.2. Association of deer and marmots with management

Chi Square test was computed to know the association between the park management and distribution of deer pellets. Cross tabulation of deer pellets and management zones were analyzed which shows that the deer pellets absence is very high in the buffer zone (92.5 %) and presence of deer pellets is higher in the core area. The presence percentages for classes (few, moderate and many) were very less in buffer zones including zeros.

Table 3-1. Cross tabulation between management zones and pellets group

		Management Zone		Total
		Buffer	Core	
Red Deer	Absent	92.5%	37.0%	59.1%
	Few	7.5%	33.1%	22.9%
	Moderate	0.0%	15.5%	9.3%
	Many	0.0%	14.4%	8.6%
Total		100%	100%	100%

Chi Square test shows highly significant association between park management and the distribution of the deer pellet (Chi Square, $\chi2$ =94, df =3, P<0.001). The low p-value and the high chi square show that there is a strong association between the distribution of deer and park management. Thus, we reject our null hypothesis that there is no association between management zone (core, buffer) and abundance of deer pellets (refer annex 7.7)

The chi square also used to analyze the association between park management and the distribution of marmots burrows. Cross tabulation of marmot's burrows and management zones were analyzed which shows that the marmot's absence class percentage is very high in the buffer zone (82.5 %) and presence percentage of burrows is higher in the core zone.

Table 3-2. Cross tabulation between management zones and marmots burrows

		Management Zone		Total
		Buffer	Core	
Marmot Burrows	Absent	82.5%	60.8%	69.4%
	Few	10.0%	25.4%	19.3%
	Moderate	4.2%	7.2%	6.0%
	Many	3.3%	6.6%	5.3%
Total		100%	100%	100%

Result of $\chi2$ test shows that there was a highly significant association between park management and the abundance of the marmots burrow. (Chi Square, $\chi2$=16.4, df =3, P<0.001). The p-value is lower with the higher value of the chi square so, our result shows that there is strong association between the distributions of marmots and park management. Thus, we can reject our null hypothesis that there is no association between management zone (core, buffer) and abundance of marmot burrows

3.3. Red deer and livestock's association

Chi square was performed to observe association between deer and sheep/goat pellets abundance. Table 3-3 shows the cross tabulation of column total between the sheep and deer and this revels that there was negative relation between the occurrence of deer and sheep/goats. This result clearly shows that the presence classes of red deer (few, moderate and many) are lower (1.3% and 0 %) but the absence classes of sheep are higher (42.5 %, 19.5% and 21 %). Thus, the results demonstrate when a deer pellet is less; there are many sheep/goats pellets.

Table 3-3. Cross tabulation between pellets group of sheep/goats and deer

		Sheep and goat- pellet group				Total
		Absent	Few	Moderate	Many	
Red deer- pellet group	Absent	16.1%	51.8%	86.8%	97.4%	59.1%
	Few	42.5%	28.2%	13.2%	1.3%	22.9%
	Moderate	19.5%	12.9%	.0%	.0%	9.3%
	Many	21.8%	7.1%	.0%	1.3%	8.6%
Total		100%	100%	100%	100%	100%

The result of Chi square test shows that there is a significant negative association between the distribution of deer and sheep/goat pellets (Chi square, $\chi 2=137$, df =9, P<0.001). The p-value is lower with the higher value of the chi square, so our result shows that there is strong negative association between the distributions of deer pellets and sheep/goats pellets. Thus, we reject our null hypothesis that there is no association between management zone (core, buffer) and abundance of deer pellets.

In addition, chi square shows that there is negative association between deer pellets and cow dung abundance. Cross tabulation between the cow dung and the deer pellets shows that when deer is absent, than there is presence of the cow dung. We observe that when deer pellets were absent than cow dung presence classes were 100 percent. When, deer dung is many, and then the presence class for cow (few, moderate and many) is approaching to zero. Therefore, our result shows that deer pellets abundance are high where there is lower abundance of cow dung.

Table 3-4. Cross tabulation between cow dung and pellets of red deer

		Cow- pellet group				Total
		Absent	Few	Moderate	Many	
Red deer- pellet group	Absent	42.3%	96.3%	100%	100%	59.1%
	Few	32.2%	2.5%	.0%	.0%	22.9%
	Moderate	13.0%	1.3%	.0%	.0%	9.3%
	Many	12.5%	.0%	.0%	.0%	8.6%
Total		100%	100%	100%	100%	100%

Furthermore the result of Chi square test shows that there was a significant negative association between the distribution of the deer and cow dung (Chi Square, $\chi 2=79$, df =9, P<0.001). The p-value is lower with the higher value of the chi square, so our result shows that there is strong negative association between the distributions of deer pellets and cow dung. Therefore, we reject our null hypothesis that there is no association between the distribution of deer pellets and cow dung in park

Figure 3-3. a) Domestic horses in HNP, 2007 b) Marmots in its burrows in HNP, 2007

To determine the association between abundance of deer pellets and horse dung in the park, chi square was performed. There exists some association between them. The association is not apparent like that of cow and sheep/goats. Table 3-5 of cross tabulation shows that when horse dung is absence than deer absence class has higher percentage value. However, when deer presence class is many than absence class of horse has higher value than that of the horse presence classes (few, moderate and many). Thus, we can say that there is some association between the deer pellets and horse dung distribution.

Table 3-5. Cross tabulation between pellets group of deer and horse dung

		Horse- pellet group				Total
		Absent	Few	Moderate	Many	
Red deer- pellet group	Absent	75.0%	57.6%	49.3%	71.9%	59.1%
	Few	12.5%	22.4%	28.4%	25.0%	22.9%
	Moderate	0.0%	9.4%	16.4%	3.1%	9.3%
	Many	12.5%	10.6%	6.0%	0.0%	8.6%
Total		100%	100%	100%	100%	100%

Furthermore, the result of Chi Square test shows there was a significant association between the distribution of the deer and horse dung (Chi Square, $\chi2=18.3$, df $=9$, $P<0.03$). The p-value is a bit bigger than for the sheep/goats and cows. In addition, the $\chi2$ value is lowest i.e. only 18.3. Statistically there is a significant relation between the distribution of pellets group of deer and horse dung. It compels us to reject our null hypothesis that there is no association between the distribution of deer pellets and horse dung in park.

3.4. Screening predictors for logistic regression model

3.4.1. Correlation among different environmental variables

Screening the continuous predictor variables based on Pearson correlation coefficient with the level of significance and visually by the pairwise scatter plots (refer appendix 7.5) was completed in initial phase of model. The pairwise scatter plots shows that some predictors seemed to be inter-correlated which is further supported by the correlation matrix.

Table 3-6. Correlation Matrix between environmental variables

	Rod	Riv	Roc	NDVI	Slp_a	Elv	Sol	For	Gers	Max_t	Min_t	PPT
Rod	1	**.188**	**-.396**	**.350**	**.371**	**.582**	**.048**	**-.416**	**.311**	**-.562**	**-.542**	**.525**
Riv	.001	1	.372	**-.106**	**.063**	**.011**	**-.060**	**.362**	**-.154**	**-.041**	**-.013**	**.014**
Roc	.000	.000	1	**-.451**	**-.272**	**-.603**	**.011**	**.858**	**-.719**	**.574**	**.596**	**-.597**
NDVI	.000	.034	.000	1	**.258**	**.523**	**-.081**	**-.488**	**.433**	**-.529**	**-.539**	**.526**
Slp_a	.000	.138	.000	.000	1	**.485**	**-.053**	**-.340**	**.328**	**-.490**	**-.476**	**.475**
Elv	.000	.423	.000	.000	.000	1	**-.070**	**-.751**	**.772**	-.965	-.956	.961
Sol	.204	.150	.421	.081	.180	.114	1	**-.014**	**-.014**	**.106**	**.103**	**-.085**
For	.000	.000	.000	.000	.000	.000	.407	1	**-.902**	**.702**	**.723**	**-.747**
Gers	.000	.004	.000	.000	.000	.000	.404	.000	1	**-.763**	**-.791**	**.828**
Max_t	.000	.239	.000	.000	.000	.000	.033	.000	.000	1	.984	-.990
Min_t	.000	.411	.000	.000	.000	.000	.038	.000	.000	.000	1	-.986
PPT	.000	.403	.000	.000	.000	.000	.071	.000	.000	.000	.000	1

(Correlation: Upper right and Significance: Lower left block)
Codes-Rod: Distance to roads, Riv: Distance to river, Roc: Distance to rocks, NDVI, Slp_a: Slope, Elv: Elevation, Sol: Solar radiation, For: Distance to forest, Gers: Distance to gers: Max_t: Maximum temperature, Min_t: Minimum temperature, PPT: Precipitation

Table 3-6 shows strong correlation between some of the continuous environmental predictors. There is strong negative correlation between the maximum temperature and elevation, minimum temperature and elevation, minimum temperature and precipitation, maximum temperature and precipitation. Similarly, there is the strong positive relation between the maximum and minimum temperature.

3.4.2. Analysis among different continuous environmental variables

Appendix 7.1 shows the group's box plots of each environmental predictor by presence and absence of red deer records. For the minimum annual temperature the median, the h-spread are well separated so, the minimum temperature is one of the good predictor. Similarly, the distance to gers is also similar to that of the minimum annual temperature with well-separated spreads in plots. The maximum annual temperature is also good predictors for deer presence and absence. Distance to roads also seems good predictor with apparent spreads and median value of the presence record occurring around 1500 meters and absence record around 500 meters. Distance to river is not the good predictor. The median of values between the absence and presence are similar with the median around 2000 meters. The altitude is also one of the good predictor. The median and h-spread are well separated. The presence data are well represented at higher altitude with the median around 1500 meters. The absent data has the median around 1200 meters but the spread is almost approaching 1400 meters.

Solar radiation is not good predictor with the spread and median being similar. The h-spread are also similar in range. Distance to roads also one of the good predictors with well-separated median. The absence records are mostly farther to forest distance around median of 5000 meters and the median of the deer presence is near almost 2000 meters to forest distance. The mean annual precipitation is one of the good predictors with the well-separated predictors. For the slope, the median is well separated, with the well separated h-spread. Still we can see some overlaps between the absent and presence spreads. Like the annual minimum temperature, the annual maximum temperature is also good predictor with well-separated median and h-spread. The median is around 68ºC for absence record and 57 ºC for the presence records. Thus from the box plots the annual minimum temperature, annual maximum temperature, annual mean precipitation are excellent predictors. Similarly, the distance to gers, distance to rocks, distance to roads and distance to forest and are good predictors for deer absence and presence. The predictors like distance to rivers, solar radiation and slope are not good predictors as indicated by the box plots.

3.4.3. Analysis among categorical environmental variables

Total 301 observation points were used to predict the probability of the deer presence/absence records. The categorical variables used in the model are aspect, management zone, vegetation types and soil types.

Table 3-7. Summary of Pearson's Chi square test for categorical variables

Variables	Types	Chi-Square	df	Sig.
Aspect Types	Six Classes	7.503	8	.484
Management Zone	Two (core and buffer)	67.530	1	.000
Vegetation classes	Six Classes	163.410	5	.000
Soil Types	Five Classes	182.328	4	.000

Note: Refer the classes types in the appendix 7.2

Table 3-7 show's aspect as the classified predictors is not significant having lower chi-square value. Soil types is highly significant with the chi square of 182, similarly the vegetation classes with chi square of 163 and also the management zones with chi square of 67. The three categorical predictors are highly significant for the red deer prediction (refer Table 3-7).

3.4.4. Summary of important predictors for red deer

Some predictors were not included in the model after screening with correlation coefficient and box plots. There was strong relation between the elevation and the annual minimum temperature, annual maximum temperature and precipitation. Thus, only elevation was considered in the model. Similarly, the aspect types were not included in the model, which was not significant. Predictors used in the final model are; categorical variables: management zone, vegetation classes, and soil types, and continuous variables: altitude, distance to gers, distance to rocks, distance to roads, distance to forest, distance to river and solar radiation.

3.5. Logistic regression model

3.5.1. Model result of Forward conditional logistic model

Finally, after the prior screening process, 12 variables were included in the logistic regression model. We carried out the forward conditional binary logistic regression for the distribution data of red deer presence and absence with codes (ELEVATIO: Elevation, ROAD: distance to road, RIVER: distance to river, ROCK: distance to rocks, NDVI: Normalize difference vegetation index, SLOPE_AN: slope angle, SOLAR: solar radiation, FOREST, Forest types, GERS: Distance to gers, VEGETAT: types of vegetation, SOIL: types of soil, ZONE: management zones). The logistic model includes 301 observation points collected in the field based on the presence and absence of the pellets groups.

Table 3-8. Summary of forward conditional binary logistic

	Predictor	Intercept (B)	S.E.	Chi-Square	df	Sig.
Model 1	ELEVATIO	.020	.002	84.466	1	.000
	Constant	-28.156	3.038	85.916	1	.000
Model 2	ROAD	.001	.000	21.955	1	.000
	ELEVATIO	.016	.002	47.997	1	.000
	Constant	-24.270	3.220	56.820	1	.000
Model 3	ROAD	.002	.000	27.444	1	.000
	RIVER	-.001	.000	9.718	1	.002
	ELEVATIO	.017	.002	46.422	1	.000
	Constant	-24.065	3.346	51.731	1	.000

Figure 3-5 shows that maximum area under the ROC (Revivers operating characteristic) curve was for the elevation and similar result obtained from the forward conditional logistic model. Thus, in the first model only the elevation was included. Variable road was entered in the second model and finally the variables river and slope angle in the final model.

Table 3-9. Model summary of forward conditional binary logistic

Model	Chi-square	df	Sig.	-2 Log likelihood	Nagelkerke R Square	AIC
Model1: Elevation	199.867	1	.000	207.301	.654	209.3
Model2: Elevation + Distance to roads	228.609	2	.000	178.559	.718	182.5
Model 3: Elevation + Distance to roads + Elevation	239.458	3	.000	167.710	.740	173.7
Model 4: Elevation + Distance to roads + distance to river + slope Angle	245.509	4	.000	161.659	.752	169.9

Table 3-9 shows the models with elevation is itself better at predicting the deer occurrence, with the Nagelkerke R square = .65 and not much difference with the final model (Model4: X^2=245, df=4, P<0.00) with Nagelkerke R square = .75.

3.5.2. Best logistic model for red deer prediction

The final logistic model for red deer distribution is predicted by elevation, distance to roads, slope and distance to river. According to our best model, the probability of distribution of the red deer finding is high at higher elevation, near to river, higher slope and away from the roads. The slope is not significant individually but significant when combined in the model as shown in Table 3-8. Based on our logistic model the probability of finding red deer was computed using following equations.

Equation 5: Log *p*/ (1-*p*) = [elevation] * .015 + [slope] * .089 + [distance to road] * .002 - [distance to river] * .001 - 22.199)

Equation 6:

$$p = \frac{exp^{\text{[elevation] * .015 + [slope] * .089 + [distance to road] * .002 - [distance to river] * .001 - 22.199}}}{1 + exp^{\text{[elevation] * .015 + [slope] * .089 + [distance to road] * .002 - [distance to river] * .001 - 22.199}}}$$

Table 3-10. Coefficient of best logical regression model for red deer probability distribution

	Predictor	Intercept (B)	Standard Error	Chi-Square (Wald)	df	Sig.
Best Model	ROAD	0.00178	.000	26.884	1	.000
	RIVER	-0.00067	.000	10.704	1	.001
	SLOPE_AN	0.08889	.037	5.709	1	.017
	ELEVATIO	0.01515	.003	36.095	1	.000
	Constant	-22.19893	3.348	43.952	1	.000
For code: Refer to Table 3-8						

Table 3-10 shows that the elevation has highest chi-square value thus contributing maximum to the model, which was also supported by above finding that elevation, was only predictor in the first model.

```
    60 +                                                              +
       |O         Predicted Probability is of Membership              |
       |O         for 1.00                                            |
       |O         The Cut Value is .50                                |
    40 +O                                                             +
       |O                                                             |
       |O                                                             |
       |OOO                                                          1|
    20 +OOO                                                          1+
       |OOOO                                                         1|
       |OOOO                                                     11111|
       |OOOOOOOOO O 1       1  O      1     11  1  1 O  1 1 11111|
Predicted---------------+--------------------------+-------------------
  Prob:   0          .25          .5          .75          1
  Group:  OOOOOOOOOOOOOOOOOOOOOOOOOOO11111111111111111111111111111
```

Figure 3-4. Visualization of logistic model

3.6. Model validation

As discussed earlier in section 2.2.7, best model is the one with lowest AIC, lowest -2 Log likelihood and R^2 (for model strength). We examined from Table 3-9 that our final model fulfilled all the aforementioned criteria's. Value of AIC (169.9) and log likelihood (161.659) are lowest in final model with the highest Nagelkerke R square (.752). The other way to measure, the goodness of the model fit is accuracy measured by the area under the ROC curve (AUC). The highest AUC (.956) was obtained for our final model and similarly the AUC (.929) for first model with elevation as a single predictor. Based on the final model, the predictive Equation 6 was used to calculate the predicted probability by using raster calculator in ArcMap® 9.1.

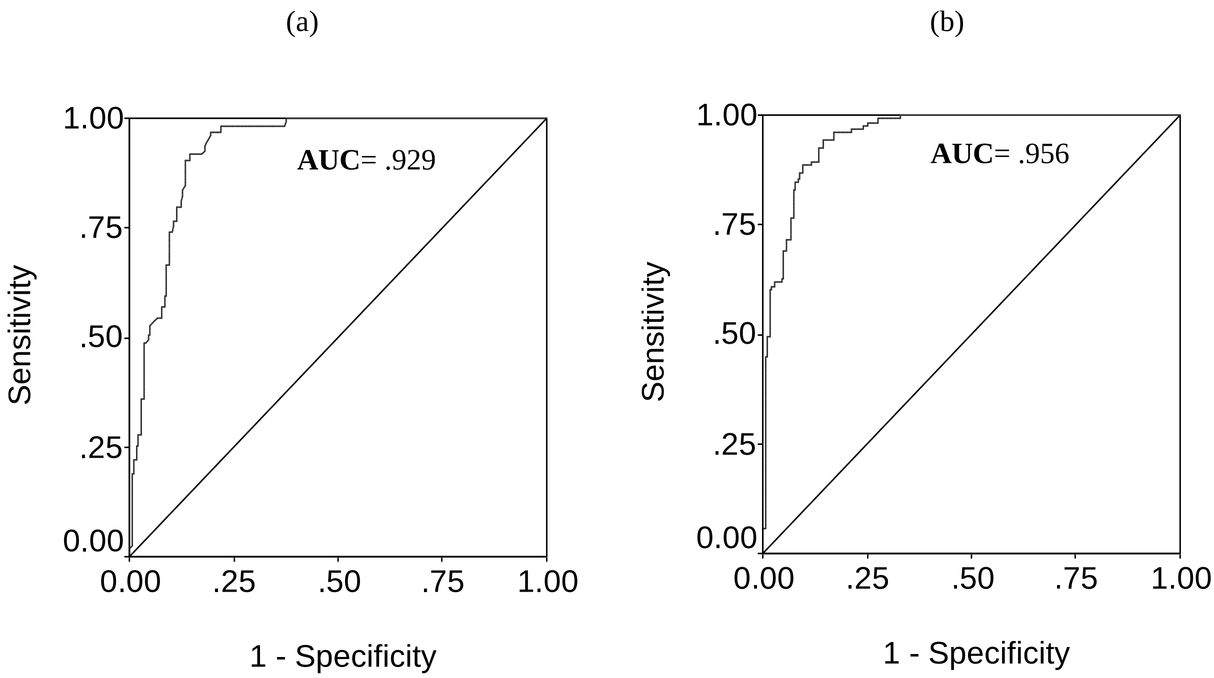


Figure 3-5. a) AUC for first model b) AUC for final model

3.7. Visualization of model

To visualize the effect of different predictors the final model was used to know the relation of different predictors in the equation. The elevation (highest chi square and highly significant) was effecting highest to the model thus the visualization of the logistic curve was computed based on different conditions. Figure 3-6-a shows probability of finding red deer when we apply conditions approximating near distance to roads, near to river and higher slope in the equation of the final model. Similarly, Figure 3-6b and c are also not good at predicating probability of finding red deer. The graphs below represented the predicted probability of occurrence for red deer with increasing elevation and varying condition for different values to road, river and slope angle.

We visualised logistic model with different condition of the predictors as shown in Figure 3-6 . Elevation is the most important predictor in the model with highest value of chi square. Thus we plotted the probability with increasing elevation. The other predictors were altered from their lowest to highest values and finally Equation 6 was used to visualize the logistic model. The best curve shows that probability highest with increasing elevation, higher slope steepness, nearer to the river and farther away from the roads.

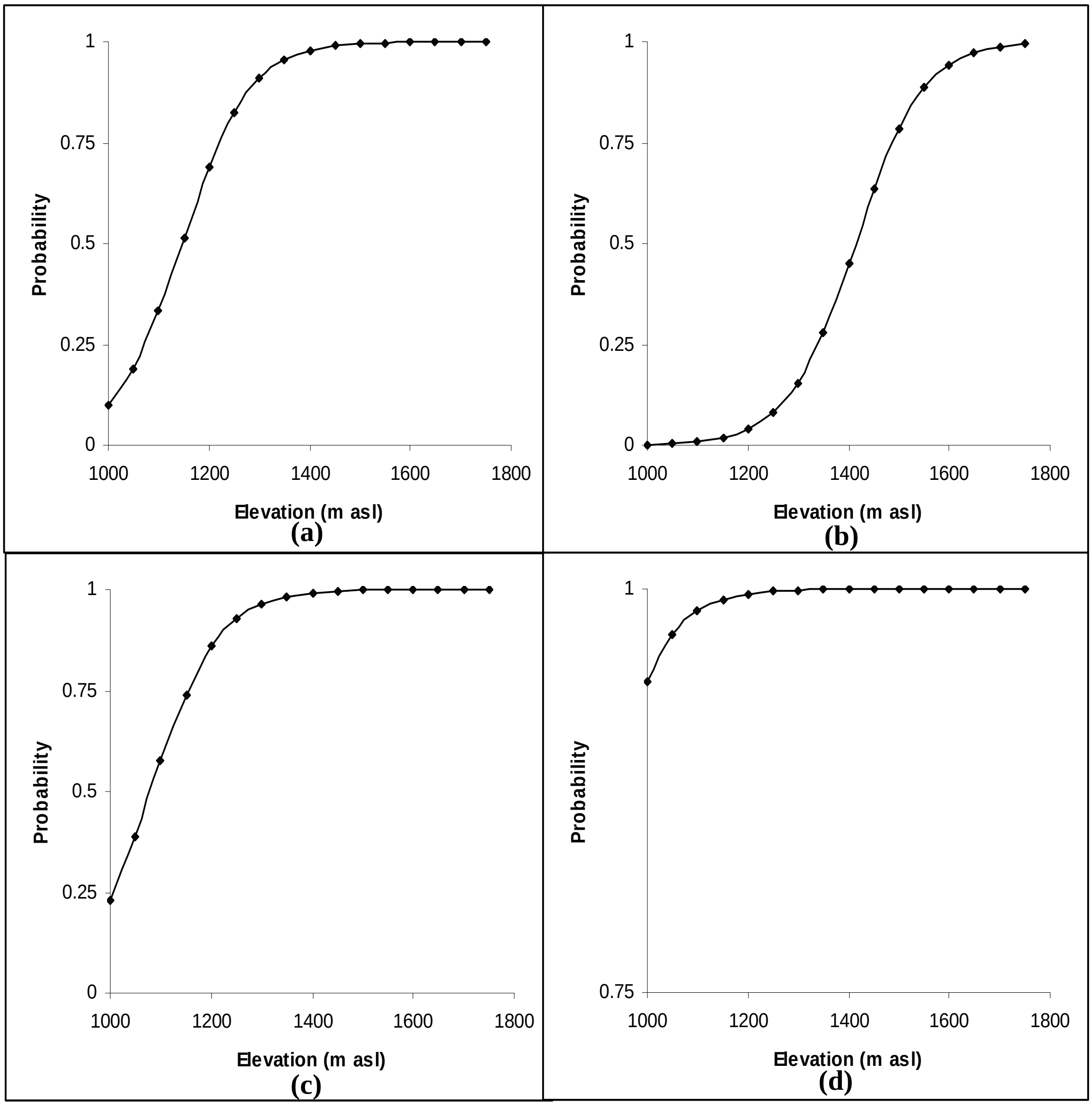


Figure 3-6. Predicted probability for occurrence of red deer by logistic model
a) 1000m from road, 100m from river and 40 degree slope
b) 100m from road, 100m from river and 5 degree slope
c) 3000m from road, 100m from river and 5 degree slope
d) 3000m from road, 100m to river, 40 degree slope

Finally, the probability map was generated by using the final logistic model to visualize the probability of finding red deer. The map in Figure 3-7 shows the agreement between the present home range in the core area. Map also shows there are suitable areas out side the core area of the park (present home range)(Usukhjargal, 2006).

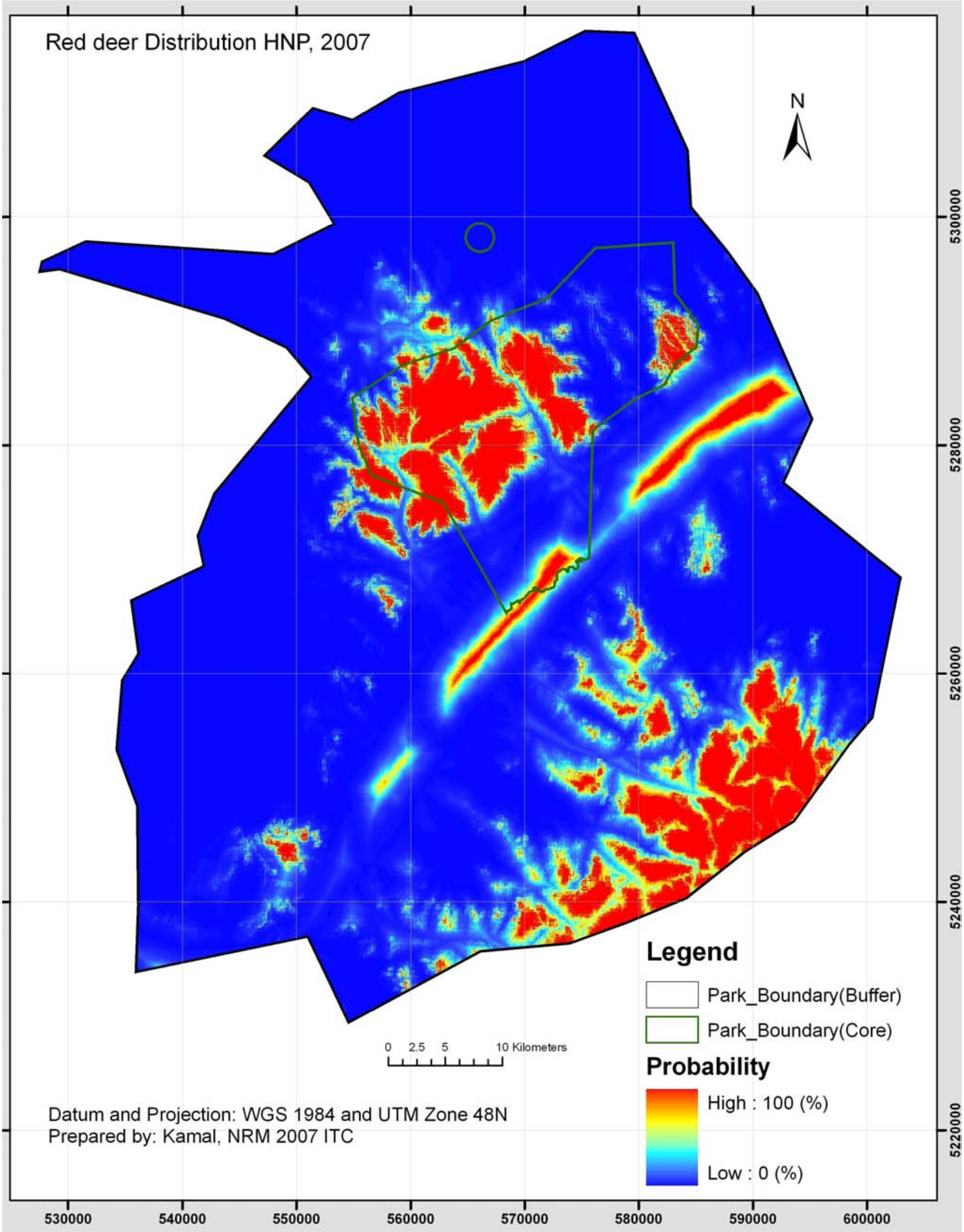


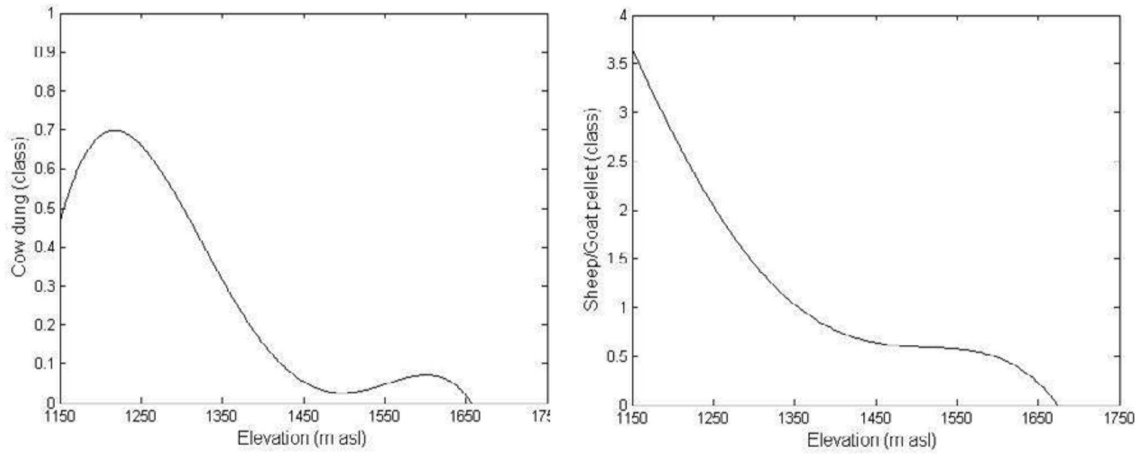
Figure 3-7. Predicted distribution for red deer in Hustai National park, 2007.

3.8. Variables related to elevation

The logistic regression model revealed elevation as the primary variable related to distribution of deer pellets. Elevation is an easy variable to include in biogeographical modelling but its significance does not necessarily mean that it causes the distribution. It could be that elevation explains distribution. In fact, some other variables related to elevation might be the true cause of observed distribution. For this reason, we further analysed the relation between elevation and number of variables that might effect the deer distribution.

3.8.1. Cow dung and sheep/goats pellet abundance

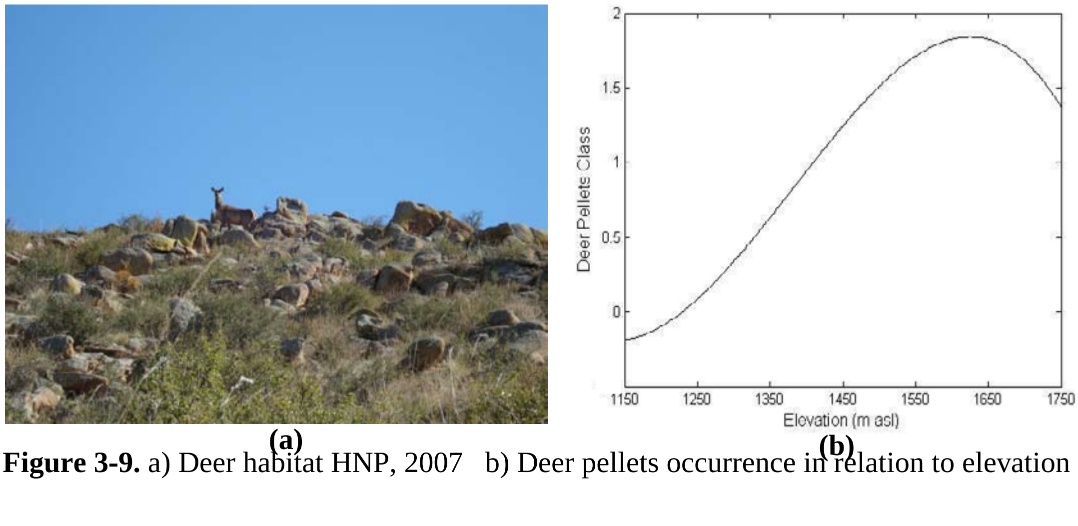
Figure 3-8 explore the relation of occurrences of sheep/goat pellets with increasing elevation. The best-fit curve (Figure 3-8-a) with R^2= 0.2038 suggest that the occurrence of cow dung is higher in lower elevation. This suggests that distributions of cows are in lower elevation i.e. in the buffer zone of HNP. Moreover, the curve (Figure 3-8-b) suggests similar results to that of cow dung occurrence. Sharp increment in the curve (from 1350 m to 1150 elevation) suggests that pellets of sheep/goats occurred in this range and is successful in predicting occurrence with R^2 = 0.5221. Therefore, we concluded that cow dung and sheep/goats pellets occurrence is less with increasing elevation.



(a) (b)

Figure 3-8. a) Cow dung occurrence b) Sheep/goats pellets occurrence with elevation

We also computed the distribution of deer pellets in relation to elevation. Elevation explained 45 % of the occurrence of deer pellets (refer 3-9-b).



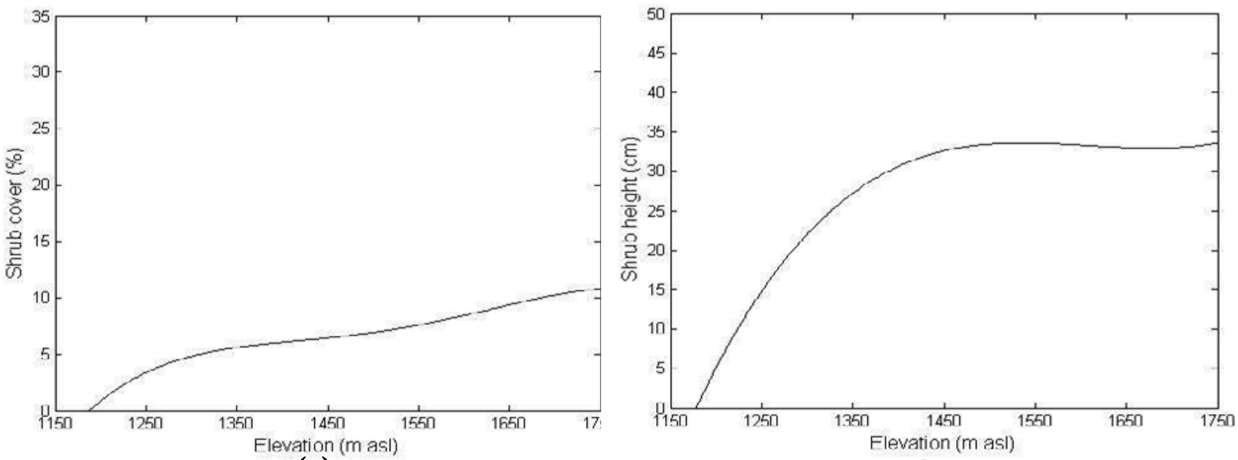
(a) (b)

Figure 3-9. a) Deer habitat HNP, 2007   b) Deer pellets occurrence in relation to elevation

Figure 3-9-b shows that the deer pellets are absence up to 1200 m elevation and occurrence rise higher with increasing elevation. This result is opposing to our result of sheep/goats and cow dung occurrence in Hustai.

3.8.2. Shrub cover and height

The distribution of animals is greatly effected by food availability. Deer distribution is also significantly effected by food availability (GISD, 2005). Thus, we collected the data on cover/height of herb, shrub and grass. There was no relation of grass and herb with elevation but we noticed some relation exists between the shrub height and cover with elevation. Figure 3-10 shows the relation of the shrub cover and shrub height with increasing elevation. Figure 3-10-a shows that the there is relation (R^2 =0.1326) with shrub cover. Shrub cover is increasing with elevation. In addition, we got similar result with the shrub height and a bit stronger relation (R^2 =0.25) for the shrub height. Therefore, there was decrease in the shrub height with decrease in the elevation. Thus, our result suggests that at higher elevation there is higher cover of shrubs and relatively higher heights of shrubs.



(a) (b)

Figure 3-10. a) Relation of shrub cover with elevation b) Relation of shrub height with elevation

We observed the vegetation cover percentage of the core zone and buffer zone (refer Figure 3-11). This suggests that the buffer zone is highly degraded as compared to the core zone. The mean of the cover is high (42%) in core zone and lower (30%) in the buffer zone. It supports the above finding that herb cover is more in higher elevation.

(a) (b)

Figure 3-11. a) Plot vegetation cover percentage b) Degraded area in buffer zone

3.8.3. Predictors (roads, forest and rocks)

We further observed the relation of the elevation with different environmental variables. Figure 3-12 shows relation between elevation and distance to roads, distance to forest, distance to gers and distance to rocks. We found that the distance to roads at lower elevation is less as compared to the higher elevation (R^2 =0.36). So, we consider fewer roads in the higher elevation than in lower elevation. Similarly, there is less forest area in the lower elevation. R-square is strongest (R^2 =0.66) for forest. We observed similar situation in field visit that the Hustai is dominated by birch forest and they are mostly located in the hillocks.

Also we further observed the relation of elevation with the distance to gers, and the result showed that the gers are located in the lower elevation. The fitted curve showed strong relation (R^2 =0.65). Our result suggests that the gers are located in the lower elevation i.e. that in the flat area of the Hustai. Rocks are also agent that are important because it provides shading during summer and shelters for the animals to hide themselves from predator (Deer Specialist Group, 1996; GISD, 2005; Hodgetts et al., 1998; Hovens and Tungalaktuja, 2005). This Study, suggests that the rocks are positively correlated (R^2 =0.54) with elevation. So, we can say that the there are less rocks in the lower elevation than compared to higher elevation.

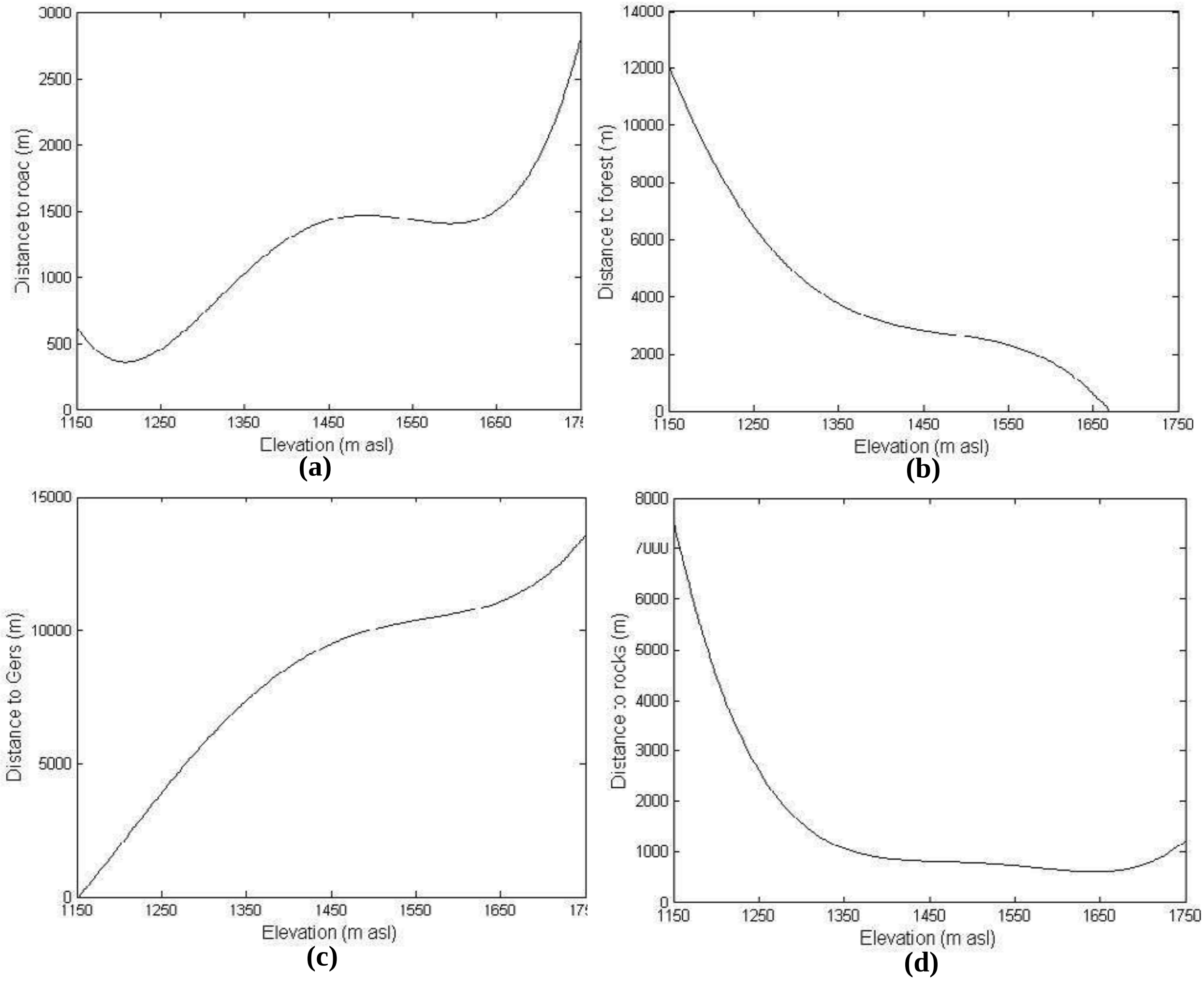


Figure 3-12 a) Relation of road with elevation b) Relation of forest distance with elevation c) Relation of gers distance with elevation d) relation of rocks distance with elevation

4. Discussions

4.1. Pellet identification

Our analysis revealed a significant difference in pellet length and width between red deer (width=10.5, length=18.1), sheep/goats (width=6.9, length=13.48) and Mongolian gazelle (width=6.9, length=8.9). Similar results are reported by Charles and Sanders (1963) for mouflon sheep (width=7.01 and length=10.48).

Identification of species based on the pellets is not always possible because of approximately similar colors, size and shapes of the different species pellets. Similar finding were made in previous studies that there is always possibility of uncertainty in identifying pellets of different species (Neff, 1968). For instance, deer pellets are similar to that of feral goats and sheep (Fraser et al., 2003). However, some studies considered the pellet identification important to validate the census results or the habitat association outcomes. Study done by Charles and Sanders (1963) shows pellets-count method based on the average short and long diameter measurement of black-buck antelope, mouflon sheep and white tailed deer pellets is a valid census method.

We compare the different pellets size of three species to find out whether it is possible to identify species from which the pellet originates. Our result suggests that it was possible to distinguish the pellets of red deer from those of sheep/goat and Mongolian gazelle due to the different pellet length. The pellets of later two were not distinguishable based on width. Moreover, the pellets of Mongolian gazelle occurred in clusters, while those of sheep and goats were dispersed. In conclusion, we had a little difficulty to distinguish the pellets of three species, and consider our results reflect their true distribution.

4.2. Distribution of red deer in HNP

The results show that deer pellet abundance (absent, few, moderate and many) differed between core and buffer zone. The park also refuge other deer species like roe deer which will not effect our result as the number are around 2-4 individuals and rarely observed (HNPT, 2006). The other species that resides the park are horses’ wolves, foxes, rabbits, wild boars etc. but they have different scats than that of the red deer.

Our result also demonstrated that deer pellets with class ’few’ (refer to appendix 7.6) occur in both the buffer and core zones i.e. some deer pellets are also found in the buffer zone. This indicates some occurrence of deer in the buffer zones. Study done by the Usukhjargal (2006) shows similar results that the red deer occurs only in the core zone (Khushuut, Artsat mountain, Shuvuun davaa mountain, Tsant and Sharilj mountain) of the national park. Game scouts and local people support these findings during the interviews.

Our results showed the lesser numbers of the deer pellets in the buffer zone. This may be possibly because there is large number of the livestock within and around national park, which affect negatively the red deer population (competition of available food resources). The natural threats in the park for red deer are the wolves (Hovens and Tungalaktuja, 2005; MNE Mongolia, 2002; Usukhjargal, 2006; WWF, 2006) . Both, red deer and wolves prefer same types of habitat where they can hide themselves from hunter and human disturbances (Hovens and Tungalaktuja, 2005). In addition, the human disturbance (e.g. livestock guarding dogs, hunting, antlers collection etc.) in the buffer zone could be the cause of less deer in the buffer zone. There is higher problem of overgrazing around the Hustai (Hovens and Tungalaktuja, 2005) and we also had similar observation during the field observation in 2007. Red deer are both the browser and grazers and their distribution is also affected by the availability of the vegetation (Patthey, 2003). Therefore, overgrazing that leads to a lesser amount of vegetation availability in buffer zone could be the other cause for the presence of few deer outside the core zone.

Our analysis revealed that the marmots burrow differed between the core and buffer zone. The presence percentage is lower in each of the classes (few, moderate and many) in the buffer zone. The Table 3-2 shows that the percentage of marmot presence is higher in the core zone as compared to the buffer zone. The body (weight) of marmots is small and they require high quality food in order to fulfil their requirement (Faupin, 2006) thus, as assumed core zone fulfils this requirement of high quality forbs and herbs. Figure 3-11 revealed that buffer zone is highly disturbed and highly degraded (also based on direct field observation). Furthermore, the effect of grazing and the disturbance causes less abundance of marmots burrows in the buffer zone.

The research also revealed that the burrows also causes degradation in dry part of the park due to the activities of marmots (observation in field) and also finding by Van Staalduinen and Werger (2007) suggests that disturbance by marmots (number around 25,000) decreases species richness in the area which is later colonized by *Artemisia adamsii*. The higher number of marmots in Hustai National Park creates the dynamic and patchy vegetation cover that finally leads to different vegetation patches (Staalduinen, 2005). Thus the above finding suggests that the marmot create bare land by borrowings.

The major problem in buffer zone of the park is the grazing and disturbance by humans (e.g. livestock guarding dogs, hunting, antlers collection etc.)(HNPT, 2006). During the field observation, we also noticed that there were no signs of marmot’s burrows in the highly disturbed part of the park. Hunting of marmots is major threat in Mongolia (Wingard and Zahler, 2006) and the Hustai is also highly disturbed area. Although the cases of the marmot hunting have not been reported in the park as such but we believe that there should be some disturbance to these species in the park, which makes them not occurring in the buffer zone.

4.3. Association between deer and livesock’s

Our analysis revealed that there is significant negative association between the dung pellets of sheep/goat and the pellets of red deer. The red deer are grazers and browsers (Deer Specialist Group, 1996; GISD, 2005; Palmer and Truscott, 2003; Virtanen et al., 2002; Vospernik, 2006). Sheep and goats are the critical components of production systems throughout the world and they can utilize the browse of numerous woody species to satisfy their needs for nutrients (Papachristou et al., 2005). Goats with their mobile and narrow muzzle can easily manoeuvres their mouths more easily among thorns to pluck small leaves which explain that goat are more effective in browsing than sheep

(Papachristou et al., 2005). We were not able to distinguish the pellets of sheep and goats. So, we assume that the goats are more causative towards competition with red deer because they can browse better than sheep. This also was supported by our field observation and interview with the local people that goats can easily browse over bushes and they reach the higher browsing height than sheep and cattle. Similar finding by Sanon, et al. (2007) suggest that mean height reached by goats when browsing was higher (1.65 m) than that of cattle (1.47 m) and sheep (0.87 m).

Buffer zone of Hustai is highly degraded due to overgrazing (refer Figure 3-11). This leads not only direct effect but the indirect effects including activities like disturbances and threats from the peoples. As explained by Sanon et al. (2007) sheep and goats shift their grazing habits due to the lack of the pastures to browsing, which leads to shift of their habitat from the grazed area to the less grazed area. We found that the deer are in the core zone of the park and sheep and goats made a shift in the feeding activities from grazing to browsing when the herbaceous biomass decreased (Sanon et al., 2007). Similar results were obtained by Yoshihara et al. (2007) that similarity found in food resources strongly suggests the possibility of competition between Mongolian gazelle and sheep and goats. Thus, we can suggest that sheep and goats compete with red deer in the national park and also disturbance due grazing like livestock guarding dogs, domestic horses etc. leads to negative association between them.

This study shows that there is significant negative association between the cow dung and pellets of red deer. Similar to the sheep and goats the cow is also part of livestock in the Mongolia. Like many part of the world, Mongolian land are used for livestock grazing and habitat of the wildlife ungulates including horses, cow, sheep/goats etc (Batsukh and Belokurov, 2005; Begzsuren et al., 2004; Faupin, 2006; Hovens and Tungalaktuja, 2005; MNE Mongolia, 2002; MNE Mongolia, 2004; Retzer, 2007; Wingard and Zahler, 2006; Yoshihara et al., 2007). As stated by Yoshihara et al. (2007) “Cows stay near gers or soums (villages) from evening through night to milk calves but leave them in morning to stay at better grasslands during daytime to feed on better forage plants”. This suggests that the cow remain near the gers, which are located in the Tuul valley. As the gers are in the buffer zone and we assume that cow graze in the buffer zone.

Sanon et al.(2007) found that the cattle browsed 10 species with different preference in different seasons and they remain near the gers. Here it’s important to state that the only food overlap does not mean competition (Putman, 1996). There could be competition for space and water. So, we can say that cows are in buffer zone but they are grazers and browsers and question can be raised, why the deer species having similar feeding behaviour are not in the buffer zone? Unlike cow the deer species are very shy animals (personal observation and interviews with local and park staff) in Mongolian steppe and they avoid humans (Patthey, 2003) and livestock like gazelles (Yoshihara et al., 2007). This supports our hypothesis that the cows are in the buffer zone and deer in the core zones but they share similar foodstuff so we can conclude that there exists negative association between red deer and cows.

The study revealed that there is significant association between the distribution of horse dung and pellets of red deer. The result was different than other cases of the sheep/goats or cows where there was a strong negative relation between them. This could be because we were not able to separate the dung of the domestic horses and the free roaming Takhi or the Przewalski horse (based on the field visit and consultation with park wildlife biologist). Unlike sheep/goats and cow, the horses are often more free ranging and they move widely (Yoshihara et al., 2007).

Another interesting finding is that the horses being grazers (Yoshihara et al., 2007), needs larger amount of the steppe grass than sheep/goats and cow (both graze and browses). This support our finding that they are distributed almost every part of the park from the highly degraded part to the core zone. There is different scenario in the park with harsh winter that horses are found at higher altitude during the summer then in spring or autumn in the core zone (King and Gurnell, 2005). Similarly the study by King and Gurnell (2005) suggest, that there is also diurnal trend in horse movement , in the morning they graze in the valley and as temperature increases during day they move towards the higher elevation to shade themselves under rocks, forest from direct solar radiation in autumn.

Hovens and Tungalaktuja (2005) suggests that the area around the park was overgrazed and at the end of the Mongolian winter lots of livestock mainly horses die from starvation. The study done in the past, regarding effect of herbivores grazing, suggest that there could be some competition with horses and deer for space or water in Hustai but none of the research has shown that there is competition for the forage (Faupin, 2006; Retzer, 2007; Usukhjargal, 2006). This also aids above finding as the relation is weak and distribution of horses is almost homogenous in the park.

Threats to the red deer in the Hustai are likely due to over-exploitation and competition with livestock for forage. Human disturbance includes hunting, and habitat disturbance. Hunting is done for collection of deer antlers, genitalia, and tails. During the field visit we found hunting is restricted inside the core zone. This suggests hunting is not restricted in the buffer zone. Buffer zone support activities like livestock grazing and human threats e.g. hunting, antlers collection etc. Also the park is not fenced and we might speculate there might be some threat of hunting inside the core area or we can presume that the red deer remain in the core because of hunter in the buffer zone.

4.4. Logistic model performance for red deer prediction

The logistic model for prediction of the species showed that the probability of the deer finding is highest with increasing altitude, nearer to the river, far away from road, and increasing slope angles. Our final model shows the distinct probability for predicting presence/absence with the entire coefficient being highly significant. The Nagelkerke R Square 0.75 is considered as good model prediction.

The interesting result was that the elevation alone (refer Table 3-9) has highest gain and was able to predict presence with the high Nagelkerke R^2 value of 0.65. We see that the predictor-elevation is statistically significant but ecologically unlikely because we know that the red deer also occurs in many part of the world at lower elevation (Achermann, 2000; Vospernik, 2006). The reason for red deer occurrence at higher elevation may thus have nothing to do with a direct impact of altitude but more likely with other variables such as disturbance and lack of grazing grounds. There is the disturbance due to grazing in the buffer zone of the park by sheep/goats and cow as we found negative association between them. Based on the result of logistic regression and the previous finding, the elevation is not a direct causative factor that determines the presence of the deer at the higher elevation.

In the previous research, red deer occurrence is also reported near to the forest area (Stankovski et al., 1998; Vospernik, 2006) and in Hustai the forest are in the higher elevation. However, this is not statistically significant because we do not found any gain for the predictor-forest in the regression analysis. Our finding and several studies also suggest that red deer prefer forest area for habitation but not necessarily because there are several cases of farmed red deer in the Europe in the range lands (Abeyesinghe and Goddard, 1998; Luccarini. S et al., 2006).

Our result revealed that the predictor-road has also higher gain next to the elevation as the chi square is higher and has lower p-value. Roads represent the hidden effects of human disturbance and we can infer that the human disturbance is considerably negative to the red deer population. Many past studies suggest that red deer always remain away from human beings (Borkowski and Ukalska, 2007; Patthey, 2003). Furthermore, because of hunting, red deer prefers area that ensures its hiding even when the natural enemies are absent (Borkowski and Ukalska, 2007). In Mongolia there is highest pressure of hunting (Bhandi and Wit, 2000; MNE Mongolia, 2004; WWF, 2006). As suggested by the Hovens and Tungalaktuja (2005) wolves were often poached in the HNP by local herdsmen (Hovens unpublished data) and there is red deer shooting by human in 2005 (Usukhjargal, 2006). There is no park boundary and many herders are around the park. Thus, we can also suspect poaching of the red deer in the park. So, road is a viable predictor because red deer try to remain away from the human, and illegal human activities mostly occurs near to roads because of the accessibility.

Equally, the predictor-river also has higher gain next to the elevation and roads as the chi square is higher and has lower p-value. Similar finding by (Patthey, 2003) suggests that the river are important for red deer where most of corridors are located. From our field observation and the consultation with the park biologist, we found that the red deer sighting is highest in the morning near the streams in the park. The wildlife mostly depends on the natural water surfaces like Rivers and streams. Thus in the summer season, the only sources of water are few remaining rivers and streams (based on the interviews with the park staff) but in winter the snow cover replaces the primary sources of water (Usukhjargal, 2006). This research is based on the data collected in the summer season and probably the winter season condition is not addressed by this research.

The research also revealed that a predictor ‘slope angle’, relates positively to occurrence of red deer. The previous finding that elevation is important for red deer could relate to this finding. As we observed that as we move higher elevation than there is steeper area with larger rocks. Red deer need shelter thus they also remain near the forest and near the rocks outcrops (MNE Mongolia, 2002). Also it support the above finding that the human disturbance (e.g. hunting, antlers collection etc.) is considerably negative to red deer and steep slope makes them hiding from the animals and predators like wolf (Hovens and Tungalaktuja, 2005). Threats to the red deer in the Hustai are likely due to poaching (deer antlers, genitalia, and tails) and habitat disturbance (competition with livestock for forage). The research outcomes are expected to be useful towards the park management.

5. Conclusions and recommendation

The distribution of red deer is distinctive in case of Hustai. The population of red deer is expanding but the area they reside at present is limited to core zone of the park. This study aims to address the question like, what is the distribution pattern to understand this process. Therefore, we studied the distribution of the red deer in Hustai National Park, Mongolia to achieve these objectives, firstly to examine potential of satellite imagery and ancillary environmental variables for modelling red deer distribution and secondly, to identify suitable area for red deer based on different vegetation attributes and ground based information. Following conclusions, presented sequentially, correspond to our research questions:

- Pellets of different species under study are distinguishable. ANOVA revealed that there was a significant difference between these three species in pellets length and pellets width. ANOVA does however not reveal which combination of species differed from each other but further post-hoc Bonferroni test indicated pellets diameter between sheep/goats and gazelle were not significantly different while pellet length of these there species differed significantly.

- There was strong association between distribution of red deer and marmots burrows with park management. Our result of chi-square revealed that there was a highly significant association between park management and the distribution of the deer pellets as well as marmots burrows.

- We observed significant negative association between the distribution of the deer and sheep/goats pellets abundance. The result of Chi Square test shows that there was a significant negative association between the distribution of the deer and sheep/goat pellets in core and buffer zone.

- Negative association between the deer pellets and cow dung abundance was observed in this study. The p-value is lower with the higher value of the chi square, so our result shows that there is strong negative association between the distributions of deer pellets and cow dung.

- There was a significant association between the distribution of the deer and horse dung but the relation is week. The result of cross tabulation and lower value of chi square suggest that there is significant but week association between horse dung and red deer pellet abundance.

- Logistic model shows highest probability of deer distribution with increasing elevation, higher slope, nearer to river and farther away from the roads. Elevation alone explains deer distribution similar to our final model.

- Elevation explains distribution, while some other variables related to elevation were the true cause of observed distribution. We found that cow dung and sheep/goats pellets occurrence is less with increasing elevation. Also we can see there was decrease in the shrub height and cover in the lower elevation. Similarly, we observed strong relation of elevation with distance to roads, distance to forest, distance to gers and distance to rocks. Elevation related factors confirmed that the human disturbance like hunting, antlers collection etc. and livestock grazing (e.g. livestock guarding dogs, direct competition for food and space) in the lower elevation is the causative factor-governing occurrence of red deer in the higher elevation.

Recommendation

We were able to predict distribution for red deer with the use of the logistic model and were able to find the causes of red deer occurrence in the core zone of the park. We recommend that the use of the high quality vegetation map (shrub, herbs, perennial and biannual grass, tree etc.) derived form the satellite imagery could be important in such study as animal distribution is related to vegetation availability.

Most of the study regarding the animal prediction and habitat selection analysis is based on the distribution data of both the winter and summer seasons. In our case, we use the summer distribution and we assume the model could be significantly improved by the use of the winter distribution data.

Further research should focus to know the distribution based of illegal hunting, which is not addressed in this research. The data on antlers collector’s during the mating season is also important in this regard as they are major threats to red deer.

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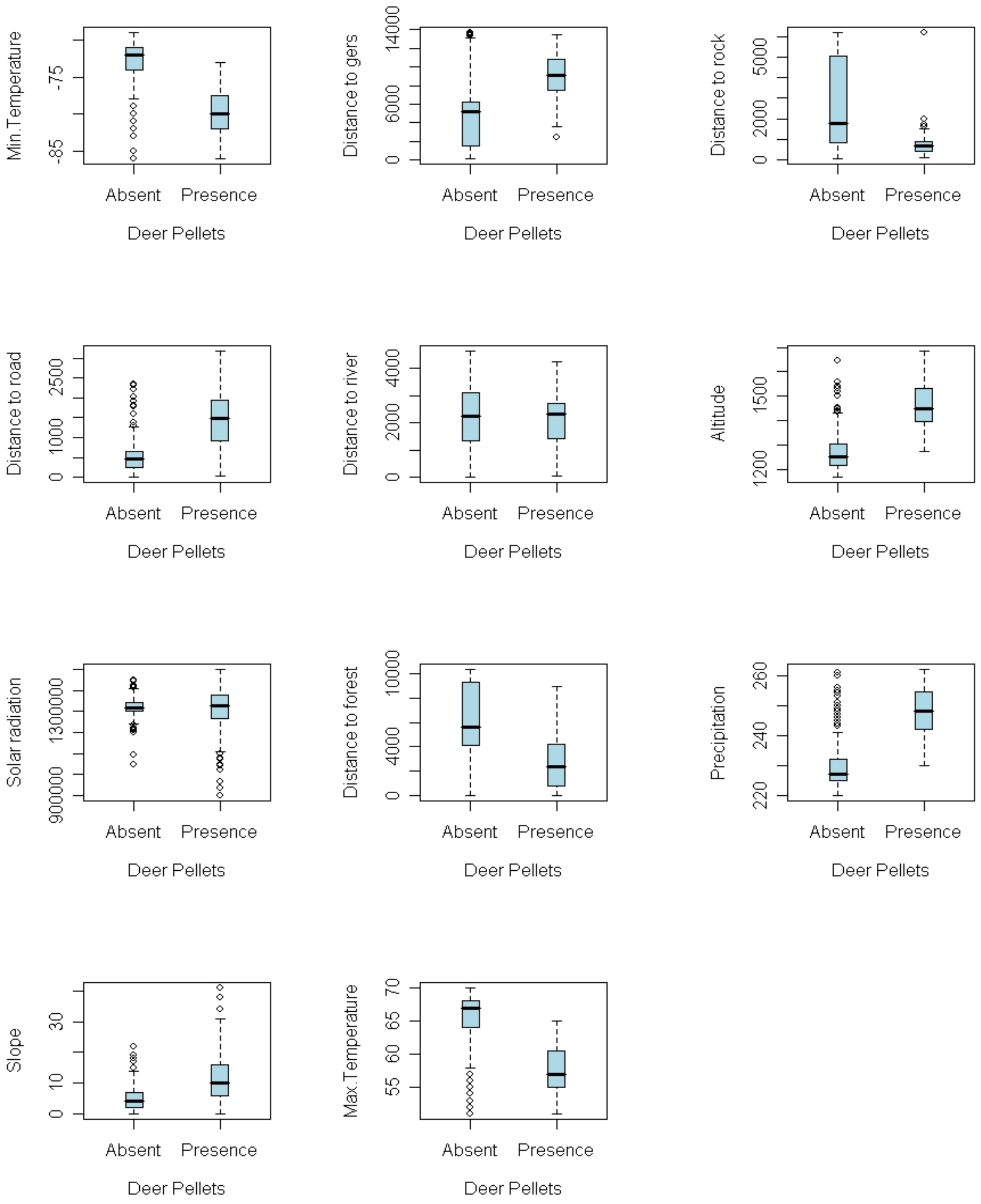
7. Appendices

7.1. Box plots of predictors and presence/absence of deer pellets



7.2. Summary of single predictors

Table: Summary of single predictors with conditional binary logistic model with 12 variables

		Coefficients	Std. Error.	Chi- Square	df	Sig.	ROC
RIVER		.000	.000	.287	1	.592	0.48
	Constant	-.247	.256	.935	1	.334	
ROAD		.003	.000	75.337	1	.000	0.89
	Constant	-2.957	.319	86.018	1	.000	
ROCK		-.001	.000	32.983	1	.000	0.19
	Constant	1.318	.253	27.141	1	.000	
NDVI		37.472	5.198	51.966	1	.000	0.77
	Constant	-7.745	1.034	56.126	1	.000	
SLOPE_AN		.180	.025	50.325	1	.000	0.76
	Constant	-1.750	.230	57.933	1	.000	
ELEVATIO		.020	.002	84.466	1	.000	0.92
	Constant	-28.156	3.038	85.916	1	.000	
SOLAR		.000	.000	1.476	1	.224	0.57
	Constant	1.660	1.674	.983	1	.321	
FOREST		-.001	.000	67.368	1	.000	0.15
	Constant	2.186	.318	47.297	1	.000	
GERS		.000	.000	58.628	1	.000	0.78
	Constant	-2.513	.321	61.431	1	.000	
ZONE(1)		21.211	5371.022	.000	1	.997	-
	Constant	-21.203	5371.022	.000	1	.997	
Vegetation Types	snw	19.175	17975.724	.000	1	.999	-
	fh	22.382	17975.724	.000	1	.999	
	lbf	42.406	21679.207	.000	1	.998	
	lsn	.000	20001.350	.000	1	1.000	
	nch	20.692	17975.724	.000	1	.999	
	Constant	-21.203	17975.724	.000	1	.999	
Soil Types	tmd	-3.387	.542	39.101	1	.000	-
	tds	-22.889	6201.910	.000	1	.997	
	smc	-.300	.561	.286	1	.593	
	mff	19.516	12118.637	.000	1	.999	
	Tmc Constant	1.686	.487	11.998	1	.001	

Codes for vegetation classes:

Lbf: Herb-grass stand on larch and larch-birch forest in combination with needlegrass-Filifolium-herb (20%) and fescue-herb (10%)

fh: Festuce-herb in combination with stony little soddygrass-herb (20%) and with shrubs

cl: Cropland

nch: Needlegrass-Cleistogenes-herb stand with Caragana microphylla and in combination needlegrass-festuce-herb on stony stand with participation of peashrub and almond

lsn: Low soddygrass-needlegrass-wormwood with participation of peashrub

snw: Stony needlegrass-wormwood-thyme with participation of peashrub and almond

Codes for soil classes:

mff: Mountain forest dark colored with mountain meadow-forest

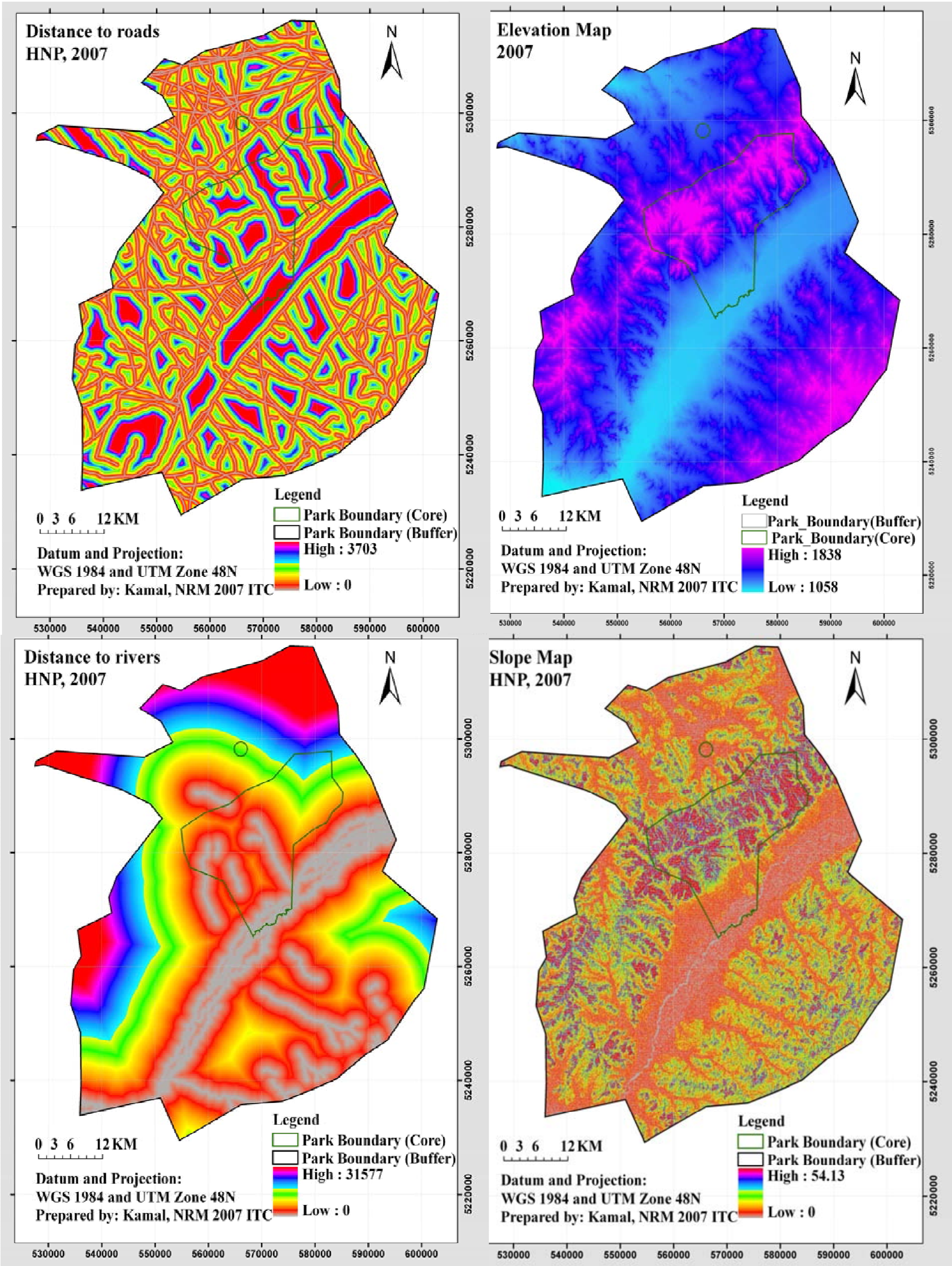
smc: Shallow mountain chernozem with shallow mountain dark chestnut

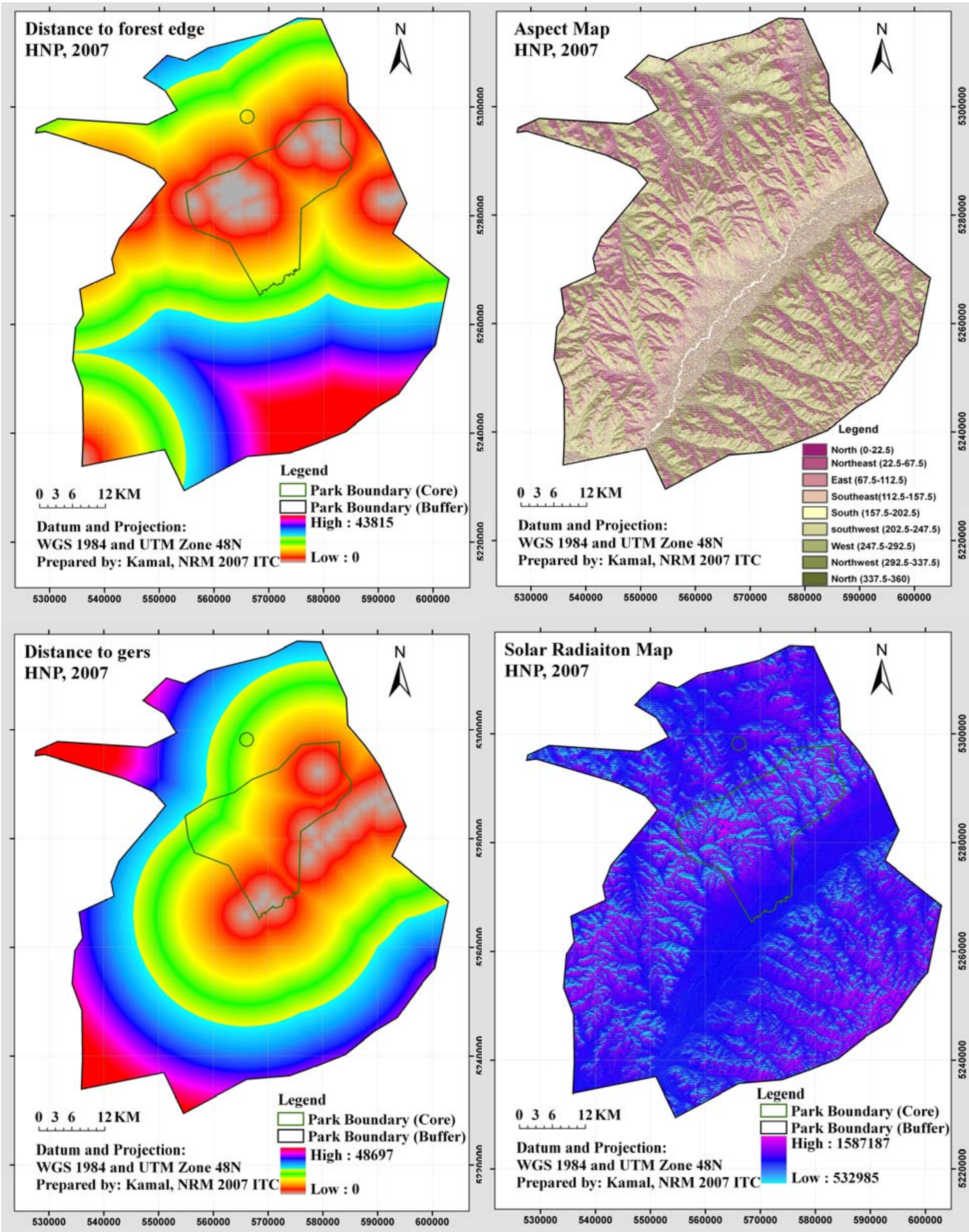
tds: Typical dark chestnut with stony dark chestnut

tmd: Typical mountain chernozem with typical mountain dark chestnut

tmc: Typical mountain dark chestnut with shallow mountain dark chestnut

7.3. Maps used for final model




Distance to forest edge
HNP, 2007
Legend
Park Boundary (Core)
Park Boundary (Buffer)
High : 43815
Low : 0
0 3 6 12 KM
Datum and Projection:
WGS 1984 and UTM Zone 48N
Prepared by: Kamal, NRM 2007 ITC
Aspect Map
HNP, 2007
Legend
North (0-22.5)
Northeast (22.5-67.5)
East (67.5-112.5)
Southeast(112.5-157.5)
South (157.5-202.5)
southwest (202.5-247.5)
West (247.5-292.5)
Northwest (292.5-337.5)
North (337.5-360)
Distance to gers
HNP, 2007
High : 48697
Low : 0
Solar Radiaiton Map
HNP, 2007
High : 1587187
Low : 532985

7.4. Field data sheet, Hustai, 2007

Form No:

Field data sheet for Red deer study in Hustai National Park Mongolia,									
Date: 0 /…./2007 mm/dd/yyyy	GPS	**X**							**Recorder's Name:** Kamal Thapaliya **Team Member's:**
		Y							

Sample plot No:					
Map Scale	Map No.	Plot Size	Elevation	Slope (%)	Aspect

	Height (cm)	**Cover (%)**
Herb		
Grass		
Shrubs		
Tree		
Bares		

	Absent	**Few**	**Moderate**	**Many**
Cow dung				
Horse dung				
Sheep Pellets				
Deer Pellets				
Gazelle pellets				
Marmots burrows				
Other Observation:				

7.5. Pairwise scatter plots of environmental variables

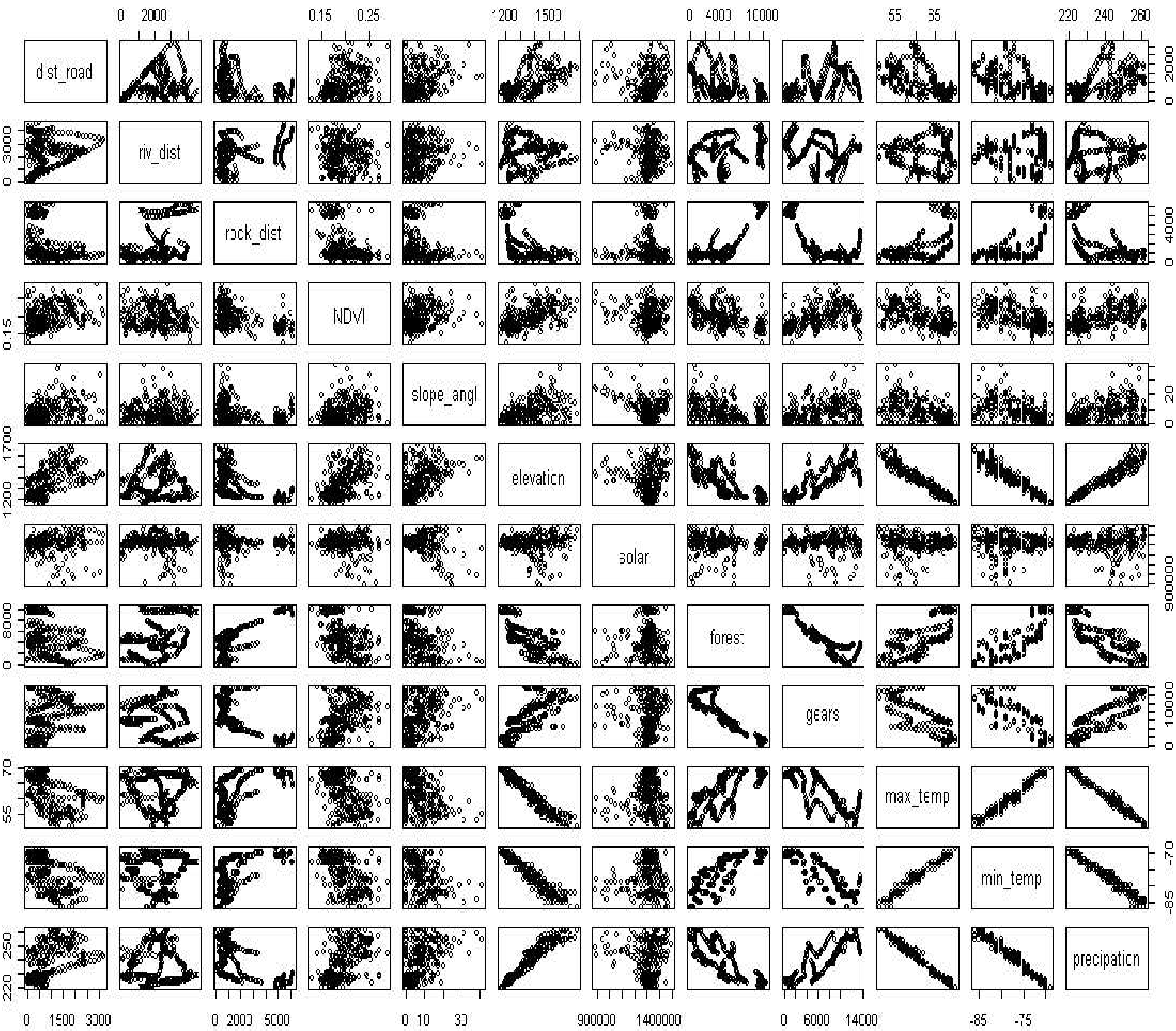


Figure: Pairwise scatter plots of environmental variables.

The variables are plotted in the sequence of **dist_road**:distance to roads, **riv_dist**: distance to river, **rock_dist**: distance to rocks, NDVI, **slop_angl**:slope, elevation: altitude, Solar:solar radiation, forest: distance to forest, gers: distance to gers, max_temp: maximum temperature, min_temp:minimum temperature, precipation:precipitation

7.6. Classification of dung and pellets groups

Species	**Unit**	**Absent**	**Few**	**Moderate**	**High**
Cattle	Dung piles	0	1-3	4-10	>10
Horses	Dung piles	0	1-5	6-20	>20
Sheep/goat	Pellets	0	<50	50-500	>500
Marmot	Holes	0	1-2	2-5	>5
Deer	Pellet groups	0	1-2	2-5	>5
Gazelle	Pellet groups	0	1-2	2-5	>5
	CODE	F	A	B	C

7.7. Results of Chi-square test, Post-hoc Bonferroni and AUC

Chi-Square Tests: Park management and distribution of deer pellets

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	94.074(a)	3	.000
Likelihood Ratio	115.621	3	.000
N of Valid Cases	301		

Count		Park Management		Total
		Buffer	Core	
DEER	Absent	111	67	178
	Few	9	60	69
	Moderate	0	28	28
	Many	0	26	26
Total		120	181	301

Chi-Square Tests: Park management and distribution of marmot's burrows

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	16.376(a)	3	.001
Likelihood Ratio	17.266	3	.001
N of Valid Cases	301		

Count		Management Zones		Total
		Buffer	Core	
Marmots	Absent	99	110	209
	Few	12	46	58
	Moderate	5	13	18
	Many	4	12	16
Total		120	181	301

Chi-Square Tests: Sheep/goat and the pellets of red deer

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	137.081(a)	9	.000
Likelihood Ratio	164.802	9	.000
N of Valid Cases	301		

a 2 cells (12.5%) have expected count less than 5. The minimum expected count is 4.58.

Count		SHEEP				Total
		Absent	Few	Moderate	Many	
DEER	Absent	14	44	46	74	178
	Few	37	24	7	1	69
	Moderate	17	11	0	0	28
	Many	19	6	0	1	26
Total		87	85	76	53	301

Chi-Square Tests: Cow dung and pellets of red deer

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	79.066(a)	9	.000
Likelihood Ratio	99.649	9	.000
N of Valid Cases	301		

a 7 cells (43.8%) have expected count less than 5. The minimum expected count is .35.

Count		COW				Total
		Absent	Few	Moderate	Many	
DEER	Absent	88	77	9	4	178
	Few	67	2	0	0	69
	Moderate	27	1	0	0	28
	Many	26	0	0	0	26
Total		208	80	4	9	301

Chi-Square Tests: Horse dung and pellets of red deer

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	18.430(a)	9	.030
Likelihood Ratio	24.040	9	.004
N of Valid Cases	301		

a 4 cells (25.0%) have expected count less than 5. The minimum expected count is 2.76.

Count		HORSE				Total
		Absent	Few	Moderate	Many	
DEER	Absent	24	98	33	23	178
	Few	4	38	19	8	69
	Moderate	0	16	11	1	28
	Many	4	18	4	0	26
Total		32	170	32	67	301

Multiple Comparisons

Dependent Variable*: Pellets Diameter*
Post-hoc Bonferroni

(I) Animals	(J) Animals	Mean Difference (I-J)	Std. Error	Sig.
Red Deer	Gazelle	3.70(*)	.231	.000
	Sheep/Goats	3.70(*)	.231	.000
Gazelle	Red Deer	-3.70(*)	.231	.000
	Sheep/Goats	.00	.231	1.000
Sheep/Goats	Red Deer	-3.70(*)	.231	.000
	Gazelle	.00	.231	1.000

* The mean difference is significant at the .05 level.

Dependent Variable: *Pellets Length*
Post-hoc Bonferroni

(I) Animals	(J) Animals	Mean Difference (I-J)	Std. Error	Sig.
Red Deer	Gazelle	8.60(*)	.333	.000
	Sheep/Goats	4.95(*)	.333	.000
Gazelle	Red Deer	-8.60(*)	.333	.000
	Sheep/Goats	-3.65(*)	.333	.000
Sheep/Goats	Red Deer	-4.95(*)	.333	.000
	Gazelle	3.65(*)	.333	.000

* The mean difference is significant at the .05 level.

Area under the Curve

Test Result Variable(s): Elevation (First Model)

Area	Std. Error(a)	Asymptotic Sig.(b)	Asymptotic 95% Confidence Interval	
			Lower Bound	Upper Bound
.929	.015	.000	.901	.958

a Under the nonparametric assumption
b Null hypothesis: true area = 0.5

Area under the Curve

Test Result Variable(s): Predicted probability (Final Model)

Area	Std. Error(a)	Asymptotic Sig.(b)	Asymptotic 95% Confidence Interval	
			Lower Bound	Upper Bound
.956	.011	.000	.935	.977

a Under the nonparametric assumption
b Null hypothesis: true area = 0.5

7.8. Interview form

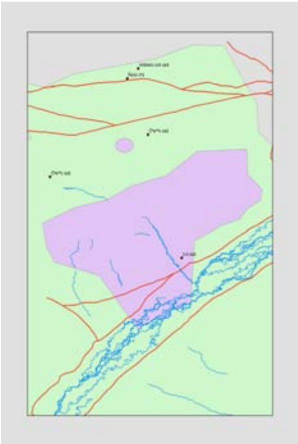
I am the student of the ITC; Netherlands doing the research entitled "**Study of Red Deer in Hustai National Park Mongolia**". Please help in filling the form.

Name:____________ Date:______________

Have you ever Sighted (Seen) Red Deer in HNP?

Yes __ if yes Where?_______________________________________ No__

Which do you think is the Most potential site for Red deer in HNP?



What do you think about the Population of Red in HNP?

Increasing	
Decreasing	
Same as before	
No idea	

What do you think about the Number of Red in HNP?

Below 300	
300-400	
400-500	
Above 500	
others	

Have you seen/found dead red deer inside or outside the park?

Yes___ if yes Where? ______________ No___

What type of habitat the Red deer preferred in HNP?

Tall grassland	
Short grassland	
Burned grassland	
Grassland with trees	
Dense Forest	

Are there the threats of wildlife to Red Deer?

Yes___if yes which animal? ______________ No___

Thanks for your great help Kamal Thapaliya,2007

7.9. Observation points

Observation	X	Y	Observation	X	Y
1	575803	5266353	**26**	569579	5277561
2	576660	5262230	**27**	567428	5287331
3	574029	5265215	**28**	572009	5281042
4	572813	5263798	**29**	572665	5283607
5	575698	5263188	**30**	576304	5297140
6	578126	5277855	**31**	580347	5291308
7	573139	5272201	**32**	576417	5290231
8	576248	5273828	**33**	577092	5299131
9	572846	5272278	**34**	574421	5290898
10	566478	5266663	**35**	580135	5297486
11	572938	5267919	**36**	573834	5290716
12	570344	5264611	**37**	573553	5288429
13	574515	5266865	**38**	569712	5281369
14	569487	5271209	**39**	580139	5290132
15	574852	5274855	**40**	579434	5294006
16	577116	5277406	**41**	570616	5298521
17	575276	5276914	**42**	569229	5292525
18	577423	5277069	**43**	564880	5294643
19	576391	5276029	**44**	568731	5297707
20	580332	5281033	**45**	566930	5289262
21	571479	5282742	**46**	570788	5290509
22	570262	5283916	**47**	574965	5297723
23	563862	5274602	**48**	570554	5296772
24	564846	5273739	**49**	568211	5289710
25	565165	5279050	**50**	570412	5296734

7.10. Results of ANOVA

DIAMETER

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	182.533	2	91.267	170.844	.000
Within Groups	30.450	57	.534		
Total	212.983	59			

LENGTH

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	745.233	2	372.617	336.595	.000
Within Groups	63.100	57	1.107		
Total	808.333	59			