MODELLING THE SEASONAL DISTRIBUTION OF WILD BACTRIAN CAMELS IN RELATION TO CHANGES OF THE ENVIRONMENTAL CONDITIONS

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DISCLAIMER

ABSTRACT

Wild Bactrian camel (*Camelus bactrianus ferus*) is a critically endangered large ungulate species. Only three distinct populations remained in the world are in Taklimakan Desert, the desert around Lop Nuur in China and the Great Gobi Strictly Protected Area (GGSPA) of Mongolia. Population size in Mongolia is approximately 500 and distribution range has been shrinking. Application of GIS and remote sensing has not been used to study the distribution. The main objective was to identify the environmental factors influencing the distribution and to predict the seasonal distribution in the study area. Distribution was predicted by MaxEnt modelling approach using presence only data with integrating the selected environmental predictors. Land surface temperature, NDVI, water sources, vegetation and soil types were used as main predictors in the modelling. Data set was separated into four seasons (spring, summer, autumn, winter) and model outputs were compared.

Both results of *t*-test ($p<0.0001$) and model prediction revealed that land surface temperature in summer has a significant influence on camel that preferring cooler areas avoiding hot temperatures of surrounding environment. Abundance of biomass did not affect the camel distribution strongly. Camel preference to intermediate level of NDVI in most seasons can imply that food intake is based on forage quantity but not quality. Positive relationship of camel probability to higher NDVI in summer suggests that they prefer to herbaceous species which appear after rainfall. Model predicts that distance to the water sources is critical for camel distribution in all seasons and high probability of camel occurrence was predicted near water sources. Shallow mountain soils were predicted as desired soil types for distribution in summer. Spatial co-existence of herbaceous plants, mountain soils and areas of lower temperature are the favourable conditions in camel distribution during summer. No particular habitat preference was predicted in other seasons.

Distribution ranges were differed in all seasons. There is a common distribution range predicted in spring, summer and autumn which can be considered as core distribution areas of annual range. Distribution of winter range is differed from other seasons. Predicted distribution range from the MaxEnt modelling occupies the camel range described by other researchers can justify that there is a consistency between survey data and satellite tracking data to model the species distribution.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

1.1. Background information

1.1.1. Historic range and population status

Wild Bactrian camel (*Camelus bactrianus ferus*) is a critically endangered large ungulate species of desert ecosystems of Central Asia. Compared to the existence of domestic Bactrian camels (*Camelus bactrianus*) widely occurred through the Central Asia with large numbers, their wild ancestor species (*C. b. ferus*) was not discovered to the science until Prejevalsky (1879) visited Lop Nur region of China in late 1870s. Latter in 1900s, the joint Russian-Mongolian expeditions, detailed studies concerning the camel biology, distribution and range took place in Mongolia's Gobi Desert (Bannikov, 1945, 1976; Zhirnov & Ilyinsky, 1986). Its distribution range has been severely reduced. The 3 main remnant populations are the Taklimakan Desert, the desert around Lop Nuur in China and the Great Gobi Strictly Protected Area (GGSPA) of Mongolia (Tulgat & Schaller, 1992). The population is vulnerable due to its small population size.

The population in Mongolia falls completely in the "A" section of GGSPA. The population of the Bactrian camel in Mongolia declined over decades from 400-900 in the 1970's (Bannikov, 1976), 480-800 in the 1980's, (Tulgat & Schaller, 1992), 300-500 in early the 1990's (Hare, 1997). However, an aerial population survey in 1997 estimated some 1985 camels (Reading, Mix, Lhagvasuren, & Blumer, 1999). The higher population estimate of the last survey could be the result of different method from the previous ground surveys. The latter were not systematic and based on extrapolations. None of these surveys detected camels outside the GGSPA.

The reduction of distribution range and habitat fragmentation was the result of the pressures of human activities and lack of conservation management. Mineral exploitation and limited financial capacity leads to poor conservation measure (Reading et al., 1999). The main threats to the Bactrian camel are hybridization and disease transmission from domestic camels, disturbance by mineral extraction, decline of oasis and predation by wolves (Clark et al., 2006).

1.1.2. Current range and distribution in Mongolia

Researchers have identified the distribution where wild camels concentrated during calving, rutting, wintering and autumn periods (McCarthy, 2000; Tulgat & Schaller, 1992) (See Appendix 4 & 5) while Reading et al (1999) determined the range reduction and mapped the core areas of distribution in the Great Gobi Strictly Protected Area. Distribution patterns were deducted from the occurrences of camels from the seasonal surveys in summer, autumn, rutting and calving periods of the year. Conservation status is well managed in Mongolia and registered as a critically endangered species (Clark et al., 2006).

Within the large range of their distribution, wild camels move for long distances in search of suitable conditions in the harsh environments. In summer, wild camels migrate to areas where plant growth begins shortly after scarce rainfall in the foothills of the mountains (Bannikov, 1976). Movements of wild camels are strongly related to a few water sources which are consisted of springs and oases in the protected area, and concentration around water sources may facilitate the predation by wolves (Tulgat & Schaller, 1992). Yet, the migratory movement of camel has not been studied by integrating the environmental conditions with modelling approach.

1.1.3. Species distribution modelling

One of the most important biological phenomena of wild animals is long distance movement. It can be described as moving away from the habitat where the critical resources become limited and seek another habitat with available resource. To study the animal movement and home range patterns, researchers have applied different statistical models such as correlated random walk (Bovet & Benhamou, 1988), persistent random walk (Wu, Li, Springer, & Neill, 2000) and state-space models (Jonsen, Flemming, & Myers, 2005; Patterson, Thomas, Wilcox, Ovaskainen, & Matthiopoulos, 2008). It is suggested that a more powerful and flexible approach is state-space modelling, and it enables to deal with the complexity of modelling animals interacting with their environment(Jonsen, Myers, & Flemming, 2003).

In order to understand the animal movement and distribution, it is important to know in what environmental conditions they survive. Not considering the ecological understandings of the species leads to the limitations in the statistical modelling to predict the distribution (Austin, 2002). Extracting the environmental factors from the satellite images is widely used for predicting the species occurrences in particular area. The use of ancillary data such as climate, terrain, soil, vegetation and access to water have been extensively used in GIS and remote sensing to predict the various species habitat and distribution (Leyequien et al., 2007). Species distribution modelling is achieved by statistical analysis. It is suggested that the combination of ecological knowledge and statistical methods are needed for current models to be evaluated (Austin, 2007).

Logistic regression is a frequently used method for modelling species distributions (Guisan & Zimmermann, 2000) and advanced model development in regression analysis provided by generalized linear models (GLM) and generalized additive models (GAMs) (Guisan, Edwards Jr, & Hastie, 2002). Models using presence/absence data mostly use multiple regression approaches with generalized techniques (GLM, GAM) (Guisan et al., 2002) and classification tree (Miller & Franklin, 2002). Three main components are described for the modelling of species distributions: an ecological model concerning the ecological theory being used, a data model concerning collection of the data, and a statistical model concerning statistical theory (Austin, 2002).

An alternative approach for species distribution modelling is using presence only data. These modelling techniques include MaxEnt and GARP (Phillips, Anderson, & Schapire, 2006; Phillips, Dudik, & Schapire, 2004), BIOCLIM (Nix, 1986) and DOMAIN (Carpenter, Gillison, & Winter, 1993). Maxent is a statistical model, and we must consider its relationship to the other two modelling components (the data model and the ecological model) described by Austin (2002) to apply it to species distribution modelling successfully (Phillips et al., 2006). The presence only modelling techniques of MaxEnt, GARP, BIOCLIM and DOMAIN were tested and concluded that MaxEnt produced the most accurate prediction than the other models and multiple evaluation measures are necessary to determine the accuracy of models (Hernandez, Graham, Master, & Albert, 2006).

1.2. Problem statement

Study of wild Bactrian camel distribution has not been assessed by integrating physical and biological environmental factors. This thesis focuses on the movement of wild Bactrian camel based on the concept described in Berger (2004) that larger the body size, the greater the distribution range of species. Species distribution modelling approach is used by investigating the changes in the environmental conditions such as land surface temperature, vegetation productivity and water sources for studying the distribution and movement.

Due to the climate of the study area that encompasses the extreme ranges of temperature and less availability of water source, wild camels adapted to have a unique body thermostat that raise their body temperature level as much as 7°C , thereby avoiding unnecessary water loss in the extreme hot conditions. Their body temperature ranges from 34 °C at night and up to 41 °C during the day, and only above this threshold they begin to sweat (Schmidt-Nielsen, Schmidt-Nielsen, Jarnum, & Houpt, 1956). Based on this

physiological feature of maintaining body temperature, this research is questioning that whether there is a spatial relationship between the camel occurrence and the land surface temperature deviations.
The Gobi Desert is characterized by semi-arid desert ecosystem. Vegetation of camel habitat is characterized by the saxaul shrub (*Haloxylon ammodendron*) that serves a staple for the camel in the absence of herbage (Mengli, Willms, Guodong, & Ye, 2006). Forage availability was identified through the different seasons, but it was not integrated with camel distribution. Vegetation types in the Gobi Desert mainly consist of shrubs and scarce distribution of perennial herbs and annual forbs communities. Therefore, the wild camel's preference of habitat vegetation types can be determined.
There are about 30 permanent springs in the study area, some of them oases with tall grasses (Tulgat & Schaller, 1992). Only at the oases, the wild camels gather in larger groups for some time and sometimes in the mountain valleys avoiding from the winds of winter (Bannikov, 1976). Grazers and browsers show different distribution patterns in relation to distance to the waterholes and springs during dry season (Smit, Grant, & Devereux, 2007). The general scarcity of precipitation and extreme alterations of temperature leading to scarcity of vegetation cover may influence the wild camel distribution highly related to the water sources.

1.3. Research objectives

The overall objective is to identify what environmental factors influence the distribution of wild Bactrian camels through the different seasons. The objectives are specified as:

1. To investigate whether the extreme hot desert temperature influences the camel distribution.
2. To investigate whether there is a preference of camel to the biomass abundance and specific vegetation types.
3. To determine the distribution in relation to distance to the water sources
4. To predict the seasonal distribution over the study area.
5. To examine the difference in the model outputs of species/environment relationship based on species data quality and quantity.

1.4. Research questions

The following research questions were formulated in order to achieve the objectives of the thesis.

1. Is the distribution related with low temperature during the hottest months in order to reduce body water loss?
2. Is the distribution related to high biomass abundance through the different seasons in order to attain forage requirements?
3. Is there a forage preference to herbaceous plants to increase water intake?
4. Is there a frequent distribution near the water sources?
5. What is the seasonal distribution of wild Bactrian camel?
6. Do the species input data quality and quantity affect the prediction of response curves?

1.5. Research hypothesis

H_0: Monthly mean land surface temperature at camel locations is significantly less than the mean land surface temperature at surrounding environment
H_1: There is no significant difference between monthly mean land surface temperature at camel locations and mean land surface temperature at surrounding environment

H_0: Monthly mean NDVI at camel locations is significantly higher than monthly mean NDVI at surrounding environments.
H_1: There is no significant difference between monthly NDVI at camel locations and monthly mean NDVI at surrounding environments.

H_0: There is no significant relationship in the preference of herbaceous species than the shrub species in the forage.
H_1: There is a significant relationship in the preference of herbaceous species than the shrub species in the forage.

H_0: There is no difference in the probability of camel presence to the distance to the water points.
H_1: There is no difference in the probability of camel presence to the distance to the water points.

2. MATERIALS AND METHODS

2.1. Study area

The study area covers the section "A" of the Great Gobi Strictly Protected Area (GGSPA) in the Gobi desert of Mongolia situated between 95º15' - 99º40' E and 42º31' – 44º41' N. Established in 1976 by the Government of Mongolia, the protected area is a home to wild Bactrian camel encompassing 44,190 km² area. United Nations designated GGSPA in 1991 as a World Biosphere Reserve which is the fourth largest in the world. Several other large mammal species including snow leopard (*Uncia uncia*), argali (*Ovis ammon*), ibex (*Capra sibirica*) goithred gazelle (*Gazella subgutturosa*), wild ass (*Equis hemionus*) and the endemic Gobi brown bear (*Ursus arctos)* inhabit in the area.

The landscape of the Great Gobi Strictly Protected Area is characterized by semi-arid desert ecosystem. Climate is harsh with the temperatures ranging from (-35ºC) in winter to (+40ºC) in summer. Average monthly precipitation is below 50 mm in summer and below 10 mm in winter. The region is consisted of highland rolling hills broken by massifs with the average altitude of 1300 m a.s.l. Landscape is characterized by dry stream beds and rocky outcrops with scarce vegetation cover dominated by desert shrubs (Bannikov, 1976). Permanent vegetation cover composed of saxaul (*Haloxylon ammodendron*), anabasis (*Anabasis brevifolia*), ephedra (*Ephedra przewalskii*), salsola (*Salsola arbuscula*) and reaumaria (*Reaumuria songarica*). Annuals and perennials become dominantly available in late summer and autumn after the rainfall.

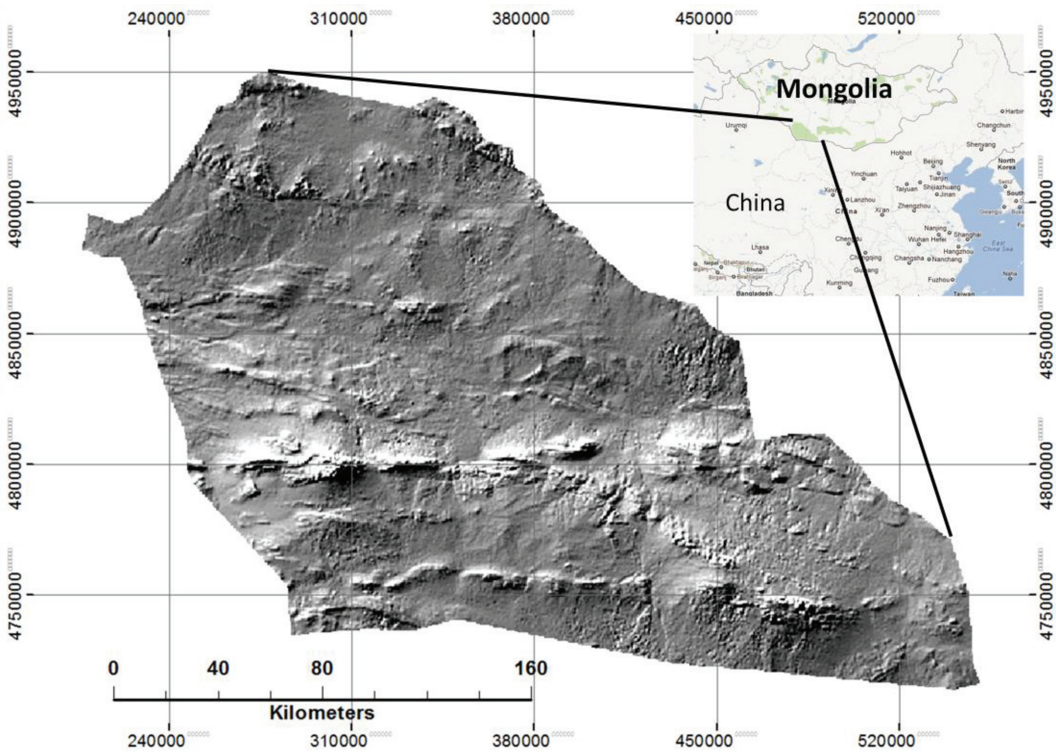

Figure 1: Study area: Great Gobi "A" Strictly Protected Area, Mongolia

2.2. Methods

2.2.1. Species data

First dataset includes wild camel presence points obtained from 7 collared individuals and data acquisition periods were during Oct 2002 - March 2004 and May 2007 – Sep 2008. The individuals were fitted with GPS-Argos collars. The data transmission procedure and collar specifications are described in Kaczensky et al (2010). 6 collars have the location accuracy of ± 150 meters and remaining one collar locations were obtained by the Doppler shift method by Argos satellite systems (Kaczensky et al., 2010). The positional errors of this collar are in 3 categories: (1) ± 150 m, (2) ± 350 m and (3) ± 1000 m. The data description of 7 tracked animals including age, sex and collar location accuracy are shown in Table 1.

Table 1: Data description of wild camel GPS locations

Collar ID	Sex	Age	Precision of error (m)	# of points
1	Female	Adult	1: ±150 2: ±350 3: ±1000	1103
2	Male	Bull	± 150	20
25778	Female	11-12 (Pregnant)	± 150	687
25805	Male	Young	± 150	13
25915	Female	Young	± 150	194
70348	Male	9-10	± 150	81
70350	Male	Young	± 150	1258
Total				**3356**

The occurrence data was used as a response variable for species distribution modelling. A total number of 3356 wild camel locations were distributed through 35 months in 2002, 2003, 2004, 2007 and 2008 (Table 2). In order to assess the distribution on a seasonal base, data was pooled into 12 months periods (from January to December).

Table 2: Distribution of wild camel GPS locations (n=3356) from January to December

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2002										7	101	109
2003	108	94	103	95	109	105	74	68	70	64	2	4
2004	5	1	4									
2007					51	181	179	173	173	165	161	181
2008	200	190	203	147	149	27	28	12	13			
Total	**313**	**285**	**310**	**242**	**309**	**313**	**281**	**253**	**256**	**236**	**264**	**294**

Second dataset includes a total of 764 presence only points obtained from surveys of camel sightings, fecal and foot track records combined with incomplete GPS tracking locations. Time periods cover March – June, August – January in 2007 and 2008 in which presence points are representative of all seasons. These 2 datasets were used in the modelling as a different input species data and compared for the model outputs.

2.2.2. Environmental predictors

2.2.2.1. Selection of environmental predictors

Selection of the predictor variables was based on the knowledge of habitat conditions that are believed to influence the distribution of wild Bactrian camels. Due to the harsh continental climate of cold winters (to -30º C) and hot summers (to +40º C), the land surface temperature (LST) may constitute as an important predictor. The relatively scarce annual rainfall of less than 100 mm leads to poor vegetation cover and only a few dozens of springs and oasis are very crucial to their water requirement. Therefore, the location of the water sources is an important predictor variable for the modelling. Saxaul (*Haloxylon ammodendron*) dominated shrubs are the main ingredients in their food (Bannikov, 1976) but they prefer herbaceous species when they are available shortly after summer rainfall (Mengli et al., 2006). Based on this concept, vegetation variables were used in this analysis. Main environmental variables are listed in Table 3.

Table 3: Environmental variables used in the species distribution modelling

	Variables	Unit	Data type	Source
1	Land Surface Temperature	Celsius degree	Continuous	MODIS/Aqua/1km/8Days/Version005
2	NDVI	Scaled to (-1 : 1)	Continuous	SPOT-Vegetation 10-day composite
3	Distance to water points	Meters	Continuous	Feature point layer from survey data
4	Distance to drainage lines	Meters	Continuous	DEM 30 meters (Flow accumulation analysis)
5	Vegetation classes		Categorical	Mongolia's National Scale Classified Map (1: 1000 000)
6	Soil types		Categorical	Mongolia's National Scale Classified Map (1: 1000 000)

2.2.2.2. Climate variable

To investigate how wild camels respond to hot temperature environment, monthly mean land surface temperature (LST) layers were extracted from MODIS Aqua (1 km, Version 5) satellite imagery dataset which were provided on online web source "IRI/LDEO Climate Data Library". Total of 35 monthly mean LST images from 2002 (Oct - Dec), 2003 (Jan - Dec), 2004 (Jan - Mar), 2007 (May - Dec) and 2008 (Jan - Sep) were used in the analysis. LST data are pooled into 12 months of a year. A total of 3279 monthly mean LST values were extracted including Jan (243), Feb (278), Mar (310), Apr (242), May (309), June (313), Jul (281), August (253), September (256), October (236), November (264) and Dec (294) using camel presence points. Min/max LST of study area and observed LST for camel locations are shown in Figure 2 from January to February. Monthly LST images were averaged into 4 seasons (Appendix 3).

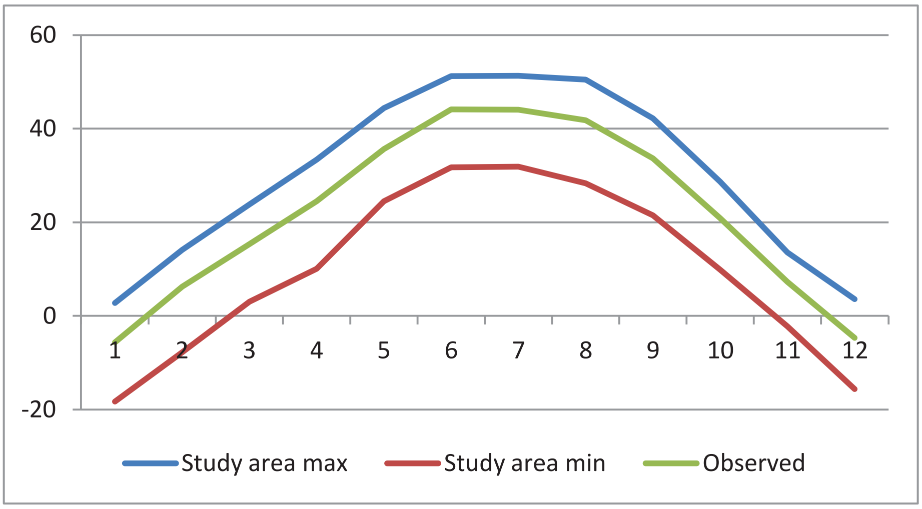

Figure 2: Observed LST range at camel locations. Vertical axis: temperature in Celsius scale, Horizontal axis: months

Separate set of LST values were extracted to test the difference between the observed LST at camel locations against the mean LST value calculated for surrounding environments. To calculate the mean LST for surrounding environment, a circle area with the radius of 25 km was created at each camel location (n=3279) and mean LST was calculated for each circle area. The reason for choosing a distance of 25 km was based on the result of spatial autocorrelation test for the LST at camel locations (Figure 3). The correlogram shows an approximate distance of 25 km, at which the correlation coefficient between the observed LST values approaches zero. A paired two sample T-test was used to test the significance between mean LST at camel locations and mean LST for surrounding buffer area.

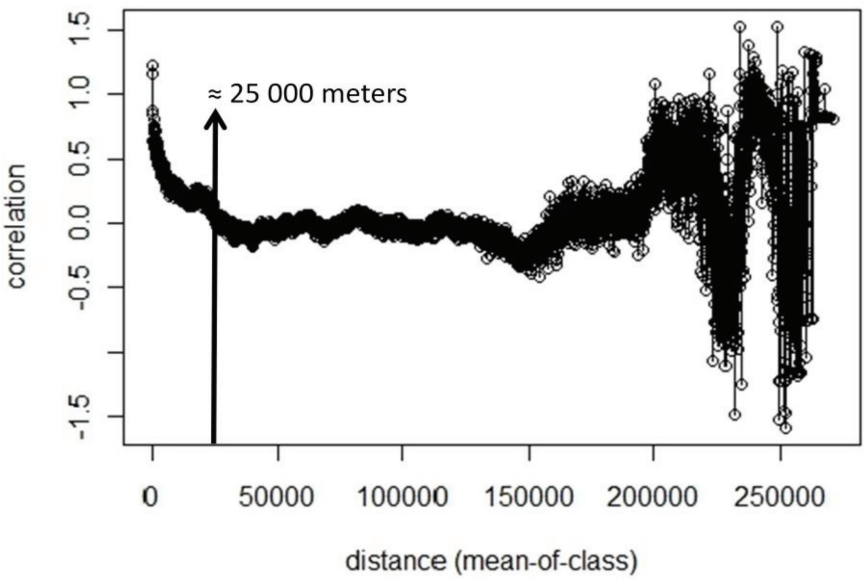

Figure 3: Correlogram showing the distance range of 25 km at which the correlation coefficient (r) between the LST values approaches zero.

2.2.2.3. Vegetation related variables

Monthly NDVI layers were extracted from 10 days composite SPOT-NDVI imagery set with the resolution of 1 km. Total of 35 monthly NDVI images extracted for Oct – Dec of 2002, Jan – Dec of 2003, Jan – Mar of 2004, May – Dec of 2007 and Jan – Sep of 2008. NDVI data are pooled into 12 months of a year. A total of 3356 NDVI values at camel locations were extracted for 12 months intervals: Jan (313), Feb (285), Mar (310), Apr (242), May (309), Jun (313), Jul (281), Aug (253), Sep (256), Oct (236), Nov (264) and Dec (294) as shown in Table 1. Monthly NDVI images were averaged into 4 seasons (Appendix 4).
Another set of NDVI values were extracted to test the difference between the monthly NDVI values at camel locations versus the mean NDVI calculated for the surrounding environment of 20 km buffer. The spatial autocorrelation was tested based on NDVI values at camel locations and the correlogram shows an approximate distance of 20 km, at which the correlation coefficient approaches zero (Figure 4). A paired two sample T-test was used to test the significance between the observed NDVI at camel locations and mean NDVI of surrounding buffer area.

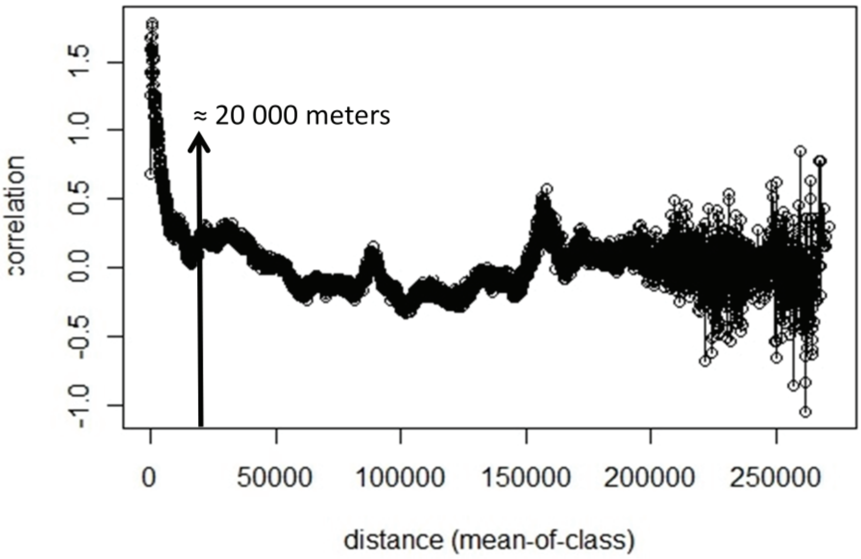

Figure 4: Correlogram showing the distance range of 20 km at which the correlation coefficient (r) between the NDVI values approaches zero.

Mongolia's national scale vegetation community map of 1:1000 000 scale was used in the analysis. There are 24 types of vegetation communities distributed in the study area (Figure 5) and, description of the legend is shown in Appendix 1.

2.2.2.4. Other important variables

Distribution of water sources is very critical for the wild camel's survival. The locations of 35 water bodies were recorded from the surveys conducted in the previous years. These locations were imported into into ArcGIS and Euclidean distance was calculated. Distance to the drainage lines were calculated from flow accumulation areas in the park. Flow accumulation areas were extracted from DEM using hydrology tool in the spatial analyst tool in ArcGIS. The national soil map of 1:1000 000 scale was used in the analysis (Figure 6). There are 20 different soil types distributed in the study area and description of the legend is shown in Appendix 2.

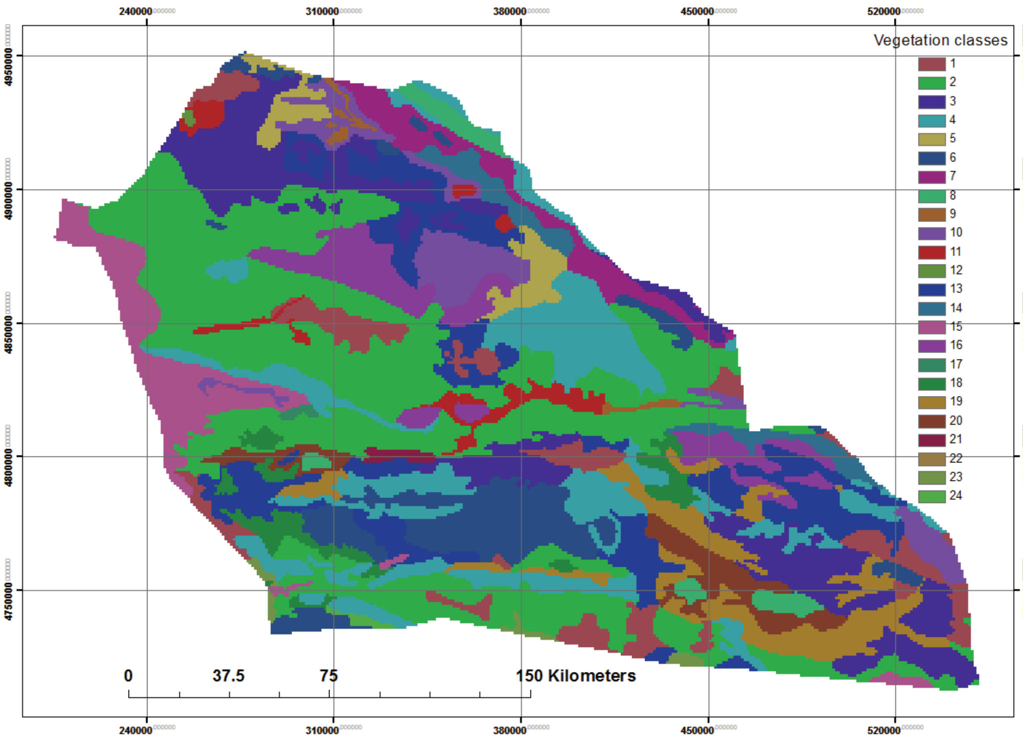

Figure 5: Vegetation map of the study area

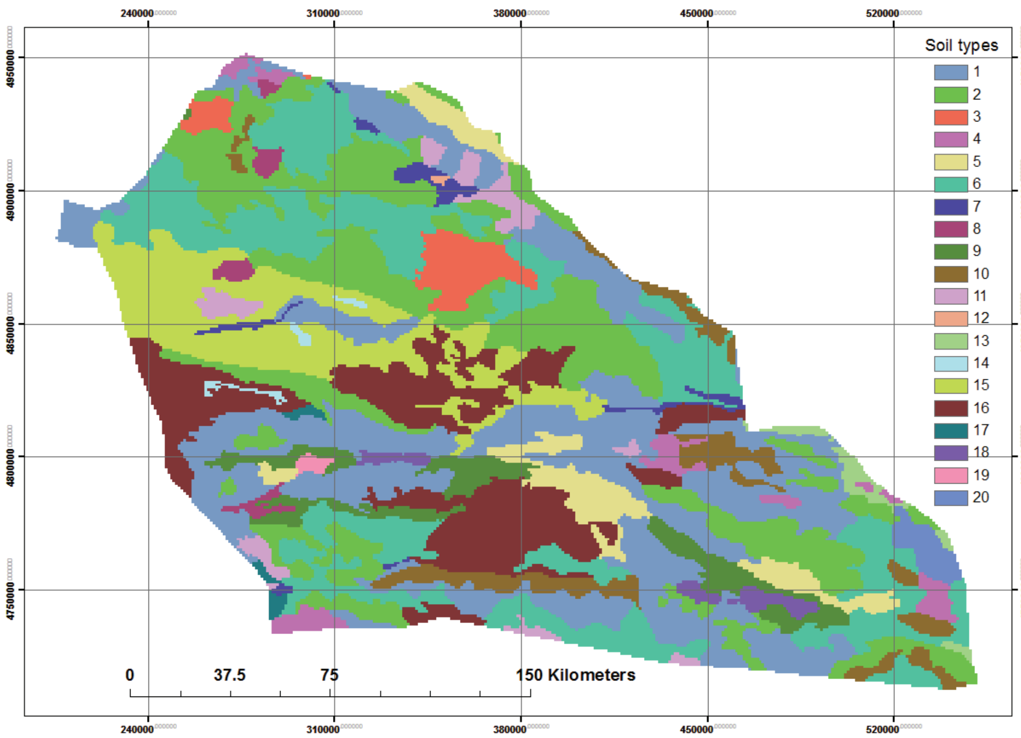

Figure 6: Soil map of the study are

2.2.3. Multi-Colinearity of predictor variables

Multicolinearity exists if there is a linear relationship between the continuous explanatory variables in the statistical analysis especially in multiple regression (Farrar & Glauber, 1967). In ecological multiple regression, multicolinearity causes inaccurate model parameterization, decreased statistical power and high effect of multicolinearity variable can be excluded from the modelling (Graham, 2003). The variance inflation factor (VIF) is used as a most common diagnostic in testing multicolinearity problem and following equation is applied (Das & Chatterjee, 2011). See equation (1)

$$VIF = 1/(1-R^2) \qquad \text{Equation (1)}$$

R^2 is the coefficient of determination calculated from linear regression. As R^2 approaches zero, the value of VIF result to infinite number. Thus, VIF greater than 10 indicates strong effect of multicolinearity. The VIF of continuous environmental variables were calculated using linear regression in SPSS 16.0 statistical software.

2.2.4. MaxEnt modelling

MaxEnt modelling approach uses only presence records of species and, instead of the absence data used for the other modelling algorithm such as GLM, GAM and BIOMOD, it uses background data that randomly chosen from the study area (Pearson, 2007). Two main inputs for the MaxEnt modelling are species presence data and environmental data such as temperature, rainfall, NDVI, soil types and elevation etc. The main concept of this approach is to calculate the probability distribution of maximum entropy (the distribution that is most spread out, or closest to uniform) considering the set of constraints in the incomplete information of species distribution (Elith et al., 2011; Phillips et al., 2006). Detailed statistical explanations of MaxEnt and discussions of various applications to species distribution modelling are described in (Elith et al., 2011; Phillips & Dudík, 2008; Phillips et al., 2004). The predictive performance of MaxEnt modelling was better than GARP with higher AUC values (Phillips et al., 2006).

MaxEnt modelling was performed on seasonal basis that presence data was divided into spring, summer, autumn and winter locations. Two separate datasets used in the modelling are: 1) 764 presence records from wild camel sightings, fecal/foot track records and incomplete satellite GPS locations; 2) 3356 presence records from 7 GPS collared animals during Oct 2002 – March 2004 and May 2007 – Sep 2008. Thus, 2 data inputs were compared for 2 model outputs in 4 seasons.

The database file of camel presence data was converted into CSV (Comma delimited) format in Microsoft Excel. All the environmental variables were processes with 1 km resolution using the georeference of WGS 84 with UTM Projection zone of 48N. Because of MaxEnt software requirement, environmental layers were converted into ASCII grid format for the modelling. As evaluated by Philips and Dudik (2008) that applying the hinge feature tool in the MaxEnt algorithm improved a model performance substantially. Therefore, hinge feature was selected in order to get realistic response curves from the modelling.

2.2.5. Explaining the response curves

MaxEnt produces 2 types of response curves: 1) Variable's response curve averaged by other predictor variables, 2) Variable's response curve that is created using only variable itself. Second type of response curve was used to explain the predicted probability by MaxEnt, because it is easy to interpret if there are strong correlations between variables. Alternatively, the frequency distribution chart of predictor variables' values at the camel presence points was overlapped on the output response curves. Based on the ranges of values in the horizontal axis from the response curves, binning the histogram charts of variable values at camel locations was considered. Given an assumption that MaxEnt prediction is primarily based on the variable values at camel locations, it is possible to explain the behaviour of response curves predicted by MaxEnt and helps to interpret the relationship of variables against probability more easily.

2.2.6. Model evaluation

Most common model evaluation approach for model performance is using are under receiver operating characteristic (ROC) curves and researchers have compared it with different algorithms (Elith, 2002; Elith et al., 2011; Fielding & Bell, 1997; Hernandez et al., 2006; Phillips et al., 2006). Area under ROC curve (AUC) is a threshold independent test that is formed by plotting the sensitivity against “1-specificity”. Sensitivity is described as the proportion of observed presences correctly predicted whereas, “1-specificity” is the proportion of observed absences correctly predicted (Pearson, 2007). So, if model gives better performance, a distance of ROC curve from threshold line increases.

Although, AUC test requires both presence and absence data, Philips et al (2006) has proven that MaxEnt modelling can produce AUC using randomly selected background data (pseudo-absence) as an observed absence data.

3. RESULTS AND DISCUSSIONS

3.1. Analysis of land surface temperature

The summer LST range at study area was between 30.6 – 50.9ºC above zero whereas, it was between -13.8 and +6.8 Celsius degree in winter. The result of t-test showed that in summer there is a significant difference between observed LST and mean LST for surrounding environment with confidence level of 95%. The null hypothesis with $T_{stat} = -5.77$, rejected in the lower tail, reveals that LST at camel locations is significantly lower than the mean LST for the surrounding environment. There was no statistical significance observed in winter ($p>0.05$), slight difference in autumn and significantly lower temperature in spring (Table 4). Camel body temperature may vary from 34°C to more than 40°C and high body temperature means that heat gain from the hot environment is reduced in order to avoid water evaporation (Schmidt-Nielsen et al., 1956). In summer, wild camels usually graze in the morning and in the evening but they lie down during the day (Bannikov, 1976). In order to reduce the body water loss, they may spend less energy by becoming inactive during the daytime in summer. Thus, the response of wild camels to the temperature can be explained as preferring lower temperature areas and they become inactive.

Table 4: Result of paired 2 sample T-test between observed LST at camel locations (Observed T^{o}) and mean LST at surrounding buffer (Buffer T^{o}) at $\alpha=0.05$

	Spring	Summer	Autumn	Winter
Observed T^{o}	25.49	43.17	21.48	-1.10
Buffer T^{o}	25.62	43.50	21.42	-1.05
df	860	846	755	814
T statistics	-3.2	-5.77	1.81	-1.14
p value	0.0006	5.40E-09	0.03	0.13

3.2. Preference of wild camel to NDVI

The result of analysis of wild camel preference to NDVI is shown in Table 5. There were higher NDVI values observed at camel locations in summer (0.064) and autumn (0.061) compared to the winter (0.050) and spring (0.046). A paired 2 sample T-test result showed that there is a preference of camel to NDVI in winter. There is significant low value of $p < 0.05$ and greater $T_{stat}=4.37$. This revealed that wild camels prefer to higher NDVI during winter. In the other seasons, this showed negative association related to NDVI. But level of negative significance was greater during spring.

Table 5: Result of paired 2 sample T-test ($\alpha=0.05$) between observed NDVI at camel locations (Observed NDVI) and mean NDVI at surrounding buffer (Buffer)

	Spring	Summer	Autumn	Winter
Observed NDVI	0.046	0.064	0.061	0.050
Buffer	0.048	0.065	0.061	0.049
df	860	846	755	891
T Statistics	-4.47	-1.8	-0.21	4.37
p value	4.3E-06	0.03	0.41	6.7E-06

3.3. Multicolinearity diagnostics

Preliminary multicolinearity test amongst the continuous variables showed that elevation had high correlation with land surface temperature. Therefore, elevation was excluded from the analysis. There are 6 environmental variables used in the modelling and 4 of the continuous variables were tested for multicolinearity diagnostics and VIF values were calculated for each season (Table 6). There are no VIF values greater than 10 thus, selected variables are all used in the modelling.

Table 6: VIF values from multicolinearity test shown in 4 seasons

Variables	Spring	Summer	Autumn	Winter
NDVI	1.69	2.68	2.14	1.71
Land surface temperature	2.42	3.96	3.21	1.33
Distance to water points	1.67	1.99	1.86	1.50
Distance to drainage lines	1.51	1.45	1.50	1.22

Note: There are no VIF values greater than 10 thus, selected variables are all used in the modelling.

3.4. Outputs from MaxEnt modelling

Two different presence dataset were used in the modelling therefore, two modelling outputs were compared. First dataset consists of mixed occurrence data including camel sighting, fecal/foot track records and incomplete GPS locations as described in the methodology section. Second dataset consists of 7 collared individuals' GPS locations with 3356 records. In this section, MaxEnt outputs of first dataset refer to "Mixed data model" and second dataset refer to "GPS data model".

3.4.1. Mixed data model

3.4.1.1. Jackknife test

The jackknife tests of model training gain were compared with 4 different seasons including spring, summer, autumn and winter (Figure 7). The variable of distance to the water points constitutes the most important variables in the modelling in all seasons except autumn. Vegetation and soil types were the secondary important variables in all seasons. But their highest gain in the modelling observed in autumn. In contrast, distance to the drainage lines were the least contributing variable in all seasons. Land surface temperature in winter contributed more importance than it did for the other seasons. In all cases, NDVI appears to be the least significant contributor in the training gain. Only in autumn, categorical variables of soil and vegetation affected the MaxEnt prediction at most. Table 7 shows the most contributing variables affected the MaxEnt prediction in four seasons.

Table 7: Variable contributions in "Mixed data" model outputs shown in percentage. Highlighted cells show significant variables.

	Variables	Spring	Summer	Autumn	Winter
1	**Distance to drainage lines**	1.51	9.8	1.50	1.3
2	**Land surface temperature**	0.3	4.3	7	21.8
3	**NDVI**	3.5	1.7	0.7	2
4	**Soil types**	22.4	20.8	44.3	28.2
5	**Vegetation types**	27.1	14.8	38.4	9.1
6	**Distance to water points**	45	48.6	8.4	37.6

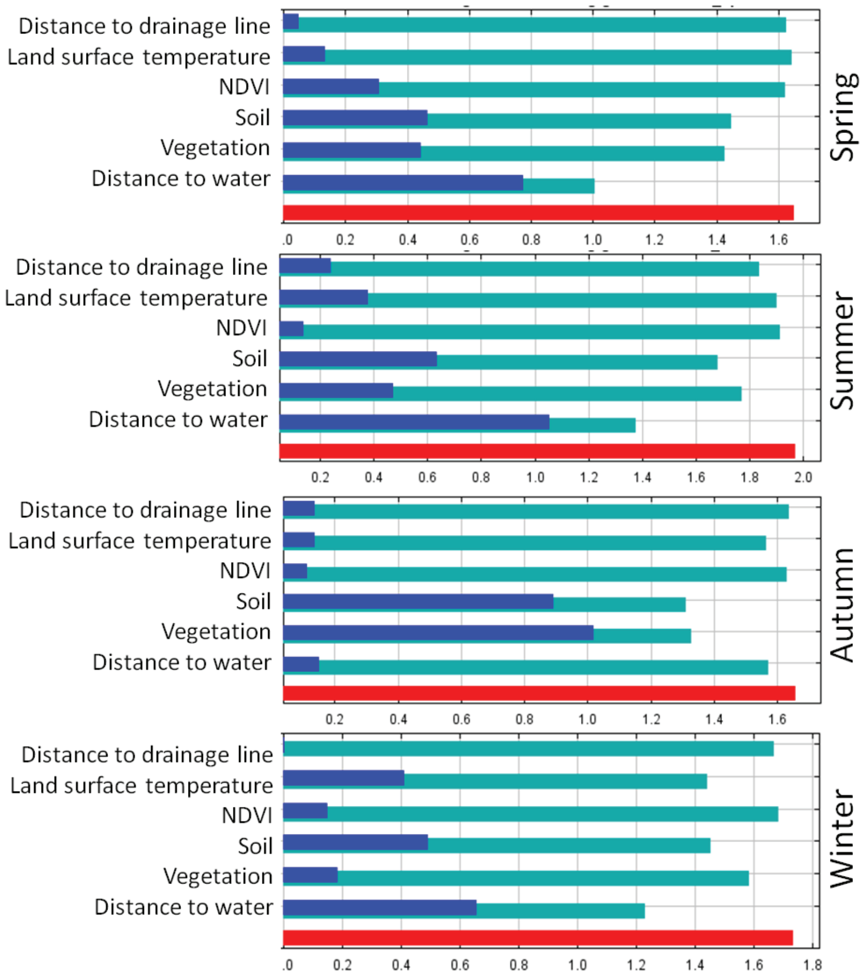

Figure 7: Jackknife test of environmental variables used in "Mixed data" modelling

3.4.1.2. Response curves of continuous variables

Response curves for land surface temperature (LST) were compared with four different seasons (

Figure 8). The summer LST was recorded at highest of all seasons ranging from +30ºC to +50ºC and mean LST at camel locations was +43.1ºC in summer. This value is greater than the mean LST of study area. There was a high probability of camel associated with low LST in summer, thus the probability of camel decreases from p=0.8 as LST increases. LST range was from +34ºC to +48ºC in summer. But the histogram chart displays high frequency of observed LST at camel locations ranging from +40ºC to +42ºC. But there was no linear relationship predicted for other 3 seasons and highest probability (p=0.65) was predicted at intermediate range of LST in spring (+29 ºC), autumn (+26ºC) and winter (-2 ºC), respectively. Higher frequency of observed LST predicted the highest probability.
Response curve of NDVI showed positive relationship that probability of camel increases from 0 to 0.8 as NDVI increases from 0.04 to 0.14 in summer Figure 9. This can be the effect of herbaceous species availability after summer rainfall. The prediction of NDVI was highest at p=0.65, and the frequency of observed NDVI was highest between 0.1 and 0.12. Negative relationship of NDVI to the camel probability was found for autumn and winter. But observed highest frequency NDVI values were predicted as p<0.5. But in autumn, high frequency of observed NDVI values were predicted highest. Average annual NDVI of study area was observed relatively low at maximum 0.14 in summer and minimum 0.04 in winter. Wild camels preferred intermediate range of NDVI with mean value of 0.06-0.08. This can infer that camels do not require biomass quality in their forage attainment but quantity.

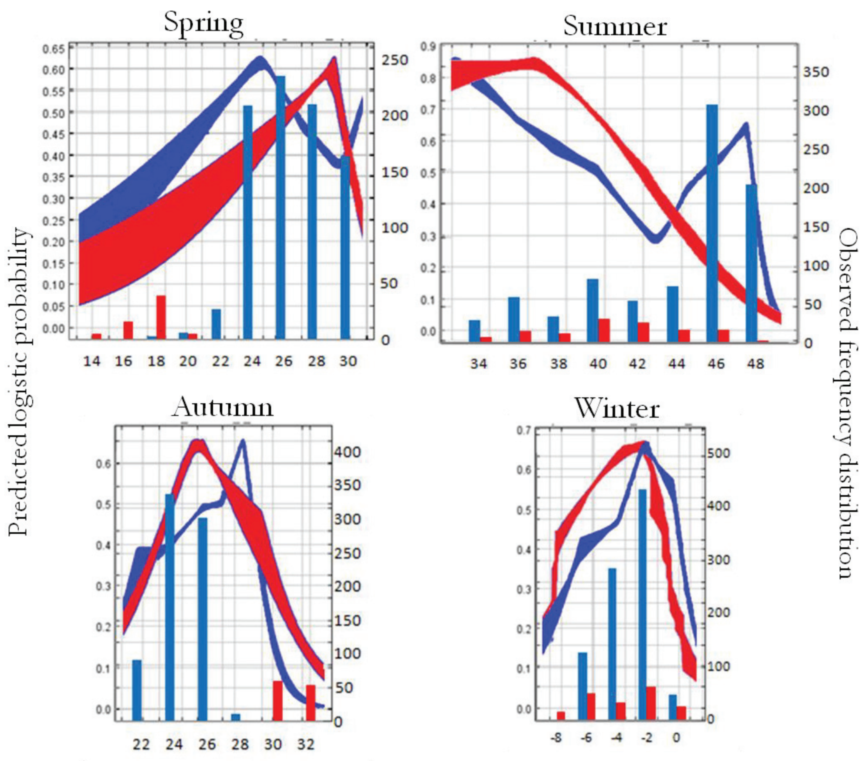

Figure 8: Response curves of land surface temperatures (ºC) predicted from the modelling. Histogram charts show the frequency distribution of the observed variable values at camel locations. *Blue:* "GPS data" model, *Red:* "Mixed data" model

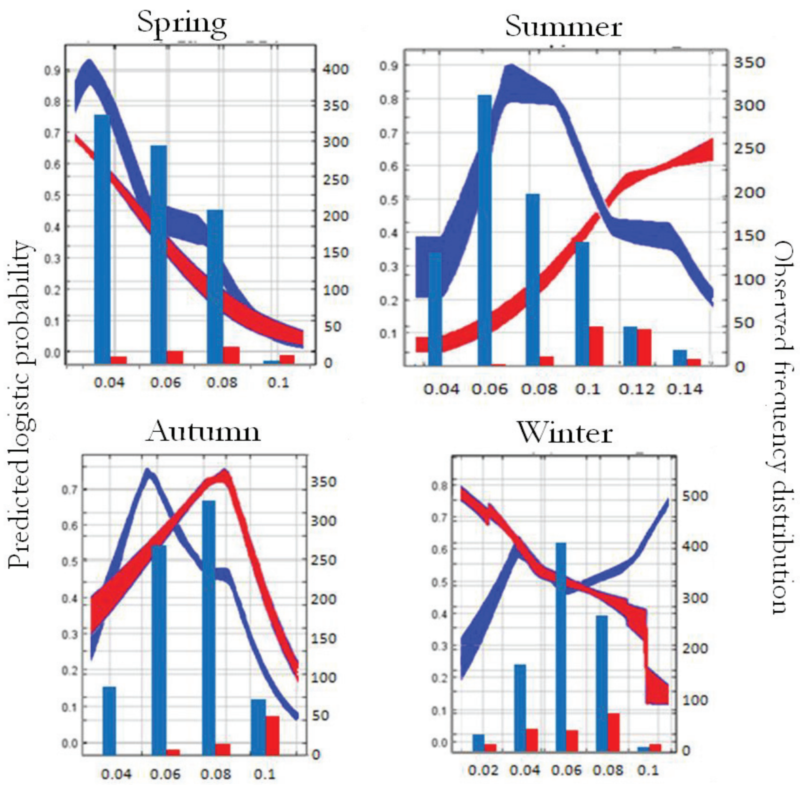

Figure 9: Response curves of NDVI predicted from the modelling. Histogram charts show the frequency distribution of the observed variable values at camel locations. *Blue:* "GPS data" model, *Red:* "Mixed data" model

Distance to the water points was the most contributing variable in the Maxent modelling. There were 35 water point localities were used in the modelling. The probability of camel occurrence from "mixed data" modelling is significantly higher within the distance range of 10 km in all seasons (Figure 11). But in autumn, there was an increasing trend of occurrence probability at 40 km distance range. Distance to the water points showed perfect negative relationship to the camel probability in all seasons. Camel probability decreases sharply, as distance increases from the water points. Highest probability was predicted (>0.6) within 10 km of distance from water points in all seasons.

Distance to the drainage lines was the least contributing variable in the modelling. In general, negative relationships were found in the seasons except summer. Model predicted that general trend of probability decreases with the increasing distance from the drainage lines in spring, autumn and winter. Highest probability of occurrence is within 1 km far from drainages then sharply decreases (Figure 12).

3.4.1.3. Prediction of categorical variables

Two main categorical variables used in the modelling were the maps of vegetation and soil types. Legend descriptions of both maps are presented in Appendix 1 and 2. Table 8 shows the vegetation and soil types dominantly occupied by camels as predicted from the modelling. The classes predicted the camel probability of p>0.6 were chosen as the most preferred class for camel distribution. Probability of shrub land communities dominated by perennial herbs and annual forbs were predicted at highest in summer (Table 8). Other shrub land communities with camel probability of p>0.6 were predicted for all the seasons. Probability of shallow mountain brown soil was greater than 0.6 in summer whereas, the probability of soil of steppe valley and depression (grey-brown extra arid soil) were greater in other seasons.

Table 8: Preference of vegetation and soil types by wild camel predicted from "Mixed data" modelling

	Map legend	Classes	Spring	Summer	Autumn	Winter
Vegetation	6, 20, 21	Perennial herbs with shrubs		+		
	1, 20	Annual forbs (Onion) with shrubs		+		
	1, 6, 10,11, 16, 17, 19	Shrubs (Saxaul, Salsola, Ephedra, Zygophyllum spp.)	+	+	+	+
Soil	5, 9, 19	Shallow mountain brown soil		+		
	1, 8, 15, 16	Soil of steppe valley and depression (grey-brown extra arid soil)	+		+	+

3.4.2. GPS data model

3.4.2.1. Jackknife test

The jackknife tests of model training gain were compared with 4 different seasons (Figure 10). The variable of distance to the water points constitutes the most important variable only in winter. But vegetation and soil types were the important variables in all seasons. Highest gain of the vegetation was observed in winter and spring. The distance to the drainage lines were the least contributing variable in all seasons. Land surface temperature had the minor contribution in all seasons. Compared to "mixed data" model curves, NDVI contributed more importance in "GPS data" model for training gain. Table 9 shows the most contributing variables affected the MaxEnt prediction in four seasons.

Table 9: Variable contributions in "GPS data" model outputs shown in percentage. Highlighted cells show significant variables.

	Variables	Spring	Summer	Autumn	Winter
1	**Distance to drainage lines**	1.2	5	1.6	2.2
2	**Land surface temperature**	6.9	14	7.5	9.3
3	**NDVI**	18.6	26.5	30.9	1.4
4	**Soil types**	17.4	16.7	31.6	16.4
5	**Vegetation types**	43.2	27.2	13	23.1
6	**Distance to water points**	12.7	10.5	15.4	47.6

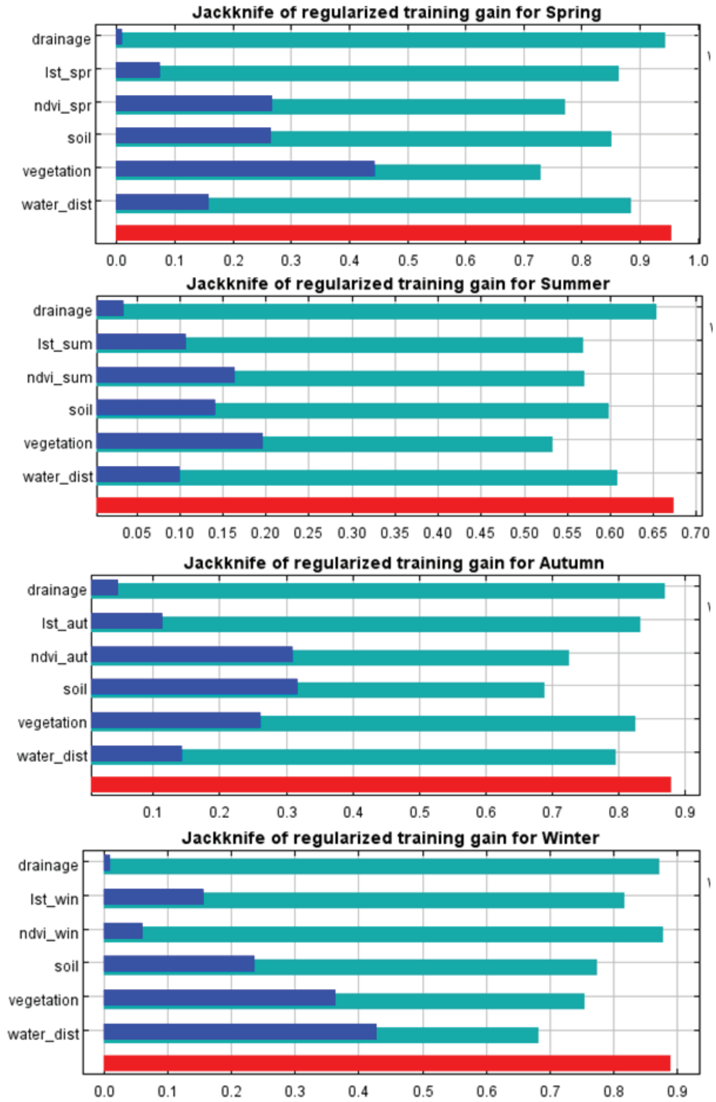

Figure 10: Jackknife test of environmental variables used in "GPS data" modelling

3.4.2.2. Response curves of continuous variables

Response curves for each predictor variables were compared with four different seasons. Similarly in "mixed data" model, high probability of camel associated with low LST in summer (Figure 8). In general trend, the probability of camel decreases from p=0.8 as LST increases in summer and LST range was from +30ºC to +52ºC. Histogram chart displays the frequency of observed LST at camel locations ranged from +44ºC to +48ºC. Only in this range, the response curve showed a sudden increase in the camel probability from p=0.3 to p=0.6, and then it decreases. No linear relationship was predicted for other 3 seasons and highest probability (p=0.6) was predicted at intermediate range of LST in spring (+23 to +29 ºC), autumn (+23 ºC) and winter (-4 ºC), respectively. Both models predicted that probability of camel occurrence is highest at +30ºC in summer and it decreases as LST becoming hotter. But observed LST at camel locations were higher at +40 – (+45ºC). The high probability of model prediction at +30ºC can be the effect of using randomly chosen 10000 background "pseudo-absence" points. This means these points were predicted as suitable range for camel distribution.

Response curve of NDVI showed a left skewed bell curve relationship that probability of camel (p=0.7) was highest at lower intermediate values of NDVI (Figure 9). Only in winter, it showed high probability of p=0.65 in upper intermediate range. Average annual NDVI of study area was observed relatively low at maximum 0.14 in summer and maximum 0.04 in winter. Wild camels preferred intermediate range of NDVI with mean value of 0.06. No significance of NDVI preference can infer that camels do not require biomass quality in their forage attainment but quantity. Prevalence of the camel stomach content consist of shoots, twigs and stems of common shrubs of Gobi desert but herbaceous plants constitute in smaller quantity (Bannikov, 1976). Relatively lower amount of NDVI and scarcity of vegetation cover may lead this species to intake any available vegetation.

Distance to the water points showed the highest probability (p=0.6) prediction within the distance range up to 40 km in spring, summer and autumn. But in winter, the highest probability of (p=0.6) occurrence was predicted within 10 km (Figure 11). Camel probability generally decreases, as distance increases from the water points. Oases occur at the upstream areas of dry river beds or bottom of a valley between the ridges. Only at the oases, wild camels gather in large groups (Bannikov, 1976). This can explain that water source is critical for wild camels' survival in the extremely dry and hot landscape. The distance range of 40 km was predicted at highest probability in "GPS data" model which was different than the result of "Mixed data" model. Only in winter, it was similarly predicted with "mixed data" model of 10 km distance of highest probability.

Distance to the drainage lines was the least contributing variable in the modelling. As predicted in "mixed data" model, negative relationships were found in the seasons except summer. Highest probability of p=0.55 was predicted at distance range from 2 to 4 km (Figure 12). Model predicted that general trend of decrease in the probability as the distance increases from the drainage lines. Only in summer, positive relationship of camel probability was seen as the distance from drainage lines increases. Highest probability of p=0.8 was predicted at 12 km. Occurrence near to drainages in mountain defiles would provide them a shelter from cold winds of winters. In contrast, the camel probability has positive relationship with the distance from drainage in summer in both models. This can be explained by their distribution is shifted to higher elevation areas with mountain soils where the herbs become available in summer as discussed previously.

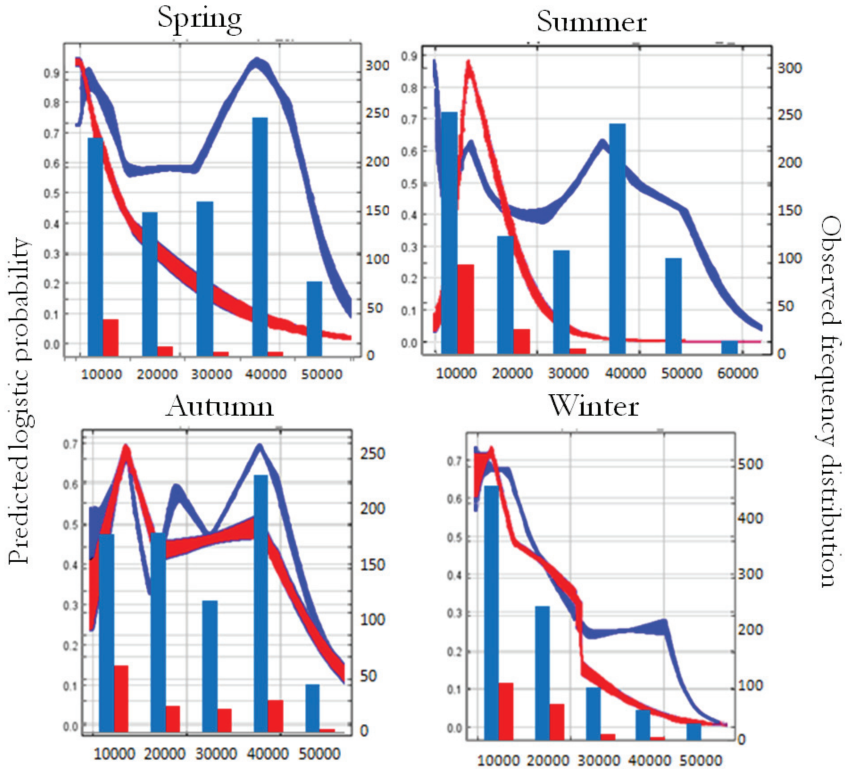

Figure 11: Response curves of distance to water points predicted from the modelling. Histogram charts show the frequency distribution of the observed variable values at camel locations. Blue: “GPS data” model, Red: “Mixed data” model.

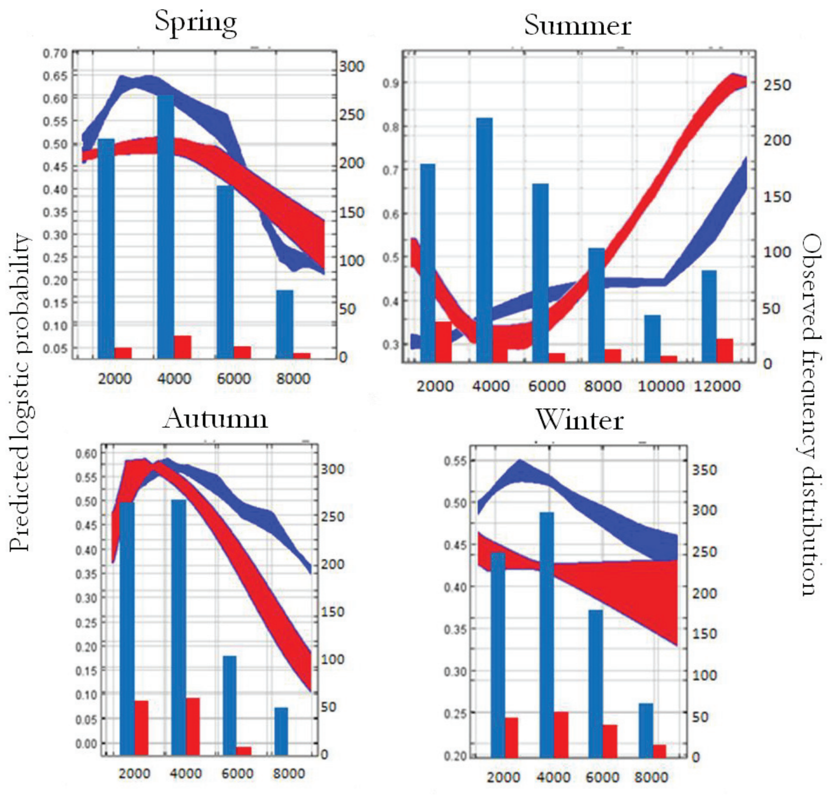

Figure 12: Response curves of distance to drainage lines predicted from the modelling. Histogram charts show the frequency distribution of the observed variable values at camel locations. Blue: “GPS data” model, Red: “Mixed data” model

3.4.2.3. Prediction of categorical variables

The "GPS data" model produced similar results as shown in "mixed data" model. Table 9 shows the vegetation and soil types mostly occupied by camels as predicted from the modelling. The classes predicted the camel probability of p>0.6 were chosen as the most preferred class for camel distribution. Legend descriptions of both maps are presented in Appendix 1 and 2. Probability of shrub land communities with participation of perennial herbs and annual forbs were predicted at highest in summer and in winter (Table 9). Other shrub land communities with camel probability of p>0.6 were predicted for all the seasons. Both models produced similar results on predicting the suitable classes of vegetation. The results imply that preference of wild camel for herbaceous species is critical in summer. The evidence of rainfall only occurring in the summer, leads herbaceous species growth. This particular community in the summer can be the main desirable habitat where wild camels move to attain enough water.

Probability of shallow mountain brown soil was greater than 0.6 in summer whereas, the probability of soil of steppe valley and depression (grey-brown extra arid soil) were greater in other seasons. Soil type was the second important variable in the model prediction of camel occurrence. It is predicted that most suitable soil class is shallow mountain brown soil. This is typical chestnut soil which characterized as moderately deep, well drained soils on gently sloping hills to very steep ridges. This soil type only occurs in the South Western rolling hills of the study area where the grasses and annual forbs temporarily appear in late summer. As the grasses and forbs are preferred to camels palatability, higher probability of the camel is explained by this soil type. As discussed previously, the lower temperature environment is associated with high camel occurrence in summer; this could be evidence that moving to the higher elevation area where the temperature is cooler.

Table 9: Preference of vegetation and soil types by wild camel predicted from "GPS data" model

	Map legend	Classes	Spring	Summer	Autumn	Winter
Vegetation	6	Perennial herbs with shrubs		+		
	1	Annual forbs with shrubs		+		+
	4, 10, 18, 19	Shrubs (Saxaul, Sympegma, Nitraria, Anabasis, Zygophyllum spp.)	+	+	+	+
Soil	5, 9, 19	Shallow mountain brown soil		+		+
	1, 3, 8, 16	Soil of steppe valley and depression (grey-brown extra arid soil)	+		+	+

3.4.3. Predictive distribution maps

Both models ran with 4 different seasons; spring, summer, autumn and winter. A total of 8 predictive maps were produced. In each model, camel distributions were compared in 4 different seasons and each seasonal distribution was compared for 2 separate models entitled by "mixed data" and "GPS data" model. Map colour gradient in Figure 13 indicates the probability of camel occurrence increasing from 0 (red) to 0.9 (green).

Seasonal distribution ranges were differed in all seasons from 2 different models. According to the model prediction, there is a common distribution areas were identified between summer, autumn and spring ranges. These areas can be considered as core distribution areas

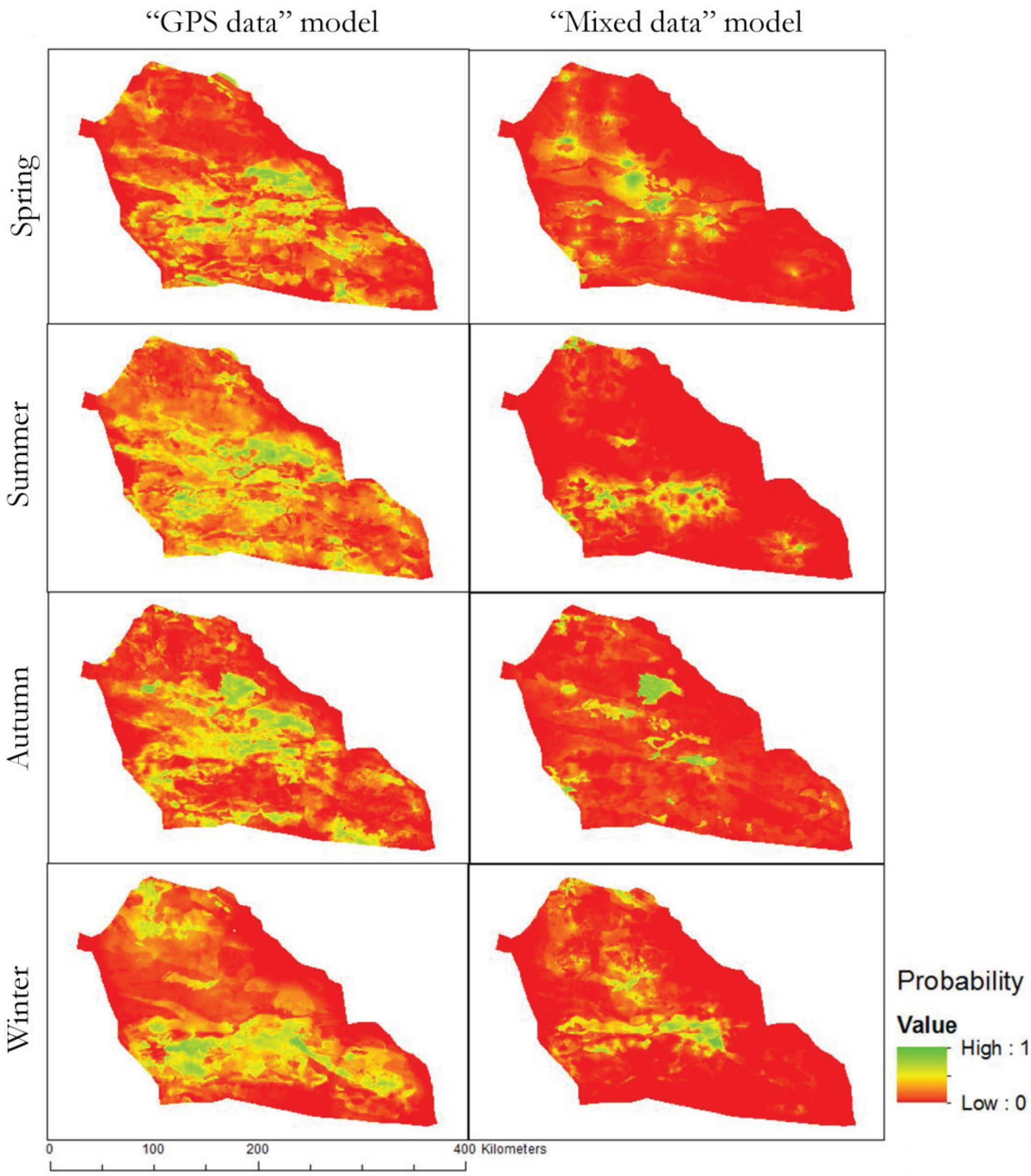

Figure 13: Predictive distribution maps of 2 different models in 4 different seasons.

of annual range. This area is located to the North West from the Centre of the park (Figure 13). But wintering range was predicted to be towards South of the park and elongating from West to East. Seasonal distribution of wild camels were assessed previously by McCarthy (2000) and Tulgat & Schaller (1992) (See Appendix 4 & 5). Predicted distribution range from the MaxEnt modelling occupies the camel range described by the researchers stated above. This can justify that there is a consistency between survey data and satellite tracking data to model the species distribution.

"GPS data" model used substantially large quantity of occurrence points (n=3356) compared to the "Mixed data" model (n=764). This may affect the outputs generated from the modelling. Actual distribution of complete dataset (n=3356) shows more realistic camel range so does the predicted distribution. Exponential curves of environmental predictors from incomplete data produced more smooth curves than complete dataset. Fluctuations in the curve smoothness could be violated from spatially autocorrelated distribution of points.

However, the curves showed generally the similar trends in both modelling. Both models performed significantly better than at random prediction.

3.4.4. Model performance and evaluation

The area under receiver operating characteristics (ROC) curves of 2 different model ("Mixed data" and "GPS data" model) outputs were compared in Figure 14. Each model ran for 4 different seasons and total of 8 test statistics of model performance were produced. "Mixed data" model performance with AUC > 0.9 was substantially better than the "GPS data" model performance with AUC < 0.9. In all cases, the accuracy of training data was always greater than the accuracy of test data (Figure 14).

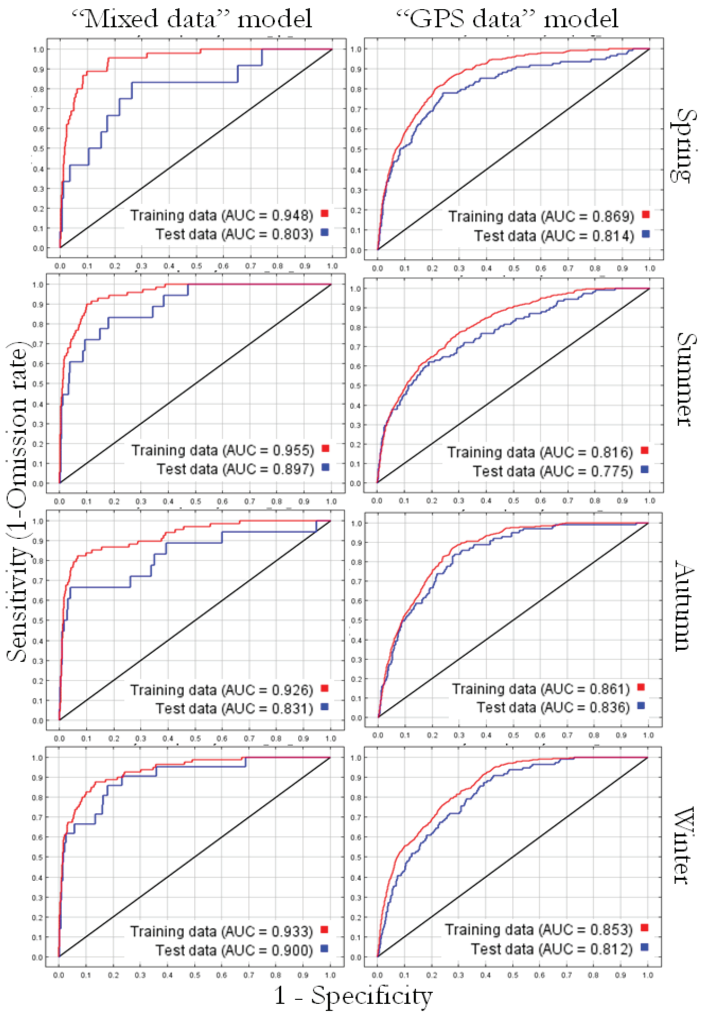

Figure 14: Area under ROC curves (AUC) of 8 different MaxEnt modelling evaluations.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1. Conclusions

This study primarily investigated the species/environment relationship of wild Bactrian camels in Mongolia on a seasonal basis. We examined the potential environmental predictors changing through the different seasons and how this species respond to changes in the environmental conditions in their distribution. We also compared two different species responses created from the modelling based on two sets of species presence data that differ in both quality and quantity. Main conclusions derived from this research are described in the following statements.

The study area is characterized by extreme hot temperature range during summer compared with other seasons. By inferring from the result of t-test, wild camels prefer to occur in the areas cooler than surrounding hot environments in summer. Model prediction can imply that probability of occurrence decreases with the increase in the temperature. There was no significant response to temperature was observed in other seasons.

Biomass productivity of the study area is relatively low. Biomass abundance is not considered as a strong predictor for camel distribution. Camel preference to intermediate level of NDVI in most seasons can imply that food intake is based on forage quantity but not quality. Positive relationship of camel probability to higher NDVI in summer suggests that they prefer to herbaceous species which appear after rainfall.

Based on the model prediction, probability of occurrence was greater in the herbaceous plant communities in summer. This result implies that preference of wild camel to herbaceous species is critical in summer. The evidence of rainfall only occurring in the summer, leads herbaceous species growth. This particular community in summer can be the main desirable habitat where wild camels move to attain enough water.

Model predicts that distance to the water sources is critical for camel distribution in all seasons and high probability of camel occurrence was predicted near water sources. Past survey results of numerous researchers showed that abundant number of wild camel herds were found near water sources. Result of this study matches with findings of other researchers.

Shallow mountain soils were predicted as favourable soil types for summer distribution. This is typical chestnut soil which is characterized as moderately deep, well drained soils on gently sloping hills where the grasses and annual forbs temporarily appear in summer. Spatial co-existence of herbaceous plants, mountain soils and areas of lower temperature are the favourable conditions in camel distribution during summer. No particular habitat preference was predicted in other seasons.

Two sets of presence only data used in the modelling are: 1) “Mixed data”, 2) “GPS data” which are different in both quality and quantity. Different model response curves were generated from two data sets. This can be concluded that quantity of data substantially affect the model outputs. However, AUC tests reveal that low quantity data model performance (AUC = 0.94) was better than higher quantity data model performance (AUC = 0.84).

Distribution ranges were differed in all seasons. There is a common distribution range predicted in spring, summer and autumn which can be considered as core distribution areas of annual range. Distribution of winter range is differed from other seasons. Predicted distribution range from the MaxEnt modelling occupies the camel range described by other researchers can justify that there is a consistency between survey data and satellite tracking data to model the species distribution.

4.2. Recommendations

This was first study of modelling the distribution of wild Bactrian camels in Mongolia. In order to investigate the species/environment relationship, it is important to select the most potential environmental factors influencing the distribution. It is recommended that further detailed studies are eligible for large ungulates by investigating response curves from MaxEnt modelling. Examining the model response curves is recommended as appropriate approach to study species/environment relationship.

Due to the general scarcity of vegetation in the semi desert area, biomass abundance may not be a potential environmental predictor for wild camels. Therefore, nutritional contents of the main edible plants of camels considered to be an important attribute for later study.

According to the result of model performance, high quantity of presence points may violate the model performance by spatial autocorrelation. Less quantity presence data gives better model performance but it still should contain better quality of temporal and spatial information.

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APPENDIX

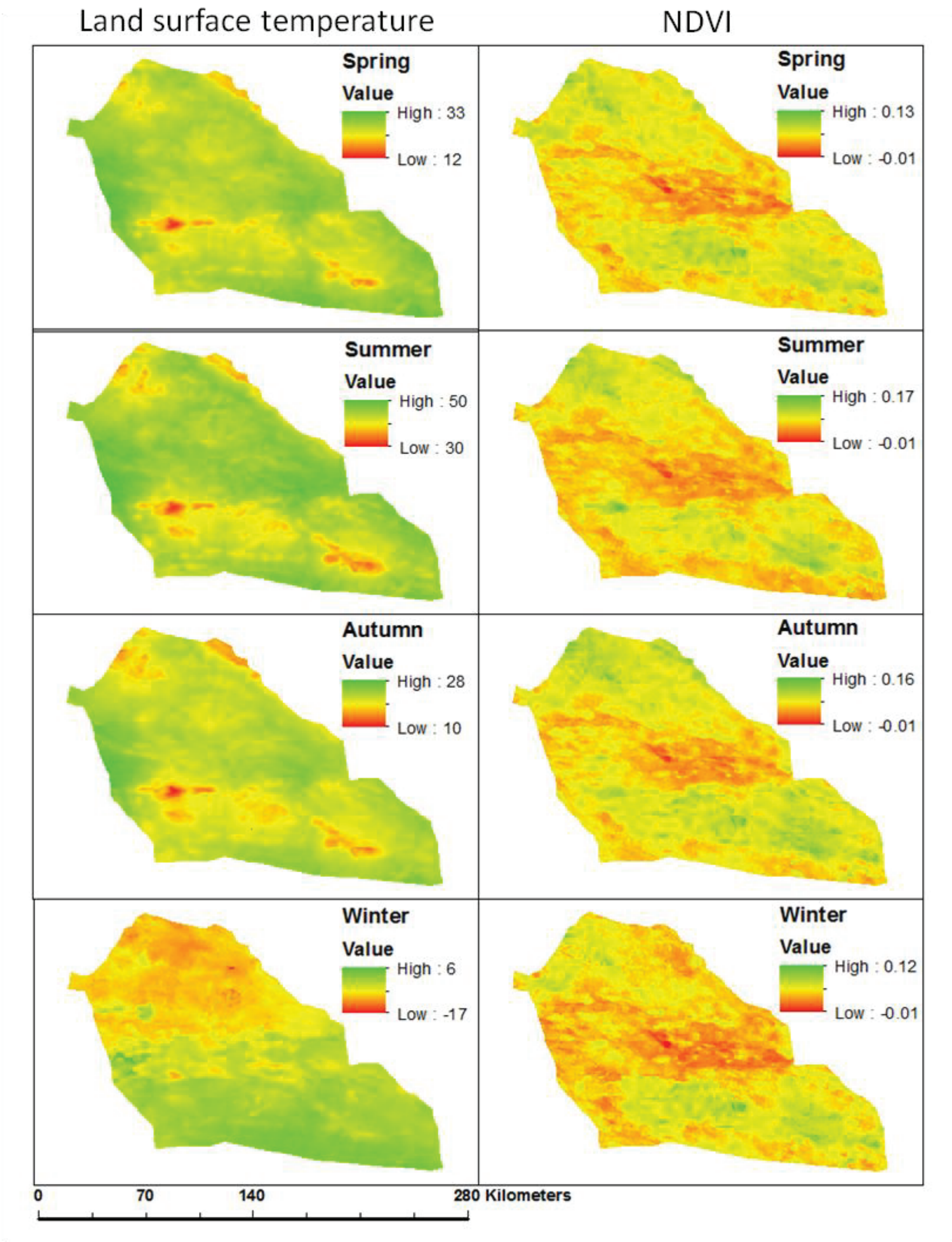
Apendix 1: Description of the soil map legend

Legend code	Class	Type
1	Soil of steppe valley and depression	Grey brown extra arid with sairic
2	Low mountains and rolling hills soil	Shallow stony grey brown with typical grey brown and sairic
3	Soil of steppe valley and depression	Grey brown extra arid with solonchak
4	Low mountains and rolling hills soil	Typical grey brown with shallow grey brown
5	Mountain soil	Shallow mountain brown steppified desert with sairic
6	Soil of steppe valley and depression	Sair with grey brown desert extra arid
7	Other soils and bare land	Takyre-like with sands weakly fixed
8	Soil of steppe valley and depression	Grey brown (non division with eolian deposits weakly fixed sands)
9	Mountain soil	Shallow mountain brown steppified desert with typical mountain brown desert-steppe
10	Mountain soil	Shallow mountain gray brown with typical mountain gray brown
11	Soil of steppe valley and depression	Grey brown (non division) with eolian deposits grey brown desert gypsic
12	Soil of humid areas	Meadow solonchak with solonchak meadow
13	Soil of steppe valley and depression	Grey brown desert stony with sairic
14	Saline soil	Solonchak with sand weakly fixed
15	Soil of steppe valley and depression	Grey brown extra arid with takyre-like
16	Soil of steppe valley and depression	Grey brown extra arid
17	Other soils and bare land	Weakly fixed sands
18	Mountain soil	Mountain brown desert-steppe with typical mountain brown desert-steppe
19	Mountain soil	Shallow mountain light chestnut with shallow mountain brown desert-steppe

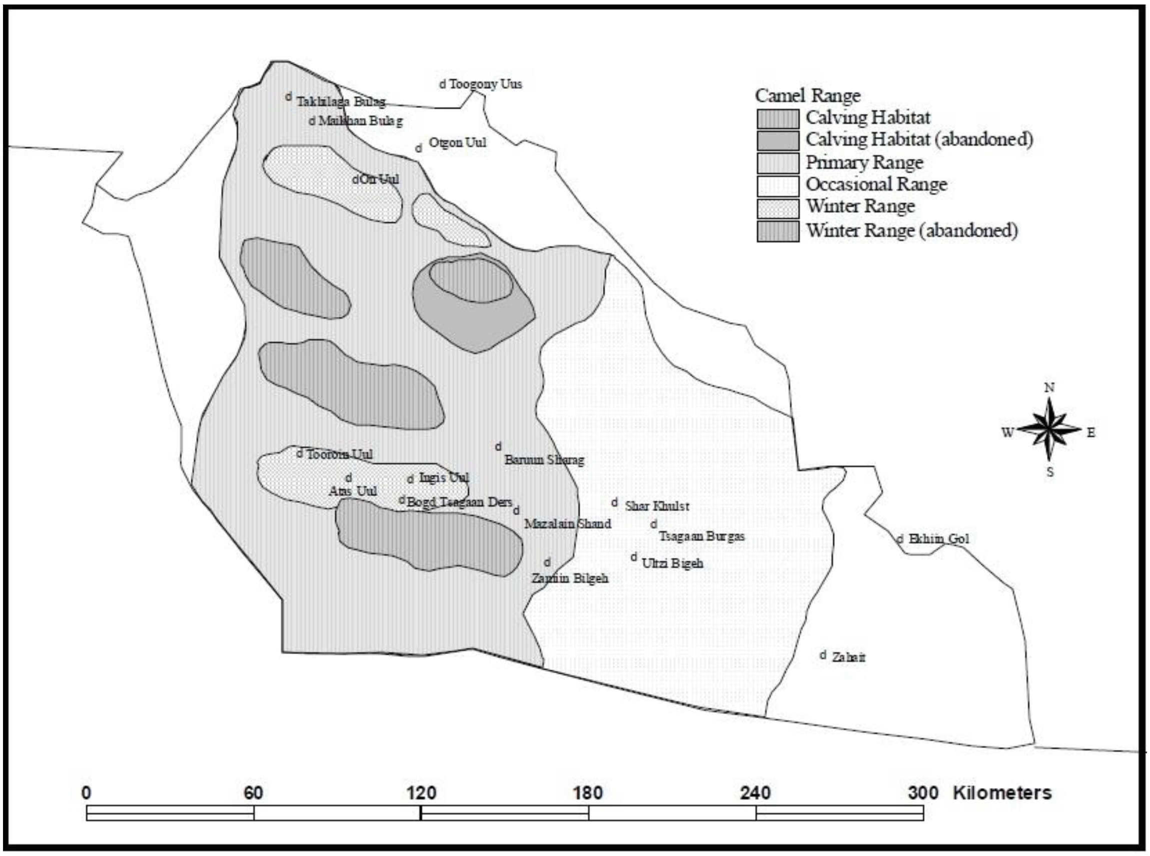
Appendix 2: Description of the vegetation map legend

Legend code	Vegetation community
1	Low Haloxylon with participation of annual russianthistle, Anabasis
2	Rarel Iljinia, Haloxylon (70%) in combination with Haloxylon-Ephedra on dry riverbed
3	Stony Anabasis-Sympegma in combination with Haloxylon-shrub (40%) on sandy hill (Zygophyllum, Mongolian almond)
4	Stony Sympegma, Sympegma-Anabasis with participation of Haloxylon (on dry riverbed)
5	Anabasis-russianthistle (Reaumuria, Sympegma regelii) in combination with Ajania-Eurotia-low needlegrass (30%) and with participation of Mongolian almond, Zygophyllum
6	Stony russianthistle (Reaumuria, Anabasis, Sympegma regelii), Eurotia-russianthistle with participation of low needlegrass
7	Bindweed-Ephedra, bindweed-Eurotia with participation of Reaumuria
8	Stony wheatgrass-wormwood, wormwood-wheatgrass with participation ofCaragana leucophloea, needlegrass
9	Russianthistle-Reaumuria in complex with Reaumuria-Nitraria (10%)
10	Low Haloxylon with participation of Reaumuria, russianthistle
11	Nitraria, Nitraria-Haloxylon
12	Stony wormwood-low needlegrass, wormwood-onion-low needlegrass with participation of Caragana leucophloea, russianthistle
13	Russianthistle-Haloxylon
14	Sympegma-Reaumuria (in Dzungarian and South Gobi of Altai), Reaumuria
15	Unsuitables: sand, canyon, solonchak, dry riverbed with solitary bushes, dry circular salt marsh none vegetation, glacier, stony surface
16	Stony Reaumuria, Reaumuria-Anabasis with participation of Haloxylon (on dry riverbed)
17	Ephedra, Ephedra-Haloxylon
18	Stony Anabasis, Anabasis-russianthistle
19	Zygophyllum-pearl russianthistle with participation of Mongolian almond (Amygdalus mongolica)
20	Stony low needlegrass-Ananbasis, Anabasis-low needlegrass with participation of onion, russianthistle, Caragana leucophloea
21	Stony eurotia-Ajania, Eurotia-wormwood with participation of low needlegrass, Caragana leucophloea
22	Lymegrass-licorice in complex with Reaumuria-Nitraria (30%) and Tamarix (10%)
23	Grove of high Haloxylon
24	Anabasis with participation of russianthistle and low needlegrass (Reaumuria, Sympegma regelii in Alashaa Gobi and South Gobi of Altai)

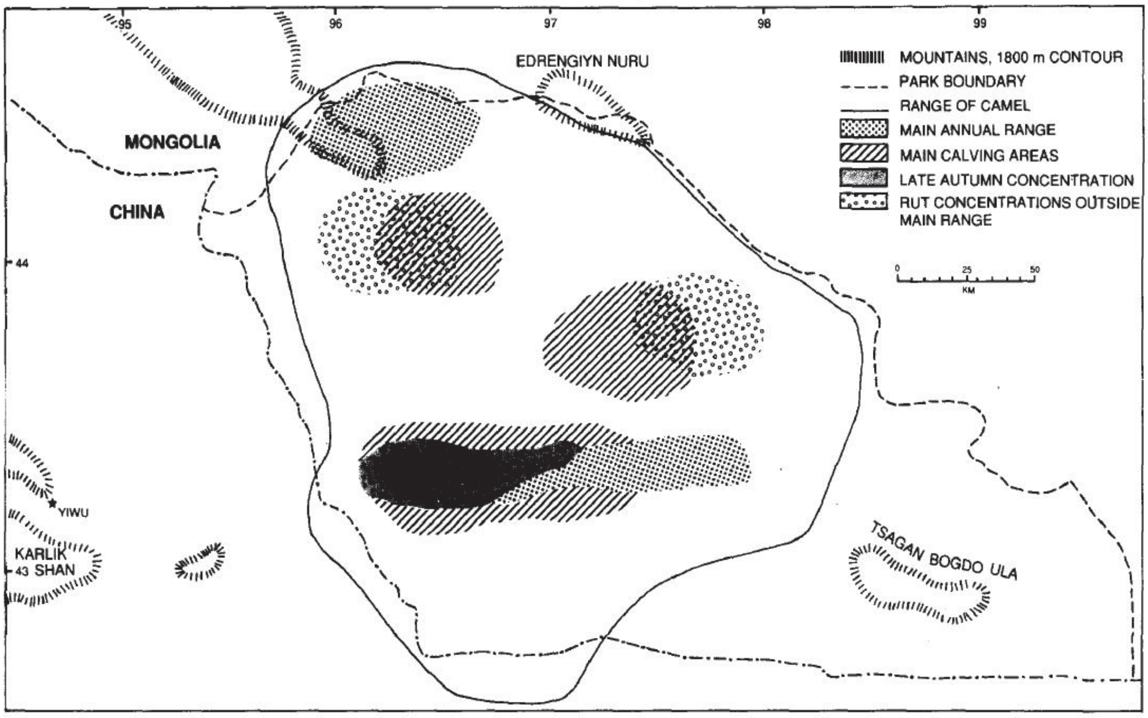
Appendix 3: Seasonal land surface temperature (ºC) and NDVI maps used in the modeling



Appendix 4: Wild Bactrian camel range described by McCarthy (2000).



Appendix 5: Wild Bactrian camel range described by Tulgat & Schaller (1992)



Appendix 6: Distribution of water points in the study area