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En studie utförd i svenska Abisko-området

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Correlations across microclimatic change, subarctic vegetation cover, and reindeer foraging preferences.

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Effects of Global Warming on Reindeer Husbandry in the Swedish Subarctic

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Abstract

The Abisko Scientific Research Station (ANS) is located in the far north of Sweden, in a subarctic environment inhabited mostly by the Sami people. ANS has conducted research for more than hundred years, with its current focus set on interdisciplinary research regarding the effects of climate-change on the subarctic environment.

Since the subarctic region changes faster than many other regions, ANS attracts climate change scientists from all over the world, with approximately 500 visitors per year, resulting in large numbers of data being generated. The present study focused on observations of temperature changes in the region, utilizing a database covering the Abisko region.

As a result of climate change, geographic characteristics of the vegetation in the Abisko region are changing, propagating at a speed determined by micro-climatic conditions such as aspect and elevation. Temperature may be considered as an effect of such micro-climatic factors, and is in conjunction with soil properties determining the vegetation characteristics.

Keywords: Abisko, research, temperature, climate change, vegetation, reindeer.

Contents

1 Introduction

1.1 Food habits of the reindeer in Sweden

The reindeer (an ungulate) in Sweden usually change their feeding habits in line with the changes of season, to ensure finding sufficient food for survival, reproduction, feeding their calves and defending them as well as themselves.

White (1981) reported that during summer, the reindeer migrate to open areas in order to find the desired food, e.g. grasses, sedges, shrubs and herbs.

Some of the nutritious plants preferred by reindeer in Scandinavia have been discussed by Alaurikka & Skuncke in 1964 and 1958:

- Shrubs, such as *Empetrum nigrum* (crowberry) and *Vaccinium myrtillus* (blueberry).
- Willows: *Salix Lapponum, Salix Lanata, Salix Hastata* and *Salix Herbacea*.
- Trees: downy and mountain birches such as *Betula nana* and *Betula tortuosa* as well as aspens, *Populus tremula*.
- Mushrooms utilized by reindeer: *Boletus edulis*, *Helvella* and *Polyporus*, and among Gastromycetes: *Bovista migrecens*.
- Elk heaths: *Deschampsia flexuosa* and *Deschampsia caespitose*.
- Meadow grasses: *Poa remota, Poa pratensis, Poa palustris, Calamagrostis neglecta, Festucae ovina, F. pratensis* and *Agrostis borealis, Tryfolium hybridum* and *Tryfolium pratense*.

As the winter arrives, the reindeer migrate to forested areas where they will spend the rest of the season.

The winter feeding is very different from the summer feeding; many summer plants do not survive during the winter season.

Klein (1986) reported that reindeer survive during winter by feeding from lichens and some vascular species. There are 18 vascular species suitable for reindeer feeding described (Skogland 1980).

Age is another important factor influencing the diet of reindeer. During their growth, calves feed mainly on young plants, leaves and grasses (Skjenneberg and Slagsvold 1968).

During winter in Scandinavia (Ahti 1961), the most common winter plant utilized by reindeer is *Deschampsia flexuosa*. The reindeer are furthermore able to dig up the juicy roots of semi-frozen plants. Examples are *Menyanthes trifoliate*, *Comarum palustre* and various sedges, i.e. *Carex rostata*.

Lichens are the most important food source for reindeer during the winter season. Ahti (1961) showed that lichens make up 85-90% of the food supplies of reindeer during winter. In contrast, only 20% of their summer diet consists of lichens (Herre 1955).

Lichens may be divided into three different groups:

- The first group includes the chief types of *Cladonia alpestris*; a plant never reaching a height of more than 15 cm. The growth rate of this lichen keeps ahead of grazing rates.
- The second group is the most extensive one and includes *Cladonia rangiferina* and *Cladonia mitis*. These lichens usually grow 3 – 7 cm thick, depending on grazing intensity.
- The third group comprises the *Stereocaulon paschale*, found in areas of high intensity grazing.

1.2 Abisko National Park

1.2.1 Location

The Abisko Valley is situated at 68º21' latitude N and 19º0' longitude E. It is situated in the Scandinavian mountains in northern Sweden at an altitude of 340 - 580 m, and surrounded by mountains ranging in height from 1000 to 1750 m, except on the north side where the valley is open to the Torneträsk, a lake with an area of 330 km2 and a drainage area of 3300 km2. The maximum depth of the lake is 182 m and its mean depth is 52 m." (Ekman, 1957).

Figure 1. Area which is situated the Abisko National Park

An ice cover is formed on the lake in the beginning of winter, breaking up as summer arrives. (Figures 2, 3 & 4).

1.2.2 Vegetation

The Torneträsk area is located between two latitudinal biogeographic zones, i.e. the coniferous forest of the Northern Boreal Zone and the Alpine Zone (Fennoscandia) (Sjors 1956). Pines, *Picea alba*, grow in the south-facing slopes of the Abisko Valley.

The alpine zone can be divided into three different biogeographic zones of different altitude. These areas are defined as high, medium and low alpine zones. In the low alpine zone, the dominant mountain vegetation type is birch forest (*Betula pubescens ssp*. *Tortuosa*).

In the western region of Torneträsk, the treeline is located at an elevation of 550 - 650 meters, except for the western part of the region, where the treeline is located at about 750 meters (Sonesson and Lundberg 1974). The most common type of forest in the Abisko valley is the birch forest, where the understory is dominated by mosses (Ahti 1961).

The understory of Abisko consists mainly of grasses, herbs, ferns, blueberry (*Vaccinium myrtillus*) and the genus Empetrum (*Empetrum hermaphroditum*) (Rune 1965). This understory is further composed by a mixture of lichens and moss-rich shrub. Where favorable enough groundwater conditions prevail, tall herbs, lush meadow, and alpine birch forest are added (Figure 4).

At dry nutrient-poor soils, *Empetrum empetrum* and *Vaccinium myrtillus* are typically found. Wetter soil conditions and abundant snow cover are indicated by the presence of *Vaccinium myrtillus*.

Subalpine shrubs are found in the birch forest, while dry heaths occur along the Torneträsk, where they are heavily exposed to the wind. In the Abisko valley wetlands, the vegetation consists of mires, bogs and fen hummocks with grasses and mosses.

Blueberry (*V. myrtillus*.) grows above the tree line in the alpine zone (Rune 1965).

In the medium alpine zone, the dwarf shrubs, *Empetrum hermaphroditum*, *Arctostaphylos alpina* and *Louiseleurea procumbens* grow. Finally, the flora in grassy areas includes *Dryas octopetala, Silene acualis, Saxifraga oppositifolea* and *Pedicularis flammea*.

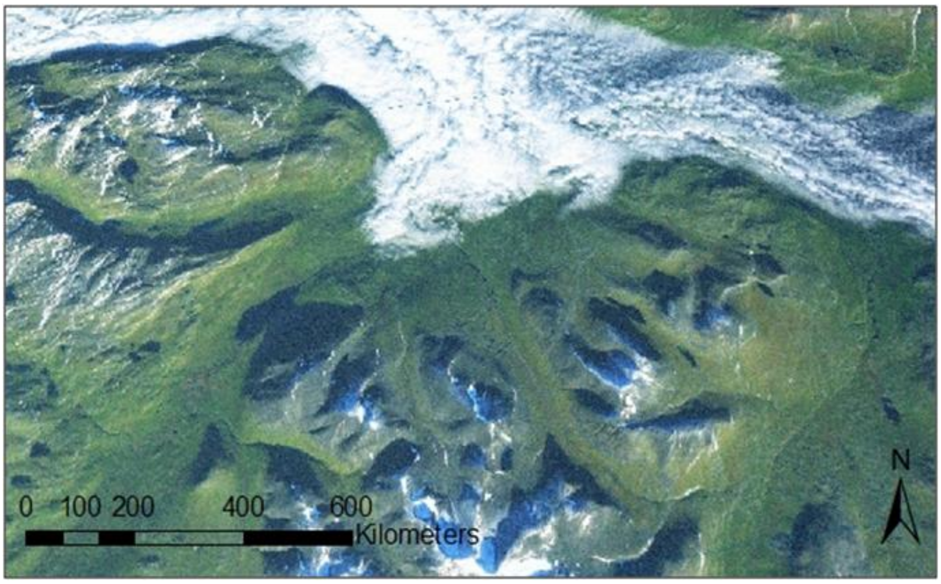

Figure 2. Map of Abisko area, using ArcGlobe

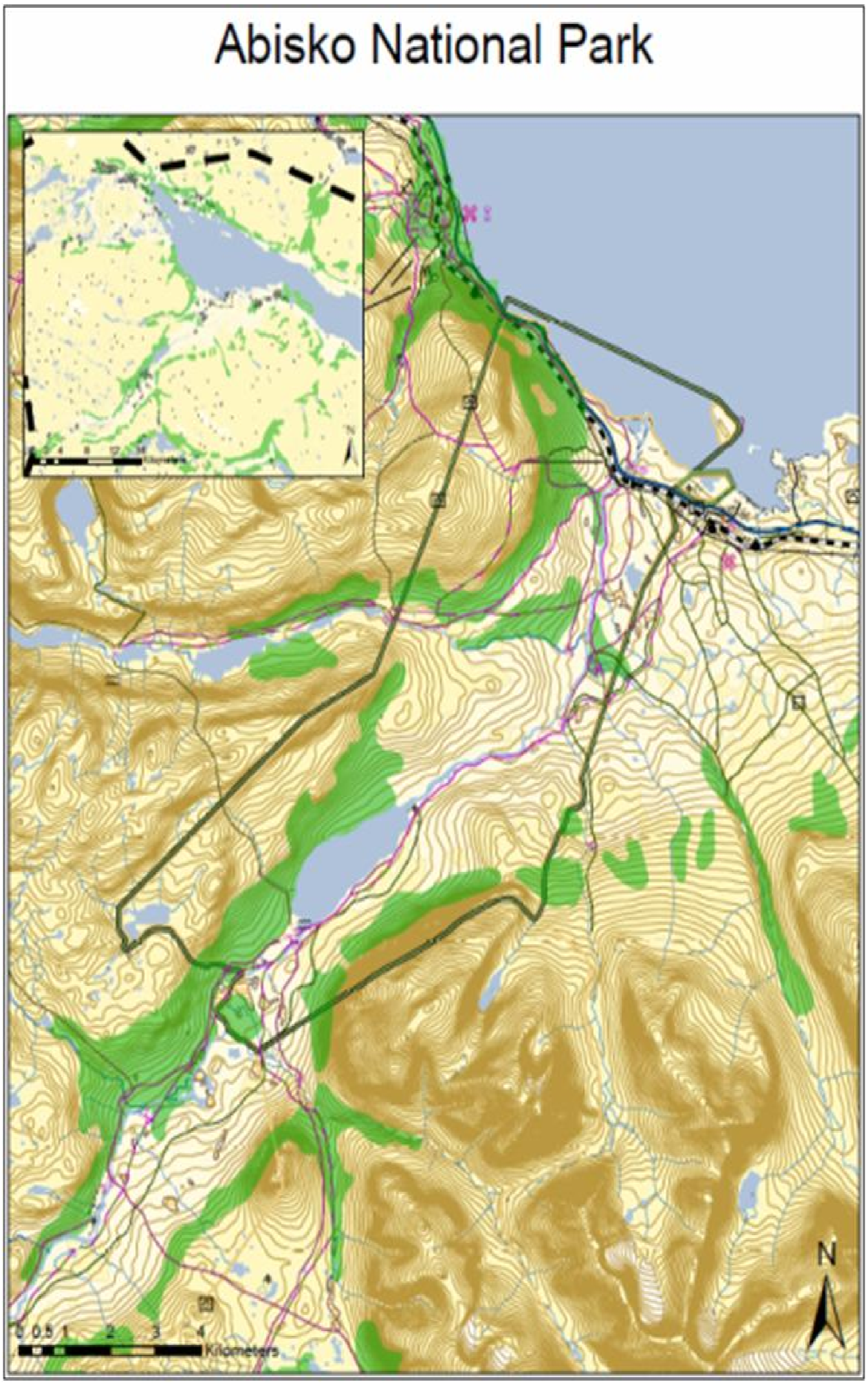

Figure 3. Boundaries of Abisko National Park, using ArcGIS

Figure 4. Vegetation map of Abisko, using ArcGIS. (Different colors represent different types of vegetation).

1.2.3 Temperature

1.2.3.1 Air temperature

The mean annual air temperature at Abisko Scientific Research Station varies through time. During the period 1951 - 1980 it was -0.9 ºC (Eriksson and Valtonen, 1974), 1913 – 1987 -0.79 ºC (Abisko Research Station unpublished data), 1913 – 1960, it was-1.0 ºC and between1966 – 1988, -1.1 ºC.

January and February are the coldest months with mean temperatures ranging between -12.5 ºC and -11.5 ºC (1966-88). The absolute minimum temperature reported was -38.9 ºC on January 28, 1978, the annual range usually being between -20 to -30 ºC. The absolute maximum temperature reported in the area was 31.3 ºC on July 14, 1954 (Abisko Research Station, unpublished data). Between 1966 and 1988, the mean temperatures of the warmest summer months July and August were 11.1 and 9.5 ºC, respectively.

1.2.3.2 Ground temperature

The ground temperature has been measured at Abisko Scientific Research Station since 1913, by means of ocular readings of mercury thermometers, placed at depths ranging between 5 and 200 cm.

The thermal pattern of the ground at Abisko is dominated by freezing and thawing alternating seasonally. Freezing usually starts in October (Stenborg 1965), leaving the ground frozen from November to May. The frost penetrates each year to a depth of 1 to 1.5 m, and may, during certain years, penetrate to 2 m depth (Ekman 1957).

The mean annual temperature, measured at 200 cm depth, ranges from a minimum of 0.4 ºC to a maximum of 2.6 ºC in the period 1926 – 1934 (Abisko Research Station unpublished data).

1.3 Temperature trends 2000 - 2100

It is necessary to explain a bit about the Climate change and how this can affect the vegetation of the Abisko National Park. In order to do that a recent study from Princeton University (Randall, 2007) will be utilized (Figure 5).

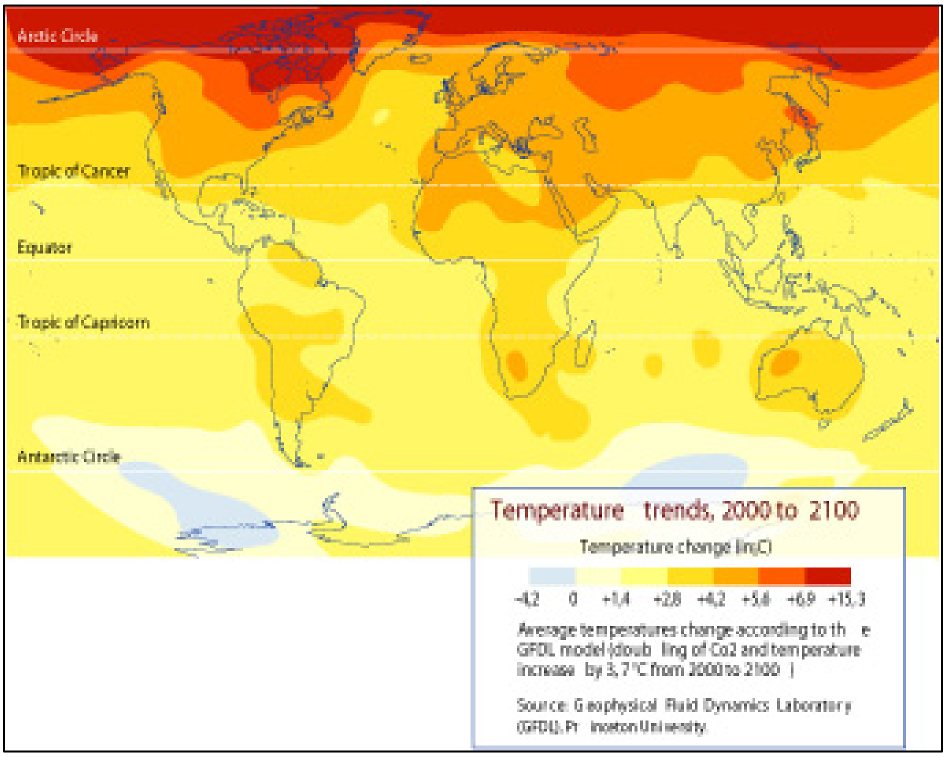

Figure 5. Temperature trends 2000 – 2100, Princeton University, NJ. (Randall, 2007)

In figure 5, global temperature trends from 2000 to 2100 have been realized using the GFDL model (Geophysical Fluid Dynamics Laboratory). At the global scale, it is predicted that CO_2 concentrations will double and temperature increase by 3.7 °C from 2000 to 2100. It is also predicted that the most dramatic change of temperature will occur at the Arctic Circle, where they are expected to increase from 6.9 to 15.3 ^{0}C during 2000 to 2100.

2 Objectives

- In this study, we wish to utilize new data from Abisko (elevation, temperature, and vegetation) in order to establish a correlation across microclimatic factors and vegetation characteristics.

- We wish to use the resulting correlative expression to predict how global warming will affect future food resources for reindeer husbandry.

3 Materials & Methods

3.1 Introduction

In order to establish a relation between the micro-climatic factors and the vegetation of the Abisko National Park, it will be necessary to work with specialized software. The Geographic Information Systems (GIS) software package ArcGIS will be adequate for assessing data regarding temperature, vegetation and elevation of the studied area. In order to correlate these geographically distributed data with data regarding vegetation cover, the statistically oriented software package STATISTICA will be used to perform ordinal regression analysis.

All the data has been obtained from the ANS (Abisko Scientific Research Station), which has been measuring different variables in the Abisko National Park since 1903. In addition, digital maps such as ortho-photos and roadmaps have been used.

Based on the above data, ArcGIS was used for retrieving data from the digital maps, and for forwarding them into STATISTICA for further statistical inference. In ArcGIS there is an important application which is called ArcCatalog, which was used for setting up a project Geo-database and for consecutive data management. The analysis tools required in the project were specially tailored within another important application called ArcGIS ModelBuilder.

3.2 Adaptation of the obtained data

3.2.1 ModelBuilder application

In order to facilitate an understanding about how data was managed, a ModelBuilder preview (Figure 6) will be used for a step-by-step illustration of data adaption. In terms of ArcGIS, ModelBuilder was used to create a new feature class which contains data regarding elevation, vegetation, and temperature; all these variables are associated with XY coordinates (location).

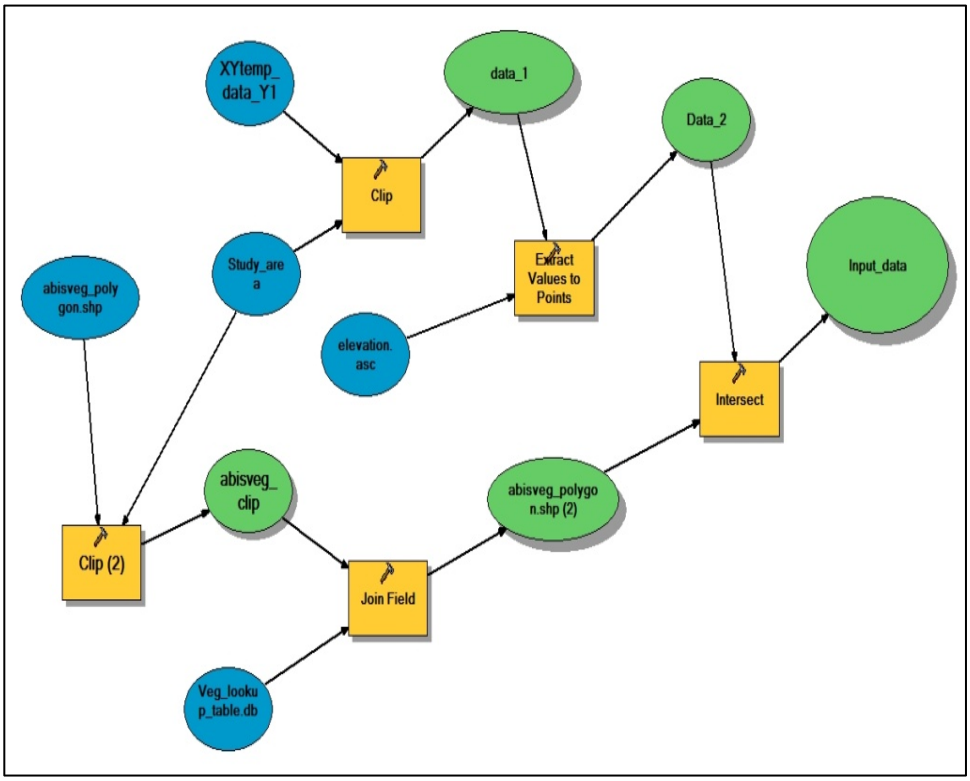

Figure 6. ModelBuilder, tool to produce the intersection of the desired data. (From left to right)

The yellow rectangles of figure 6 are assigned to the different tools that we will use in the Model Builder to produce the final input data that will be used in the STATISTICA software. The principal reason to use ModelBuilder, rather than manual operation, is that we wish to adapt large quantities of data and simultaneously control the error propagation through many individual GIS operations.

The total data cover contains 33,000 point-wise notations of the respective variables temperature, vegetation, elevation, and location, throughout the Abisko National Park.

In order to efficiently develop the ModelBuilder application, it will be subdivided into five different constituents. The first two will be called the "Clip tool" which will reduce the amount of data concerning the studied area (view figure 7).

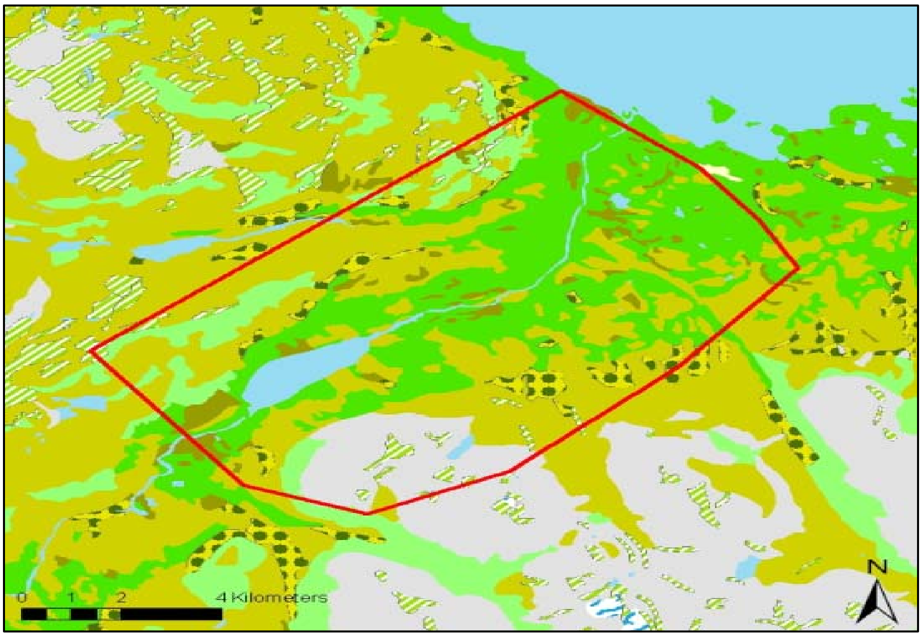

Figure 7. Studied Area of Abisko National Park. (Have been used only the polygons inside the studied area).

After having applied the clip tool, we will introduce the elevation and vegetation data. Elevation data (Figure 8) requires special attention, since we want to extract point-wise data from an elevation raster that coheres with the locations of point-wise assessed vector data.

Once we have the vegetation and the temperature with elevation data joined, we will proceed to intersect the data. But before, it will be important to adapt the vegetation data to the desired raster format, related with our interests regarding Reindeer Husbandry.

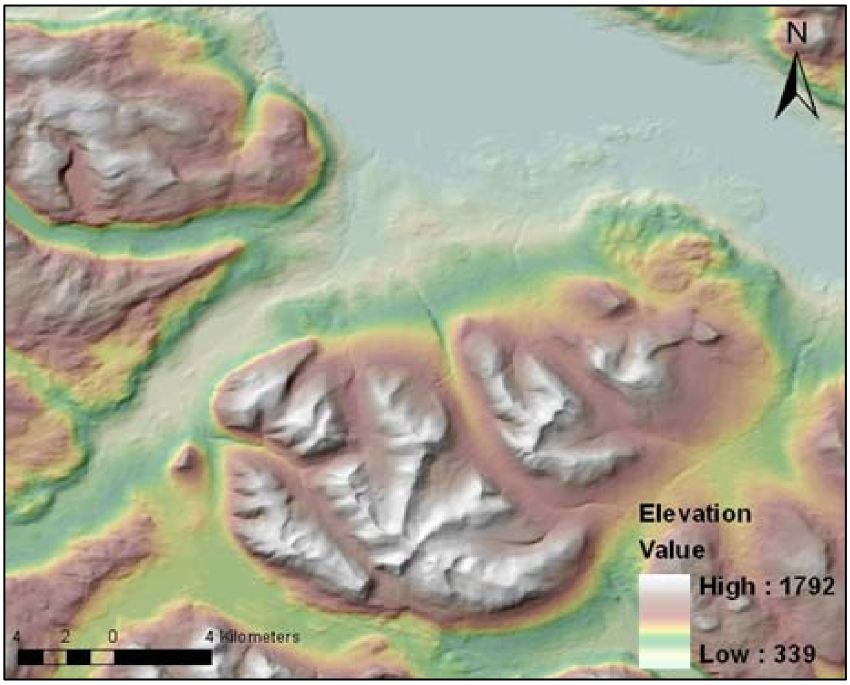

Figure 8. Elevation map of Abisko National Park

3.2.2 The special case of the vegetation data

It is important to study vegetation data separately due to the difficult understanding involved. This data is initially given as polygons which explain the type of vegetation situated through the Abisko valley (view Figure 9). But, if we look to the attributes of these polygons, these vegetation types have been encoded nominally in accordance with the National Swedish convention of vegetation nomenclature. However, we need to transform this nominal scale into an ordinal ditto, since we need to range vegetation polygons with respect to their value for reindeer foraging and husbandry.

To solve this transformation across nominal and ordinal scales, we estimated ordinal values depending on i) the interest of the reindeer feeding, ii) vegetation abundance through different seasons of the year, and iii) annually varying vegetation exposure to annually migrating reindeer.

Attributes of abisveg_polygon

FID	Shape	AREA	PERIMETER	ABISVEG	ABISVEG_ID	VEGKOD	INSLAG	SYMBOL
0	Polygon	777340030	259142	2	1	195	0	235
1	Polygon	400214	4636.6401	3	2	111	0	235
2	Polygon	394314	5870.2202	4	3	132	0	235
3	Polygon	422762	4992.6602	5	4	101	0	235
4	Polygon	1104900	8354.0703	6	5	101	0	235
5	Polygon	339045	2899.1799	7	6	131	0	235
6	Polygon	125102	2035.24	8	7	132	0	235
7	Polygon	3283600	16621.5	9	8	121	113	235
8	Polygon	16858.1	577.67499	10	9	101	0	235
9	Polygon	49615.5	978.42499	11	5121	101	0	235
10	Polygon	357748	3321.3	12	10	101	0	235
11	Polygon	304399	3539.54	13	5123	132	0	235
12	Polygon	316683	3493.53	14	12	111	0	235
13	Polygon	2594780	21202.9	15	13	113	121	235
14	Polygon	658344	3867.73	16	14	114	121	235
15	Polygon	113363	2083.9099	17	15	132	0	235
16	Polygon	547145	3953.6399	18	11	101	0	235
17	Polygon	433446	3221.47	19	16	108	0	235
18	Polygon	3805620	32017	20	5122	101	0	235
19	Polygon	1332350	15370	21	18	132	0	235
20	Polygon	325626	3364.8799	22	19	101	121	235
21	Polygon	413212	5158.6802	23	20	132	0	235

Figure 9. Different codifications of the vegetation polygons

		VEGKOD	Area of Interest	ReindeerVegetation Interests
6 Substratmarker - Block- och hällmark	Substrate land - Blocks/ boulder and flat rock	101	0	0
8 Substratmarker - Glaciär	Substrate land - Glacier	108	0	0
7 Substratmarker - Vatten	Substrate land - Water	109	0	0
11 Substratmarker - Alpin gräshed	Substrate land - Alpine grassy moor	111	1	3
12 Substratmarker - Skarp rished	Substrate land - Sharp shrubby moor	112	1	5
13 Substratmarker - Torr rished	Substrate land - Dry shrubby moor	113	1	6
15 Substratmarker - Frisk rished	Substrate land - Fresh shrubby moor	114	1	7
16 Substratmarker - Fuktig-våt rished	Substrate land - Moist-wet shrubby moor	115	2	8
19 Ängsmarker - Alpin lågörtäng	Meadow land - Alpine low ground meadow	121	1	2
21 Ängsmarker - Ängsmark	Meadow land - Meadow land	123	1	4
28 Snölegevegetation - Moderat snölega	Nival snow patch vegetation - Moderate nival snow patch	131	0	0
29 Snölegevegetation - Extrem snölega	Nival snow patch vegetation - Extreme nival snow patch	132	0	0
32 Öppna myrar - Rismyr (mosse)	Open mire land - Shrubby mire (moss)	141	1	6
34 Öppna myrar - Torrt kärr	Open mire land - Dry marshland	143	1	3
35 Öppna myrar - Backkärr	Open mire land - Sloping marshland	144	1	2
36 Öppna myrar - Vått kärr	Open mire land - Wet marshland	145	1	7
37 Öppna myrar - Blandad myr	Open mire land - Mixed marshland	146	1	7
51 Buskmarker - Vide	Bush land - Willow	150	2	8
55 Lövskogar - Lavrik hedbjörkskog	Deciduous forrest - Lichen rich moor birch forrest	161	2	9
56 Lövskogar - Mossrik hedbjörkskog	Deciduous forrest - Moss rich moor birch forrest	162	2	8
57 Lövskogar - Ängslövskog	Deciduous forrest - Meadow Deciduous forrest	163	2	10
72 Övrig mark - Tät bebyggelse	Other land - Dense populated area	192	0	0
75 Övrig mark - Ospec	Other land - Undefined	195	0	0

Figure 10. Table which explains the different values depending of the different type of vegetation

For example, the vegetation class called Lichen rich moor birch forest, has a value of 2/2 if we talk about its suitability for reindeer foraging, which is due to the lichen being the most important food source for the reindeers during mostly winter season in the Abisko area, Ahti (1961). But regarding the value referred to as “Reindeer Vegetation Interests” it has 9/10 when we have considered that in this case the reindeers during the summer season prefer to eat other sources of food such as; meadow from deciduous forest (Figure 10) (Alaurikka, 1964).

Also there are polygons with a 0 value. These polygons comprise; blocks, glaciers, water, snow-patches, dense populated areas, and undefined polygons. It is necessary to mention that the water is considered as 0 value due to in the Abisko National Park the water is very easy to find and with a very good quality too.

3.2.3 The temperature data

Finally, the last variable that we need to explain is the Temperature data. The data that we have received from the ANS, it pertains to the months of January and July of the years; 1913, 1996 and 2006. All temperatures are supplied with their associated XY coordinates.

The format wherein we received this data was as a text file, so we needed to adapt this files as shape files to a better understanding for the ArcGIS, STATISTICAL software’s, and specially also for us. To adapt the data we used the ArcCatalog as we can observe in the figure 11. We have to select the text file and choose create a feature class from XY table option and then, we can create the desired shape file.

The result is the creation of the shape file. In the Figure 12 we can observe the points of the temperature data which reflects the location and the temperature that has every point.

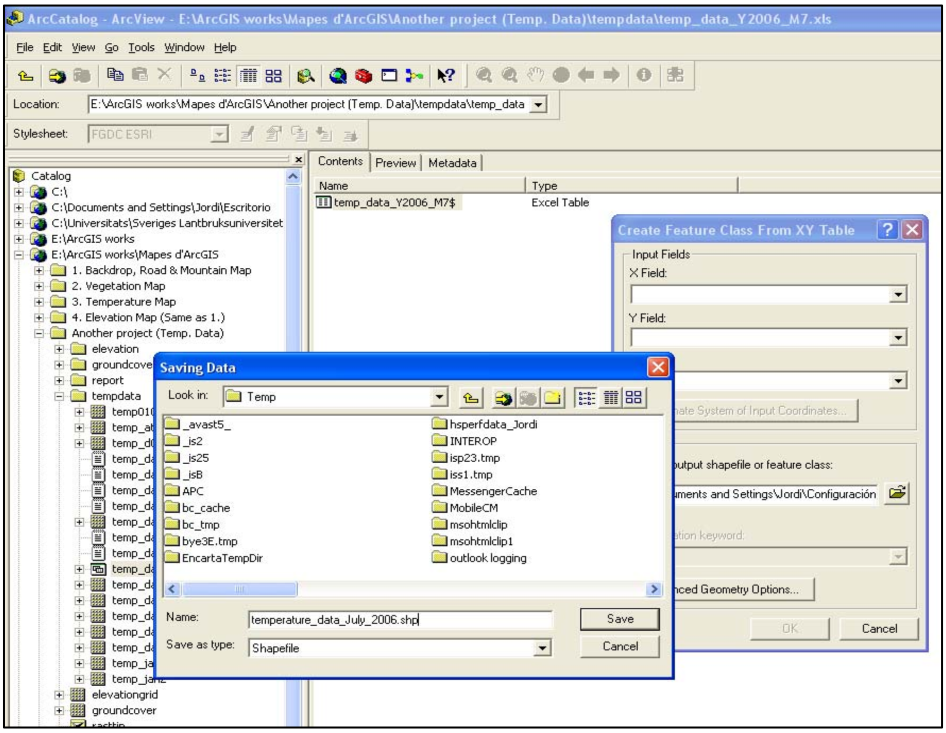

Figure 11. Saving the text file as a shape file (shp.) using ArcCatalog.

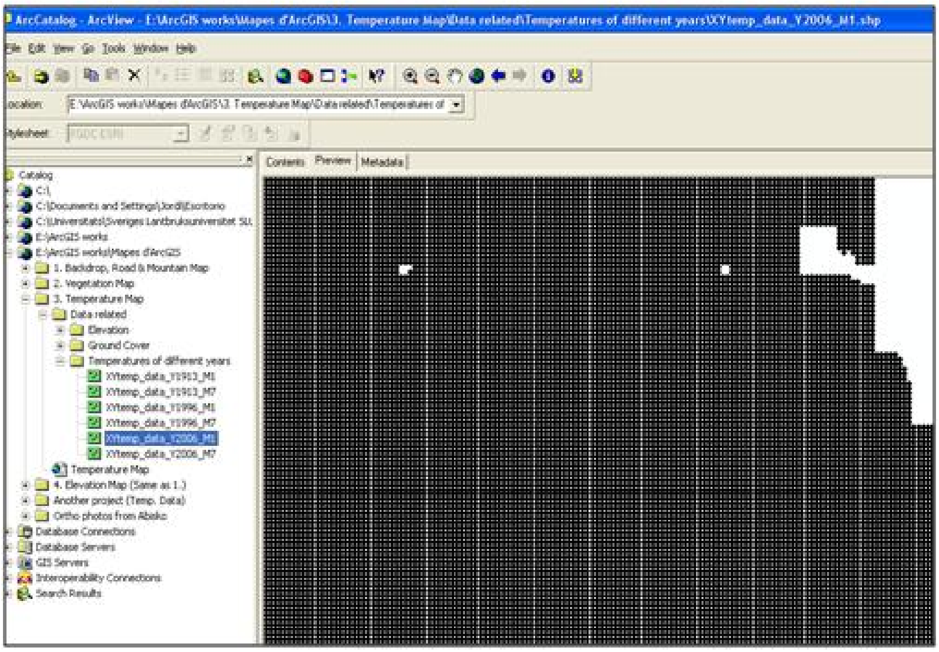

Figure 12. Points which pertain to the temperature shape file. These points will be added to the ArcGIS software.

3.2.4 The final data

After to transform all the data and joined adequately it will be necessary to create an excel file which will contain all the data studied, (Figure 13).

Area of Interest	ReindeerVegetation Interest	X	Y	Temperature	Elevation
1	2	1615924,815	7578324,892	10,0613	889,2803
1	6	1615724,815	7578324,892	10,0372	755,8564
1	2	1615974,815	7578324,892	10,0903	908,8536
1	6	1615624,815	7578324,892	10,0757	679,6276
1	2	1615824,815	7578324,892	10,0557	832,9412
1	2	1615874,815	7578324,892	10,0735	867,1668
1	6	1615574,815	7578324,892	10,5028	641,3523
1	6	1615674,815	7578324,892	10,0675	718,9636
1	6	1615774,815	7578324,892	10,0190	791,9920
2	8	1615424,815	7578324,892	10,5157	590,9199
2	8	1615474,815	7578324,892	10,5215	602,0517
2	8	1615524,815	7578324,892	10,4994	617,3136
2	8	1615274,815	7578324,892	10,5726	564,6097
2	8	1615324,815	7578324,892	10,5351	573,3072
2	8	1615374,815	7578324,892	10,5059	581,8025
1	7	1615124,815	7578324,892	10,7559	541,2344
1	7	1615224,815	7578324,892	10,5738	555,7065
1	7	1615174,815	7578324,892	10,7835	547,5235
2	8	1614874,815	7578324,892	10,7589	516,7613

Figure 13. Excel file which contains all the data studied. The XY coordinates reflect every point.

The 33,000 points of data (July & January, from the years 1913, 1996 and 2006) contain the X and Y coordinates, Area of interest values, Reindeer vegetation interests values, Temperature and Elevation values. The Temperature is in ^{0}C and the Elevation in meters.

3.3 STATISTICA software

Once the final data has been obtained, it will be necessary to use a sophisticated statistics tool which contains a suitable algorithm for Ordinal Multinomial Regression. This tool pertains to the STATISTICAL software.

$$T(y) = \beta 0 + \beta i \cdot Temp + \varepsilon\,(0, \delta 2R)$$

This formula will be divided in dependent variables and the independent variables which will try to predict the dependent variable. In our case the dependent variable will be the vegetation.

Dependent variable:

- T(y) is a link function that transforms binary (y) to the continuous scale of Temp. (Temperature, i.e.).

Independent variables:

- β0: Constant.
- βi: Elevation.
- Temp: Temperature.
- ε: Residual values such as wind, contamination, etc. (not possible to predict).
- (0, δ2R): Expected value of ε has to be 0, δ2R is the residual variance.

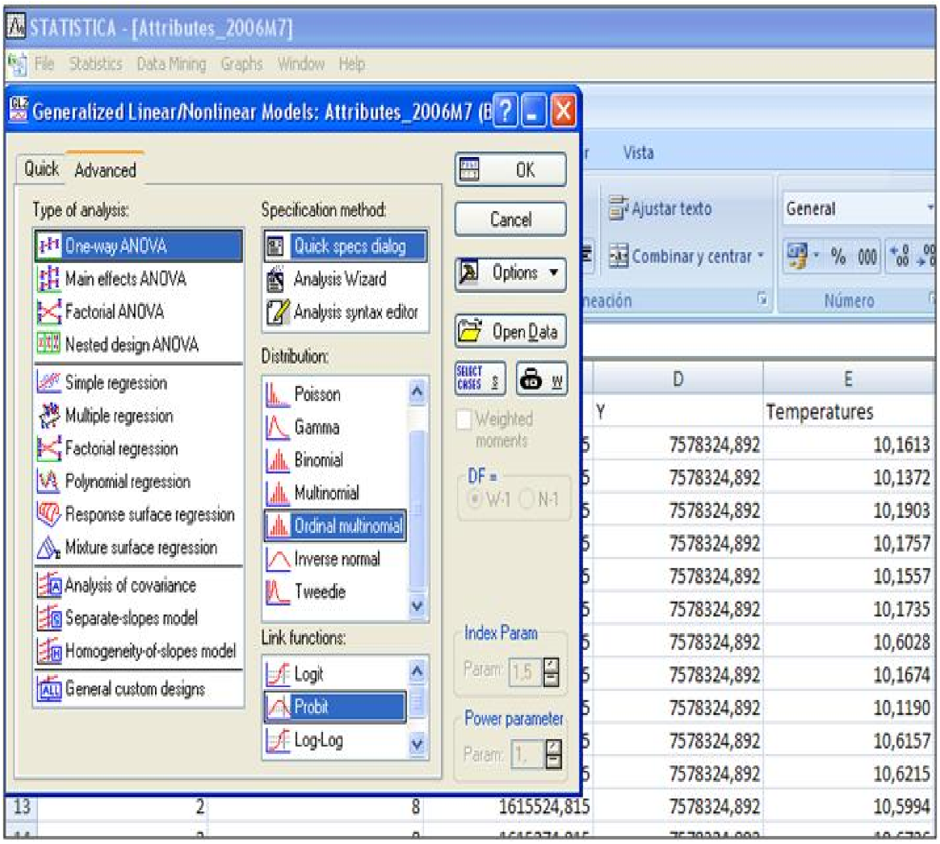

Figure 14. The Ordinal Multinomial Regression in STATISTICA software

4 Results

4.1 The statistically significant correlation

In order to establish a regression equation, it is necessary to infer whether a statistically significant correlation exists between the variables discussed above. To show this correlation and then to say that the regressions are significant, we have to observe the statistical results (Figures 22 to 27) such as Chi-square and p (prob value). If the p value is smaller than 0.05, then the Chi-square is higher than 1, and the results will be significant. See the Annex for a compilation of statistical outputs.

	Veg_3 - Test of all effects (Blad1) Distribution : ORDINAL MULTINOMIAL Link function: LOGIT		
Effect	Degr. of Freedom	Wald Stat.	p
Intercept	2	15841,96	0,00
1913_M7_Temp	1	4128,55	0,00

	Veg_3 - Likelihood Type 1 Test (Blad1) Distribution : ORDINAL MULTINOMIAL Link function: LOGIT			
Effect	Degr. of Freedom	Log-Likelihd	Chi-Square	p
Intercept	2	-30215,0		
1913_M7_Temp	1	-27835,6	4758,937	0,00

Figure 15. Example of Chi-Square and P value from the July of 1913

In our case, all the diagrams created have a p value smaller than of 0.00 and a Chi-square with a value higher than 4000, which means that there exists an extremely significant correlation between the different variables studied. This strong correlation is due to the abundance of data, with approximately 33,000 observations per variable.

Finally, in all the regressions that utilize vegetation data, it will be necessary to discard the value 0 per each vegetation codes. This value 0 (as is shown in the figure 10) pertain to; glaciers, water, dense populated areas, extreme snow patch, moderate snow patch, blocks/boulder, flat rocks and undefined lands. These materials and soil types appear as a significant constituent in the studied area, but must be discarded since they are unimportant with respect to reindeer foraging and husbandry.

Once the regressions are proved to be statistically significant, we can use them to predict climate change effects on reindeer husbandry.

4.2 The importance of the elevation

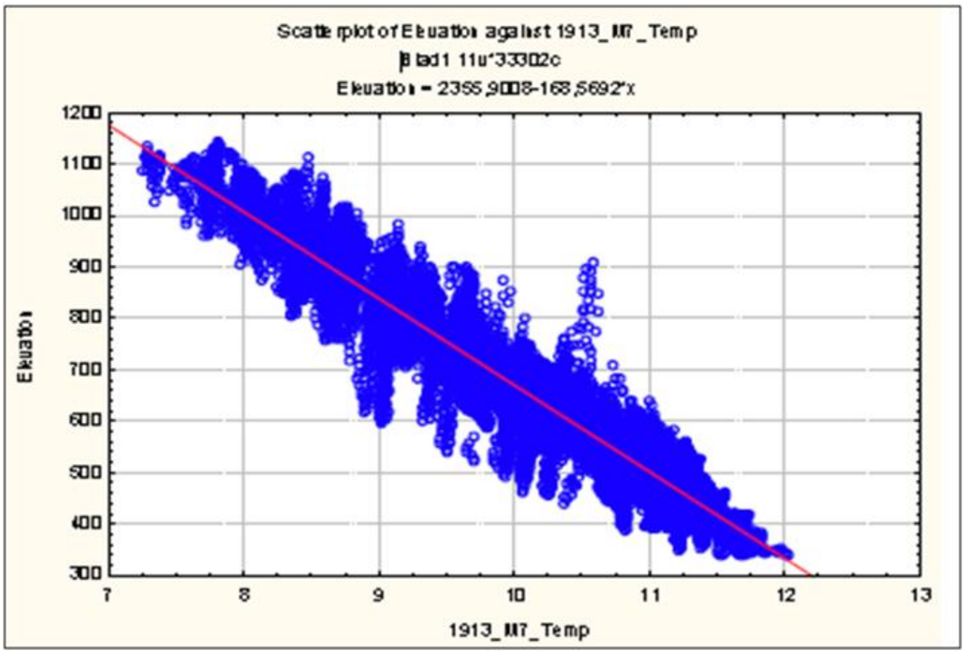

Figure 16. Elevation compared with the Temperature (July of 1913 in this case). At less elevation will be more temperature.

To develop the objectives it is necessary to describe the correlation between elevation and temperature as observed in the Abisko National Park. This influence is important due to its effect on vegetation.

As plotted in figure 16, the Y axis holds elevation data and the X axis the corresponding temperature data.

So, it is possible to deduce that at higher altitude there will generally be less temperature. For example at 8 ^{0}C pertain at 1000 meters of altitude, but at 11 ^{0}C will pertain at 500 meters of altitude.

4.3 Mean Plot Temperatures against the Vegetation codes

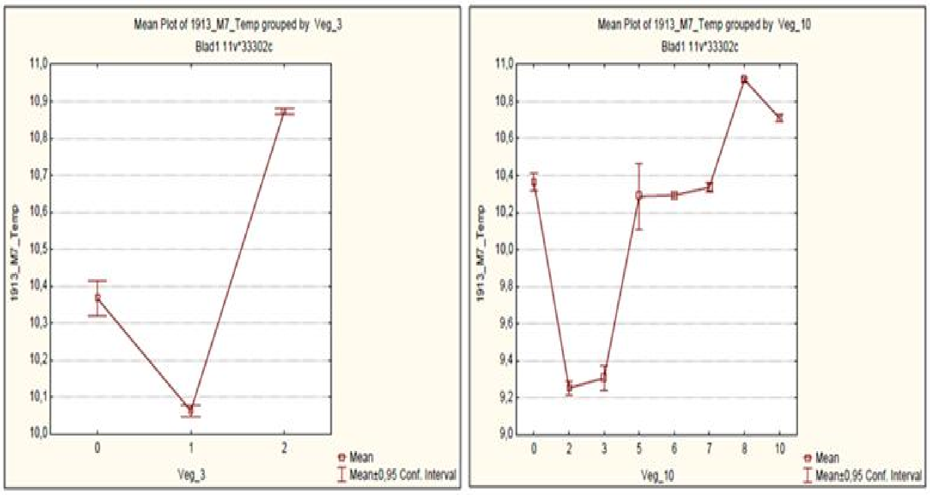

Figure 17. Mean Plot Temperature July of 1913 / Area of Interest (left diagram) / Reindeer & Vegetation Interests (right diagram)

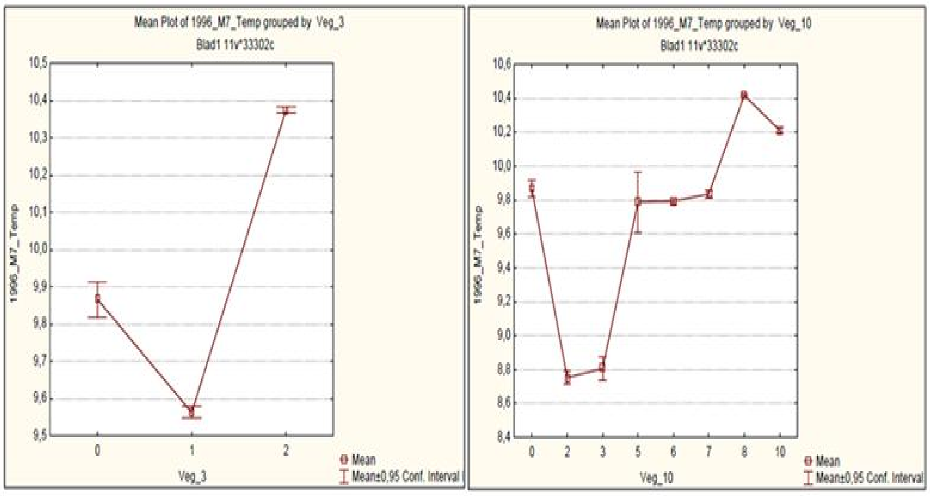

Figure 18. Mean Plot Temperature July of 1996 / Area of Interest (left diagram) / Reindeer & Vegetation Interests (right diagram)

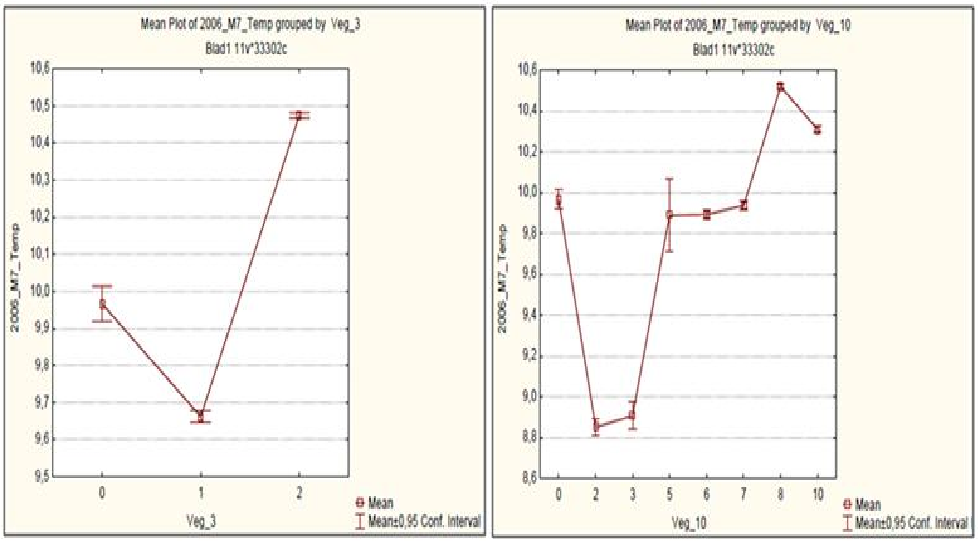

Figure 19. Mean Plot Temperature July of 2006 / Area of Interest (left diagram) / Reindeer & Vegetation Interests (right diagram)

The figures; 17, 18 and 19, show the mean values of temperature together with the two established vegetation codes. It is important to mention that observed temperatures have been increasing from 1913 to 2006, but that this increase not is statistically significant (point estimates are increasing but trend is within the 95% confidence interval).

If the value 0 is discarded as discussed above, an ascending regression line will appear (Figure 20). This means that the ordinal classification of vegetation is significantly correlated with temperature and/or elevation and, hence, that reindeer preferences may be partly described using temperature and/or elevation data.

Regarding the regression diagram (Figure 20) related with the Reindeer & vegetation interests, it is possible to subdivide vegetation classes into 3 cluster groups, where the 1:st cluster contain vegetation classes 2 and 3, the 2:nd cluster contain vegetation classes 5, 6, and 7, and the 3:rd cluster contain the vegetation classes 8 and 10.

We conclude that it is possible to create a regression line (Figure 21) that reveals that the vegetation preferred by reindeer are correlated with relatively warm situations, which means that increasing temperatures are likely to expand suitable grazing towards higher altitude, and that this will occur at the expense of vegetation adapted to colder climate.

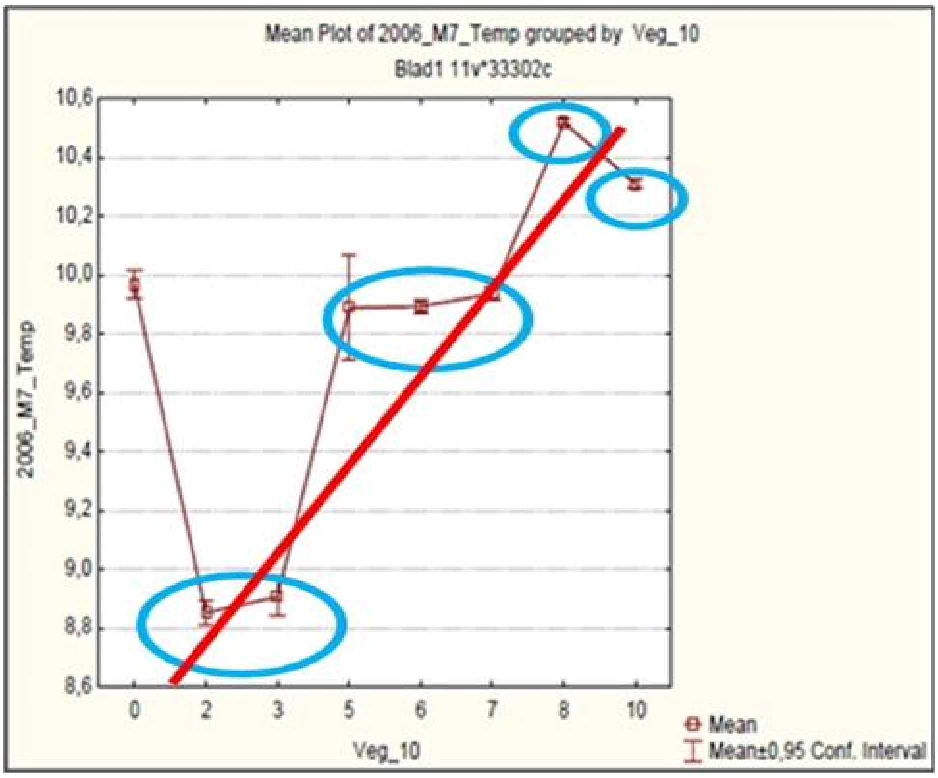

Figure 20. Imaginary red line which contains the different groups of reindeer & vegetation interests

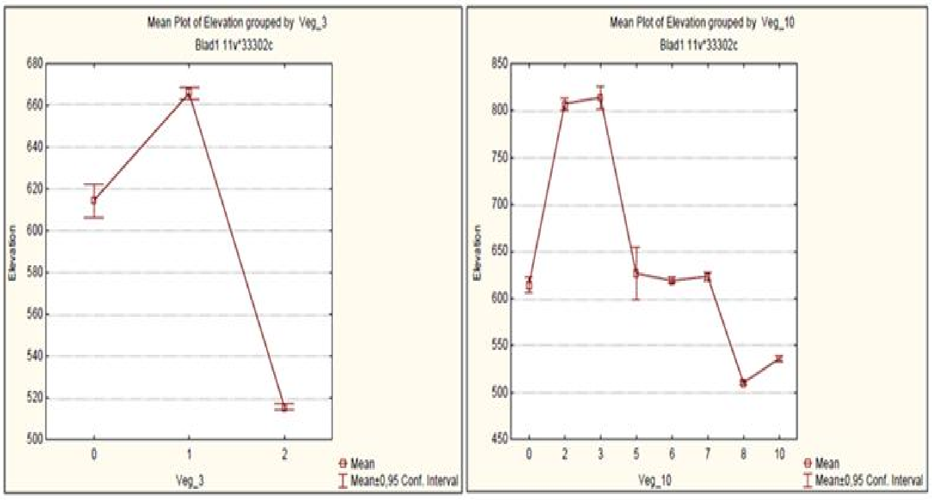

Figure 21. Mean Plot Elevation / Area of Interest (left diagram) / Reindeer & Vegetation Interests (right diagram)

5 Discussions

1. In order to regress temperature on vegetation type, the classification and coding of vegetation had to be transformed from the nominal scale type to the ordinal. In the official classification of vegetation types, there does not exist any ranking across types, i.e. the classification is nominal. This contradicts the usage of regression methodology where interval scale temperature requires at least an ordinal regressor. This situation was solved via an estimation of the reindeer foraging value of the different vegetation types, which allows for vegetation types to be ranked on the ordinal scale. The resulting ordinal values were estimated on the basis of literature studies in combination with personal opinions of experts. They might therefore be subjective and difficult to verify by scientific means.

2. With a dense field of temperature data at hand, temperature values are most probably spatially correlated. Since the ordinal regression procedures deployed assume independent values, an error was introduced that was not accounted for. The eventual correlation structures reduce the degrees of freedom assumed by the regression procedure, the significance of the associated tests is exaggerated. However, with so many measurement vales (n = 33,000), the effect of spatial correlation is expectedly small.

3. Although this thesis predicts that increasing mean temperatures will have a generally positive effect on the grazing possibilities of reindeer, it says nothing about the expected time horizon for such an effect. Neither does it inquire the effects of changing extremes. Foreseeing whether the eventual effects of changing extremes outweigh mean effects lays outside the scope of this thesis.

6 Conclusions

- As shown in the results, the vegetation codes best preferred by reindeers have been found in the warm spectra of observed summer temperatures, in the approximate range of 10 to 11 ^{0}C.

- If a future scenario of reindeer husbandry is extrapolated in the study area, we predict that the most interesting types of vegetation for the reindeers are likely to increase with warmer temperatures.

- Since temperature changes with elevation, we predict that the most interesting vegetation types are likely to expand uphill, on the expense of vegetation types adapted to colder temperatures (and hence to higher altitude).

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Annex

Effect	Veg_3 - Test of all effects (Blad1) Distribution : ORDINAL MULTINOMIAL Link function: LOGIT Degr. of Freedom	Wald Stat.	p
Intercept	2	15841,96	0,00
1913_M7_Temp	1	4128,55	0,00

Effect	Veg_3 - Likelihood Type 1 Test (Blad1) Distribution : ORDINAL MULTINOMIAL Link function: LOGIT Degr. of Freedom	Log-Likelihd	Chi-Square	p
Intercept	2	-30215,0		
1913_M7_Temp	1	-27835,6	4758,937	0,00

Effect	Veg_3 - Likelihood Type 3 Test (Blad1) Distribution : ORDINAL MULTINOMIAL Link function: LOGIT Degr. of Freedom	Log-Likelihd	Chi-Square	p
1913_M7_Temp	1	-30215,0	4758,937	0,00

Stat.	Veg_3 - Statistics of goodness of fit (Blad1) Distribution : ORDINAL MULTINOMIAL Link function: LOGIT Df	Stat.	Stat/Df
Deviance	66601	55671,1	0,835890
Scaled Deviance	66601	55671,1	0,835890
Pearson Chi²	66601	87683,8	1,316554
Scaled P. Chi²	66601	87683,8	1,316554
AIC		55677,1	
BIC		55704,4	
Loglikelihood		-27835,6	

Figure 22. Ordinal Multinomial distribution, July of 1913 / Area of Interest table

Effect	Veg_3 - Test of all effects (Blad1) Distribution : ORDINAL MULTINOMIAL Link function: LOGIT Degr. of Freedom	Wald Stat.	p
Intercept	2	15837,12	0,00
1996_M7_Temp	1	4128,55	0,00

Effect	Veg_3 - Likelihood Type 1 Test (Blad1) Distribution : ORDINAL MULTINOMIAL Link function: LOGIT Degr. of Freedom	Log-Likelihd	Chi-Square	p
Intercept	2	-30215,0		
1996_M7_Temp	1	-27835,6	4758,937	0,00

Effect	Veg_3 - Likelihood Type 3 Test (Blad1) Distribution : ORDINAL MULTINOMIAL Link function: LOGIT			
	Degr. of Freedom	Log-Likelihd	Chi-Square	p
1996_M7_Temp	1	-30215,0	4758,937	0,00

Stat.	Veg_3 - Statistics of goodness of fit (Blad1) Distribution : ORDINAL MULTINOMIAL Link function: LOGIT		
	Df	Stat.	Stat/Df
Deviance	66601	55671,1	0,835890
Scaled Deviance	66601	55671,1	0,835890
Pearson Chi²	66601	87683,8	1,316554
Scaled P. Chi²	66601	87683,8	1,316554
AIC		55677,1	
BIC		55704,4	
Loglikelihood		-27835,6	

Figure 23. Ordinal Multinomial distribution, July of 1996 / Area of Interest table

Effect	Veg_3 - Test of all effects (Blad1) Distribution : ORDINAL MULTINOMIAL Link function: LOGIT		
	Degr. of Freedom	Wald Stat.	p
Intercept	2	15838,12	0,00
2006_M7_Temp	1	4128,55	0,00

Effect	Veg_3 - Likelihood Type 1 Test (Blad1) Distribution : ORDINAL MULTINOMIAL Link function: LOGIT			
	Degr. of Freedom	Log-Likelihd	Chi-Square	p
Intercept	2	-30215,0		
2006_M7_Temp	1	-27835,6	4758,937	0,00

Effect	Veg_3 - Likelihood Type 3 Test (Blad1) Distribution : ORDINAL MULTINOMIAL Link function: LOGIT			
	Degr. of Freedom	Log-Likelihd	Chi-Square	p
2006_M7_Temp	1	-30215,0	4758,937	0,00

Stat.	Veg_3 - Statistics of goodness of fit (Blad1) Distribution : ORDINAL MULTINOMIAL Link function: LOGIT		
	Df	Stat.	Stat/Df
Deviance	66601	55671,1	0,835890
Scaled Deviance	66601	55671,1	0,835890
Pearson Chi²	66601	87683,8	1,316554
Scaled P. Chi²	66601	87683,8	1,316554
AIC		55677,1	
BIC		55704,4	
Loglikelihood		-27835,6	

Figure 24. Ordinal Multinomial distribution, July of 2006 / Area of Interest table

Effect	Veg_10 - Test of all effects (Blad1) Distribution : ORDINAL MULTINOMIAL Link function: LOGIT		
	Degr. of Freedom	Wald Stat.	p
Intercept	7	36673,76	0,00
1913_M7_Temp	1	5536,55	0,00

Effect	Veg_10 - Likelihood Type 1 Test (Blad1) Distribution : ORDINAL MULTINOMIAL Link function: LOGIT			
	Degr. of Freedom	Log-Likelihd	Chi-Square	p
Intercept	7	-57806,2		
1913_M7_Temp	1	-54740,5	6131,336	0,00

Veg_10 - Likelihood Type 3 Test (Blad1)
Distribution : ORDINAL MULTINOMIAL
Link function: LOGIT

Effect	Degr. of Freedom	Log-Likelihd	Chi-Square	p
1913_M7_Temp	1	-57806,2	6131,336	0,00

Veg_10 - Statistics of goodness of fit (Blad1)
Distribution : ORDINAL MULTINOMIAL
Link function: LOGIT

Stat.	Df	Stat.	Stat/Df
Deviance	233106	109481,1	0,469662
Scaled Deviance	233106	109481,1	0,469662
Pearson Chi²	233106	250866,3	1,076190
Scaled P. Chi²	233106	250866,3	1,076190
AIC		109497,1	
BIC		109579,9	
Loglikelihood		-54740,5	

Figure 25. Ordinal Multinomial distribution, July of 1913 / Reindeer & Vegetation interests table

Veg_10 - Test of all effects (Blad1)
Distribution : ORDINAL MULTINOMIAL
Link function: LOGIT

Effect	Degr. of Freedom	Wald Stat.	p
Intercept	7	36673,20	0,00
1996_M7_Temp	1	5536,55	0,00

Veg_10 - Likelihood Type 1 Test (Blad1)
Distribution : ORDINAL MULTINOMIAL
Link function: LOGIT

Effect	Degr. of Freedom	Log-Likelihd	Chi-Square	p
Intercept	7	-57806,2		
1996_M7_Temp	1	-54740,5	6131,336	0,00

Veg_10 - Likelihood Type 3 Test (Blad1)
Distribution : ORDINAL MULTINOMIAL
Link function: LOGIT

Effect	Degr. of Freedom	Log-Likelihd	Chi-Square	p
1996_M7_Temp	1	-57806,2	6131,336	0,00

Veg_10 - Statistics of goodness of fit (Blad1)
Distribution : ORDINAL MULTINOMIAL
Link function: LOGIT

Stat.	Df	Stat.	Stat/Df
Deviance	233106	109481,1	0,469662
Scaled Deviance	233106	109481,1	0,469662
Pearson Chi²	233106	250866,3	1,076190
Scaled P. Chi²	233106	250866,3	1,076190
AIC		109497,1	
BIC		109579,9	
Loglikelihood		-54740,5	

Figure 26. Ordinal Multinomial distribution, July of 1996 / Reindeer & Vegetation interests table

Veg_10 - Test of all effects (Blad1)
Distribution : ORDINAL MULTINOMIAL
Link function: LOGIT

Effect	Degr. of Freedom	Wald Stat.	p
Intercept	7	36673,32	0,00
2006_M7_Temp	1	5536,55	0,00

Veg_10 - Likelihood Type 1 Test (Blad1)
Distribution : ORDINAL MULTINOMIAL
Link function: LOGIT

Effect	Degr. of Freedom	Log-Likelihd	Chi-Square	p
Intercept	7	-57806,2		
2006_M7_Temp	1	-54740,5	6131,336	0,00

Veg_10 - Likelihood Type 3 Test (Blad1)
Distribution : ORDINAL MULTINOMIAL
Link function: LOGIT

Effect	Degr. of Freedom	Log-Likelihd	Chi-Square	p
2006_M7_Temp	1	-57806,2	6131,336	0,00

Veg_10 - Statistics of goodness of fit (Blad1)
Distribution : ORDINAL MULTINOMIAL
Link function: LOGIT

Stat.	Df	Stat.	Stat/Df
Deviance	233106	109481,1	0,469662
Scaled Deviance	233106	109481,1	0,469662
Pearson Chi²	233106	250866,3	1,076190
Scaled P. Chi²	233106	250866,3	1,076190
AIC		109497,1	
BIC		109579,9	
Loglikelihood		-54740,5	

Figure 27. Ordinal Multinomial distribution, July of 2006 / Reindeer & Vegetation interests table

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