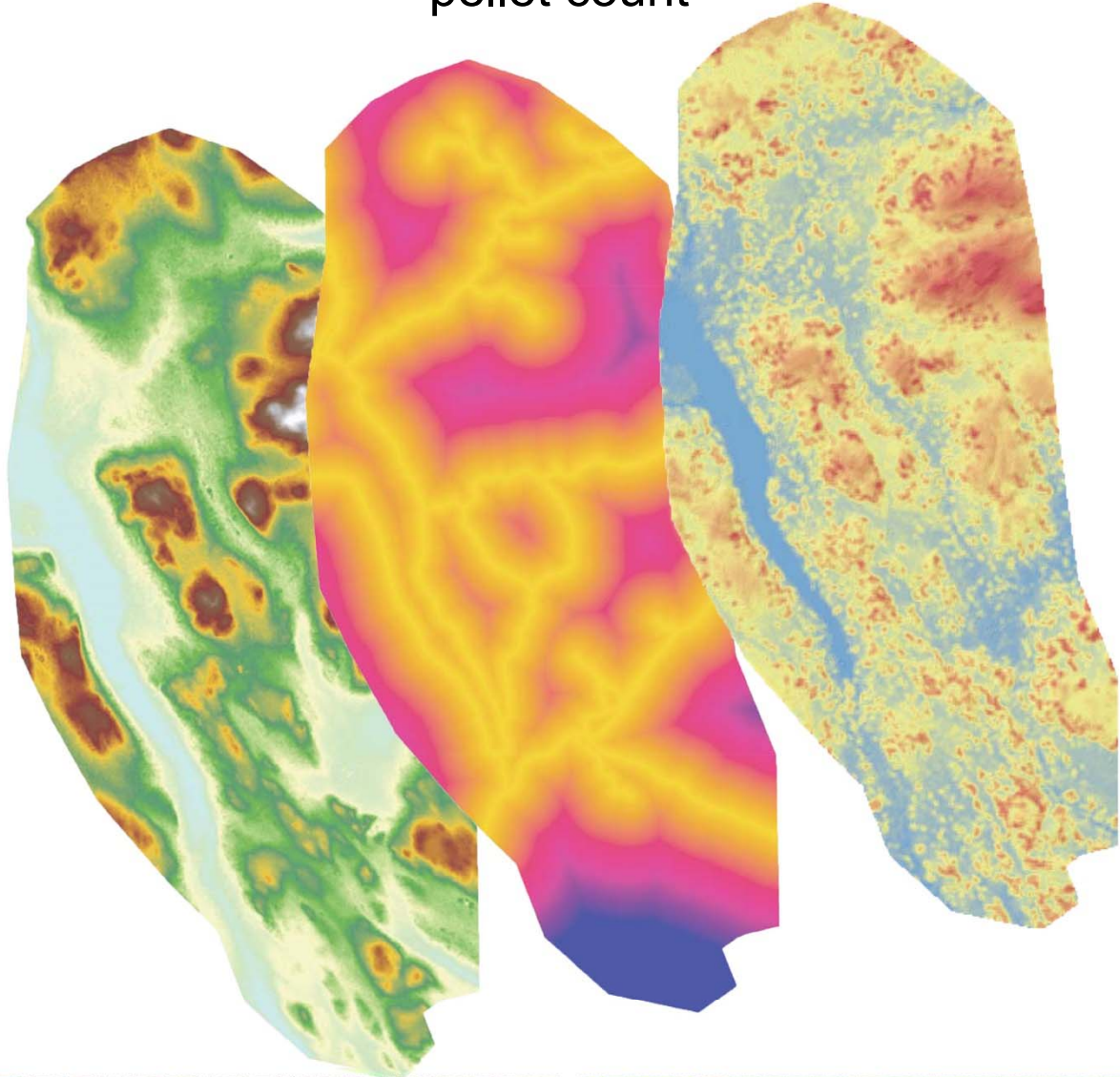


Seasonal habitat use of moose assessed by faecal pellet count



Bachelor thesis research report

Seasonal habitat use of moose assessed by faecal pellet count

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The pictures on cover page are provided by Barbara Zimmermann

Abstract

The moose (*Alces alces*) shows partial migration in Scandinavia. During the seasons access to forage sources differs, where in winter this is more limited, due to e.g. snow cover. In summer various sources are available. The age class of the forest roughly reflects the forage availability for the moose. However, besides vegetation also fear of predators and human disturbance affects the moose space use. Studies on habitat use are conducted in various ways, with most cost-effective the moose pellet counts. In this thesis I focused on the difference of moose distribution and habitat use between summer and winter, with the use of summer and winter pellet counts I studied the relation between moose presence and vegetation, abiotic factors as elevation and snow depth, and anthropogenic factors. In the end, I predicted the probability of finding moose pellets in the whole research area for the summer and the winter.

The study was conducted in the east of Norway (Hedmark County) in an area of approximately 1000 km². The area consists of different forest types, intermixed with rural areas as agriculture and human settlements. The pellet counts were done in sample squares (n = 121, n = 129, winter and summer, respectively). Every sample square consisted of 5 circular sample plots 100 m² per plot). With the use of spatial analyses techniques, I defined maps and data for different vegetation types, stand age classes, elevation, slope, aspect, and snow depth. As well as for distance to roads and settlements, and density of settlements. All data was summarised per sample plot and per sample square. I used a Generalised Linear Model (GLM) with a logit link function and moose pellet presence/absence data (binary distribution) at the sample square level. I used the estimates produced by the models to predict the probability of finding moose pellets and with the use of the resource selection function (RSF) I predicted moose pellet probability for the summer and winter for the whole study area.

In summer, higher elevation and older forests (30-60 years) resulted in higher probability of finding moose pellets (3 times higher at 800 m.a.s.l. compared to 435 m.a.s.l.). Age class 0, consisted of non-productive forest and non-forest areas, showed a lower probability, expected due to a high proportion of mires (44%) in this age class. As moose tends to avoid mires in summer.

In winter, the moose pellet probability is negatively related with elevation (probability is 1.5 times higher at 435 m.a.s.l. compared to 800 m.a.s.l.). Within the vegetation types, pine showed a positive effect on the probability of finding moose pellets. The distance to private roads seems to have an optimal distance of 700 metres. The density of cabins showed a positive effect (7.5 times higher probability in high density areas, compared to low density). However, the distance to cabins shows an increase in moose probability if distance to cabins increases (1.3 times higher probability at 3000 metres distance from cabin). This might be explained by the possibility of moose feeding station or moose uses cabin areas as a wolf avoidance technique. The prediction maps showed that 50% of the area has a probability of finding moose pellets >0.5 for summer and winter. However, the probability seems to be more concentrated in the lower areas in winter, while in summer they are more concentrated in the higher areas.

Eventually, I concluded that moose habitat use in summer results in higher elevations and likely avoidance of mires. In winter the lower elevation is preferred, together with a preference for pine forest. Most likely their habitat use is also influenced by human settlements, therefore moose might move also closer to human settlements in winter for feeding stations or as a wolf avoidance strategy.

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1. Introduction

The moose (*Alces alces*) in Scandinavia displays partial migration, i.e. a part of the population is migrating between distinct summer and winter areas, whereas others are stationary (Ball et al. 2001). Moose migration to winter areas takes part in November-January when snow is accumulating, and migration back to the summer areas is in April-May after snow melt, but before calving (Eriksen, 2006; Gundersen, 2003). Different studies suggest that migration between summer and winter areas is a tactic to avoid deep snow (Ball et al., 2001; Mysturd et al., 1997). Additionally, climatic conditions and other habitat factors affect migration, as food availability for this large-bodied browsing ungulate changes. As described in Månsson et al. (2011), the forest age roughly reflects moose forage availability within stands. With increasing forest age, access to forage in the tree layer decreases (Van Beest et al., 2010), while forage availability in the bilberry layer increases (Kardell, 1979). However, forage in the ground layer is unavailable during parts of the winter. Ball et al. (2001) found in their study little evidence for differences in vegetation composition between the moose summer and winter areas, and they also found that snow depth did not *per se* influence winter area selection of migratory moose. However, in the same study they found a significant overuse of areas with low snow depth (Ball et al., 2001). Various factors combined tend to affect habitat selection in moose (Ball et al., 2001; Månsson et al., 2012).

Food resources change throughout the year. In winter moose tends to forage in young forest stands (<30 years) (Cederlund & Okarma, 1988; Månsson et al., 2012). Pine is probably the most important winter food for moose in areas with limited access to the preferred deciduous browse species rowan (*Sorbus sp.*), aspen (*Populus sp.*) and willow (*Salix sp.*) (Ball et al., 2001; Van Beest et al., 2010). In summer a wider range of food sources are available. In spring moose primarily feed on birch trees (*Betula ssp.*), in summer on a variety of available food sources and in the autumn mainly on bilberry (*Vaccinium myrtillus*) (Cederlund et al., 1980; Hjeljord et al., 1990). According to Hjeljord et al. (1990) it is expected that a mixture of different stand characteristics, i.e. clear-cuts and different age classes will give the moose optimal forage opportunities. To study habitat use of moose, looking at different forest age classes and main tree species gives an appropriate perspective, as the stand age and tree species reflect forage availability (Kardell, 1979; Månsson, 2009; Månsson et al., 2011; Van Beest et al., 2010).

Not only optimal forage opportunities influences moose space use; also the fear for predators and human induced disturbances affect moose behaviour. This is called the “landscape of fear”, which means that prey uses fear as a mechanism to avoid or lower the risk of death (Eisenberg, 2013; Laundré et al., 2010). This results in a trade-off between safety and optimal forage habitats, induced by predators, but also by the presence of roads and settlements (Eldegard et al., 2012; Laundré et al., 2010). Studies on the effect of the wolf on the behaviour of moose in Scandinavia show no strong signs of predator avoidance activities in the moose population, and wolves seem to have high success rates in moose hunting (Eriksen et al., 2011; Sand et al., 2006). On the contrary, after reintroduction of wolves in Yellowstone National Park, the behaviour of the elk (*Cervus elaphus*) changed to more vigilance and predator avoidance (Eisenberg, 2013; Laundré et al., 2001). The lack of anti-predator behaviour can be a result of human induced hunting pressure and a longer separation between wolves and moose, making moose naïve to wolves. However, it is expected that moose will show anti-predator behaviour in the long term (Eriksen et al., 2011; Sand et al., 2006).

Besides predators, roads and settlements may influence moose behaviour, as Eldegard et al. (2012) shows that moose tends to move and forage closer to roads in winter. There seems to be a trade-off between avoiding roads and finding good forage opportunities, with moose moving closer to roads when forage availability is depleting during the winter. However, moose space use depends on the traffic volume and type of road (Eldegard et al., 2012).

Moose population estimates and habitat use are studied with different methods, e.g. by radio-telemetry, hunting data, aerial counts and pellet counts (Månsson, 2009; Månsson et al., 2011; Rönnegård et al., 2008). A recent method is the use of camera traps (Pfeffer et al., 2017). Pellet counts is often the most cost-effective method. According to Månsson et al. (2011) it is possible to successfully describe moose winter habitat selection with moose pellet counts. The pellet count surveys are usually done in sample plots which are distributed uniformly or clumped along uniformly distributed transects in a study area. The most common design in Scandinavia consists of 4 km transect lines along the edges of 1 x 1 km squares that are distributed over an entire research area. Each edge has 5 circular sample plots of 100m² (radius = 5.64 m) (Rönnegård et al., 2008). For winter densities, counts are done after snow melt by registering all pellets lying on top of the vegetation (accumulation after leaf fall). To limit the counts to a given time period, sample plots should preferably be cleaned from old pellets at the start of the period (Månsson, 2009; Rönnegård et al., 2008). Summer counts are also possible, but due to higher decomposing rate the reliability is lower (Persson, 2003). Pellet counts can be used as an indirect index of moose population density, to e.g. compare different study areas, habitat patches or time periods. There are limitations however, because the defecation rate of the moose (number of pellet groups produced per individual per day) may vary with area, habitat, activity and time of the year (Collins & Urness, 1981). However, other authors have shown that habitat selection studies by means of faecal pellets counts reveal similar results as studies based on radio telemetry and observations (Leopold et al., 1984; Loft & Kie, 1988; Månsson et al., 2011).

1.1. Client and involved people

For this research two major parties are involved, those are:

SKANDULV – Scandinavian Wolf Research Project.

- Norway and Sweden has a shared population of wolves. SKANDULV coordinates the research on this population and works on scientific questions regarding wolf ecology and management.

Inland Norway University of Applied Sciences (INN)

- The department of Applied Ecology and Agricultural Sciences.

Direct supervisor for this research was Barbara Zimmermann. During the time of the research multiple people were involved during the fieldwork phase. Students and employees from the Inland Norway University were working in the field during both field seasons.

1.2. Problem description

For research on habitat use, detailed data about the movement and distribution of moose is necessary. Usually, GPS collar data from moose is used for this purpose. However, this method is more costly compared to faecal pellet counts (Rönnegård et al., 2008) and is strongly influenced by the individual behaviour of the usually small sample size of collared moose. Therefore, an assessment with faecal pellet counts can be more effective. Pellet counts are usually only done in the winter. Due to faster decomposition of pellets in the growing season, summer counts are less reliable (Persson, 2003). Pellet counts results reliable population estimates for moose densities on a large temporal and spatial scale, but it does not take into account local habitat and environmental factors, and also the difference between summer and winter is neglected. My thesis will look more detailed into moose distribution with the use of summer and winter pellet counts. Hereby I make use of habitat factors, such as elevation,

slope, aspect, distance to roads and settlements, and vegetation types, to predict the probability of finding moose pellets.

1.3. Research goal

As part of a larger research project, the ultimate goal is to create a predictive model for moose distribution among different habitat types in the summer and winter, which can be used in further research on wolf -moose interactions. A key point included in this research is the moose distribution in relation to anthropogenic factors (roads, settlements).

This research will form the basis for a moose prediction model by assessing the difference of moose distribution among different habitats between summer and winter in Slettås research area. The research will be based on actual field data and on a literature study.

1.4. Research question

The main question for this research is:

How does moose habitat use change between summer and winter in Slettås research area?

Sub-question:

- Which habitat types are preferred in winter compared to summer?
- Does elevation and snow depth relate to seasonal movement in the winter?
- What is the average distance to roads and settlements for moose in winter compared to the summer?

1.5. Hypothesis

Based on previous research I expect the following according to the sub-questions:

Hypothesis 1: Selection of vegetation types by moose differs between winter and summer.

- I predict higher probability of finding moose pellets in young pine forest stands in winter, because then young pine trees are the main food for moose. For summer, I predict a more uniformly distributed probability of moose pellets, due to an overall abundance of multiple food sources in different vegetation types.

Hypothesis 2: Moose space use is seasonally related to elevation and/or snow depth

- I predict the probability of finding moose pellets to be negatively related to elevation and average snow depth in the winter for more easier movement and better access to food resources, while the summer distribution is not related to elevation.

Hypothesis 3: Moose space use is seasonally related to human infrastructure.

- I predict that the probability of finding moose pellets is negatively related with the distance to roads and positively with the density of houses and cabins in the winter, because houses and roads are usually built in productive areas at lower elevation and less snow. In the summer I expect the opposite relationship, to avoid human disturbance (landscape of fear).

2. Methods

2.1. Study area

The study was conducted in the eastern part of Norway (61°18'N, 11°50'E), east of Rena, Hedmark County (see appendix 1). The area is comprised by the wolf territory of the Slettås-pack and has a size of approximately 1000 km². The vegetation consists of a mix of pine, spruce and deciduous forests (74% of the area is forest) intermixed with rural areas as agricultural pastures and human settlements (4%). On average I find 0.8 houses per km² and 2 cabins per km² in the study area. Appendix 1 also shows an overview of the cabins and houses in the area. The rest of the area consist of non-forest vegetation and lakes/ivers (22%). Part of the area is owned by the Norwegian government (Statskog) and the rest is privately owned (appendix 2). Forestry is a common practice, which creates patches of clear-cuts and forests in different age classes.

2.2. Moose pellet counts

The moose pellets were counted in circular sample plots of 100m² (5.64 m radius). The sample plots were clustered in sample squares of 50 by 50 metres. Each sample square consisted of five plots, arranged at the four corners and the centre of the square (Figure 1). In total there were 68 and 76 sample squares for the winter and summer, respectively. The summer count had 8 more sample squares in the northern part of the study area due to extended wolf movements. The sample squares were distributed regularly over the area at a distance of 3.5 km between squares. Additionally, 4 transect lines were added, from low to high elevation. These transect lines already existed from a previous study on moose density in relation to elevation and snow depth. This added another 53 sample squares (n= 121 for winter and n= 129 for summer). In total 605 plots in the winter were counted and 645 plots in the summer. The winter counts were done in May-June 2017 and the summer counts in September 2017.

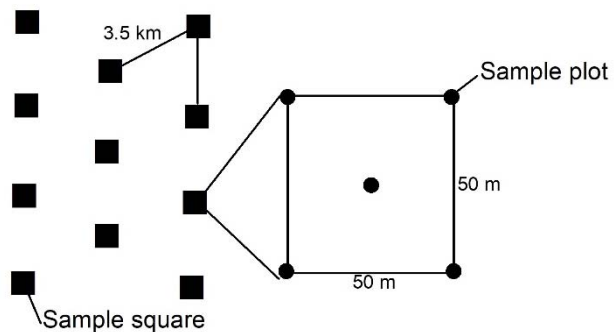


Figure 1. Study design visualised

2.3. Analyses

2.3.1. Spatial analyses

Vegetation types

I distinguished the vegetation types and age classes into different groups of main tree species, age classes and others. Main tree species included: pine forest, spruce forest, deciduous forest, coniferous forest, mixed forest and unproductive forest. Age classes of the forest stands were divided into four groups: less than 30 years, 30 to 59 years, 60 to 89 years and more than 90 years. The non-forested vegetation consisted of Mires, Open up- and lowland, Rural areas, Roads and Water. The different classes were based on previous research (Kardell, 1979; Månsson, 2009; Månsson et al., 2011; Van Beest et al., 2010). Appendix 3 shows a full description of the different groups.

Forest data was acquired by Norsk Institutt for bioøkonomi (NIBIO, 2018), the data describes stand details such as proportion of tree species, main tree species, age, volumes per hectare, etc. In combination with a vegetation map based on landsat 5 images (Johansen et al., 2009) I made a vegetation map for the whole research area with the use of ArcGIS 10.2.1 (ArcGIS, 2014). Hereby unknown areas are defined as unproductive forest if recent satellite images showed forest-like structure (Kartverket, 2018b). All ArcGIS steps are described in appendix 4.

Snow depths and elevation

Elevation data was acquired by the Digital Elevation Model (DEM) downloaded via GloVis (U.S. Geological Survey, 2018). I made the maps and data about aspect and slopes with the use of the elevation data. The snow depth data was acquired by the Norges vassdrags- og energidirektorat (NVE) (Lussana et al., 2018). For the snow depths, I used the data from 1 October 2016 till 31 May of 2016. The snow data is only added to the winter pellet count. All the steps and GIS tools I have used are written in appendix 4.

Distance to roads and settlements

N50 kartdata for roads and settlements were downloaded from Kartverket (Kartverket, 2018a). I used the 'Euclidian Distance tool' (ArcGIS, 2014) to create four rasters with 'distance to nearest' data. The classes I used were public roads, private roads, houses and cabins. For the houses and cabins I also calculated the density (per km²) with the use of the 'kernel density tool' (ArcGIS, 2014).

Summarising data per sample square

As a result, I created two data sets with the data per plot for winter and summer ("plot level"). I also created seasonal datasets at the sample square level ("square level"): A buffered squared polygon is created around the plots, with a size of 100 by 100 metre. The size is to ensure all the sample plots (clusters of 5 plots per square) will fall within the sample squares. I summarised the data of the five plots. For the number of pellets I used the sum, for the numerical explanatory variables I used the mean, and for the factors I used the most representative (the one who has the highest proportion of the square).

2.3.2. Data exploration

As part of data exploration I followed mainly the protocol from Alain F. Zuur, hereby looking at outliers in X and Y, normality of the data, amount of zeros, collinearity (correlation threshold $r \geq 0.6$) and relationships between Y and X (Zuur et al., 2010). To be able to look into the data I used the software Rstudio to apply data modification and testing (R Core Team, 2018). In addition I used the package Dplyr to make the dataset tidier (Wickham et al., 2017), I used the package ggplot2 to visualise the data (Wickham, 2009) and the package GGally to perform the collinearity check (Schloerke et al., 2017).

2.3.3. Model selection

For the model I chose a Generalised Linear Model (GLM) at the square level. The choice of the square level instead of the plot level was due to a bias of too many zeros at the plot level (zero-inflation) and the spatial autocorrelation of the plots within each square, that ended in model convergence problems when applying mixed effects models with square-id as random factor. At the square level, the data might still be spatially autocorrelated, but this is not tested. The response variable was still zero-inflated at the square level, and I chose to use logistic regression with a logit link function and a binary distribution of the response variable (pellet presence/absence). I used the Akaike Information Criterion (AIC) to find the best model. Models with $\Delta AIC < 2$ are considered as equally suitable, and the model with the lowest amount of explanatory variables was chosen. For continuous explanatory variables I also tested for polynomial effects by comparing the AIC for models with and without the squared effect included. However, due to the amount of explanatory variables, I initially categorised the

variables as: biotic (vegetation type and age class), abiotic (elevation, aspect, slope, snow depth), anthropogenic (distance to cabins, houses, private roads and density of houses and cabins). I assumed that at least one variable per category should be included in the model. Finally, I simplified the best model by excluding the variables whose confidence interval of the estimates included zero and compared the AIC of these new models with the former ones. All tested model can be found in appendix 5.

2.3.4. Moose pellet prediction and probability map

I used the estimates produced by the best models to predict the probability of finding moose pellets for summer and winter depending on different variables, this was done with the predict function from the package 'stats' in R studio (R Core Team, 2018). Different graphs, showing the relation between probability and variables, were created with the package 'ggplot' (Wickham, 2009).

The prediction maps are based on the resource selection function, hereby I used the coefficients of the model within the ArcGIS tool 'raster calculator' (ArcGIS, 2014). The formula I used for the resource selection function, with 'i' as the intercept, 'a' as an estimate and 'x' as a factor:

$$RSF = \exp(i + a_1x_1 + a_2x_2 + a_3x_3 + \dots) / (1 + \exp(i + a_1x_1 + a_2x_2 + a_3x_3 + \dots))$$

I added the hill shade layer (based on the elevation) over the prediction map and smoothed the prediction map with the 'focal statistics' tool to make the final map smoother and easier to interpret.

3. Results

3.1. Data exploration and model selection

Distance to house and distance to public roads were correlated, and I therefore excluded distance to public roads from the analysis. Similarly, the two predictors describing snow conditions were correlated with each other and with elevation (Figure 2). I decided to only include elevation in the models as a proxy of snow conditions, because the scale of the elevation data is more precise (30x30 m) than that of the snow data (1 km).

The AIC comparison resulted in the best find models for summer and winter. The summer model resulted in mod7_1 (Table 1) and the winter model mod9_w1 (Table 2) as final models.

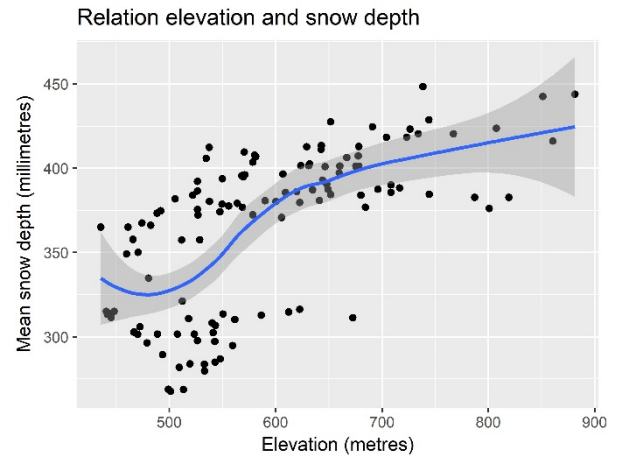


Figure 2. Relation between the elevation and snow depth, based on mean of snow depth per sample square. Smoothing added with the LOESS method.

Table 1. AIC comparison for the summer models

Models	K	AIC	Δ AIC	ModelLik	AICcWt	LL	Cum.Wt
mod7_1	6	177.2619	0	1	0.3366	-82.6310	0.3366
mod12	15	178.7628	1.5009	0.4722	0.1589	-74.3814	0.4955
mod7	8	179.3939	2.1320	0.3444	0.1159	-81.6970	0.6114

Table 2. AIC comparison for the winter models

Models	K	AIC	Δ AIC	ModelLik	AICcWt	LL	Cum.Wt
mod9_w1	16	157.6931	0	1	0.4841	-62.8466	0.4841
mod2_w	19	159.4408	1.7476	0.4174	0.2020	-60.7204	0.6861
mod9_w	20	159.5812	1.8881	0.3890	0.1883	-59.7906	0.8744

3.2. Results of models

In summer, the probability of moose pellet presence increased with elevation. The probability was on average 3 times higher at 800 m above sea level as compared to the lowest elevation in the area (435 m.a.s.l.) (Figure 3). The probability to find moose pellets in age class 2 was on average 1.9 times higher than age class 0.

Table 3. Parameter estimates for the summer model, used to predict moose pellet probability.

Factor	Estimate	std. Error	95% CI	
(Intercept)	-3.56462	1.441735	-6.390	-0.739
age_class 1	0.187367	1.477268	-2.708	3.083
age_class 2	1.649318	0.652628	0.370	2.928
age_class 3	0.435012	0.544424	-0.632	1.502
age_class 4	0.116703	0.581785	-1.024	1.257
elevation	0.005447	0.002159	0.001	0.010

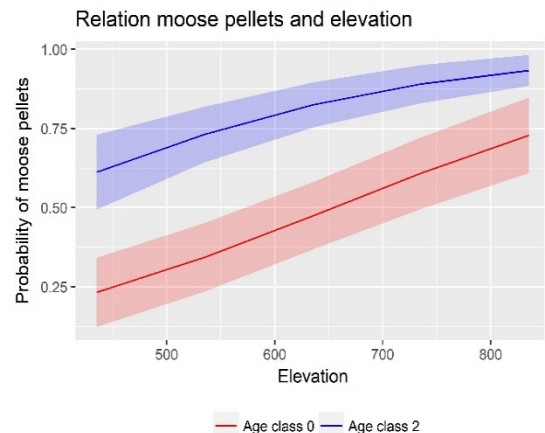


Figure 3. Relation between the probability of finding moose pellets and elevation for age class 0 and age class 2

The winter model included more predictors (Table 4). From the vegetation types the pines forest showed a positive effect on the moose probability, since zero is not included in the confidence interval. The probability of moose pellets had a hump-shaped relationship with distance to private roads, with highest probability at intermediate distance of about 700 m to the closest private road (figure 4). Contrary to the summer model, probability of moose pellets was negatively related to elevation. The probability was 1.5 times higher at the lowest elevation (435 m.a.s.l.), compared to 800 metres above sea level. The probability of moose pellets had a positive relationship with the density of cabins: The probability was 1.2 times higher at a density of 7.5 cabins per km², compared to a density of 0. However, the distance to cabin showed an increase of 1.3 times at 3000 metres from a cabin compared 0 metres (Figure 5).

Table 4. Parameter estimates for the winter model, used to predict moose pellet probability within the RSF

Factor	Estimate	Std. Error	95% CI	
(Intercept)	1.670000	2.603000	-3.431880	6.771880
mire	-0.215500	1.068000	-2.308780	1.877780
mixed forest	16.97000	1455.000	-2834.830	2868.770
other	-14.99000	1455.000	-2866.790	2836.810
pine	2.213000	0.923000	0.403920	4.022080
spruce	0.755000	0.703700	-0.624252	2.134252
unproductive	0.626100	1.043000	-1.418180	2.670380
elevation	-0.006760	0.003338	-0.013302	-0.000218
slope_deg	-0.473800	0.391400	-1.240944	0.293344
l(slope_deg^2)	0.046180	0.025240	-0.003290	0.095650
dis_private	0.007429	0.002609	0.002315	0.012543
l(dis_private^2)	-0.000006	0.000002	-0.000010	-0.000002
dis_cabin	0.000846	0.000452	-0.000039	0.001732
dis_house	0.000010	0.000314	-0.000605	0.000624
den_cabin	0.365400	0.245100	-0.114996	0.845796
den_house	-0.712400	0.451200	-1.596752	0.171952

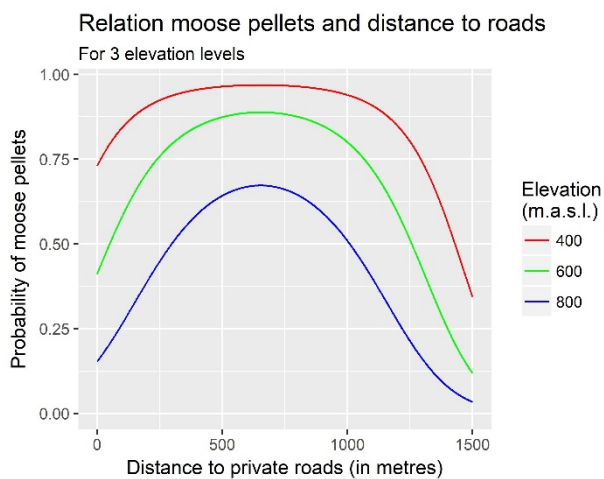


Figure 4. Relation between the probability of finding moose pellets and distance to private roads, for three different elevation levels.

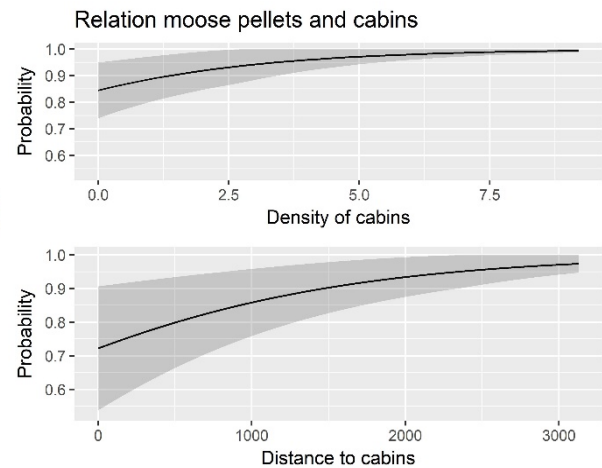


Figure 5. Relation between the probability of finding moose pellets and density of cabins, and distance to cabins.

3.3. Moose prediction map

With the estimates from the summer and winter model (shown in Table 3 and Table 4) the probability of finding moose pellets is shown for the whole research area in Figure 4. In both summer and winter $\pm 50\%$ of the area had a probability > 0.5 for moose pellet presence, however the distribution differs according to the seasons. Moose seemed to be more concentrated in lower areas in the winter, as compared to summer, when moose were more concentrated in higher areas.

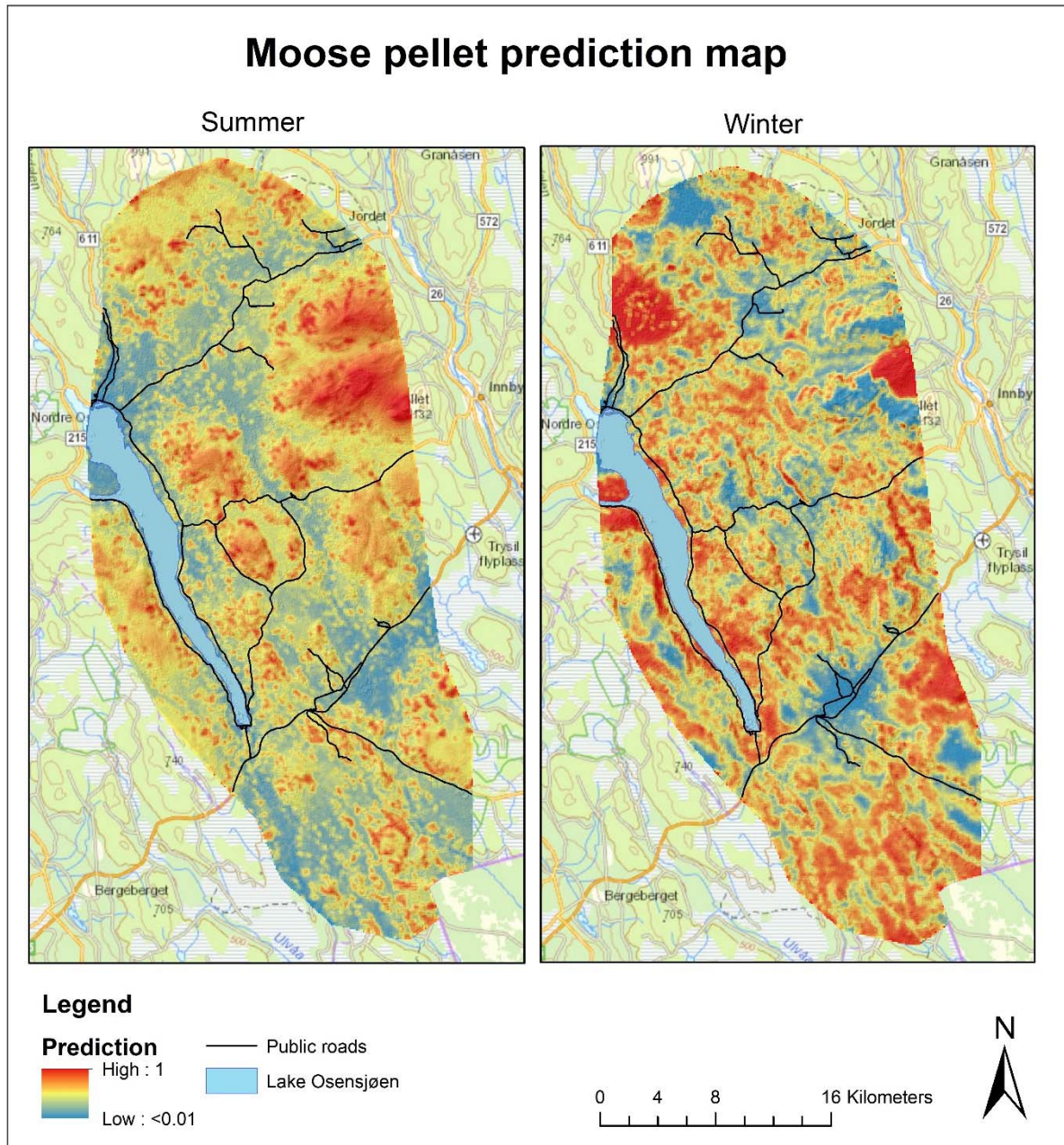


Figure 4. Moose pellet prediction map for summer and winter, based on the RSF. Background provided by Kartverket (2018b).

4. Discussion

In this thesis, I have predicted the probability of finding moose pellets for summer and winter in Slettås research area, and therefore I am able to compare the change in moose habitat selection between summer and winter.

4.1. Interpretation of the results

The summer results showed a positive relation with age class 2 (30 to 60 year old forests), resulting in a higher moose pellet probability during summer. Previous studies on moose summer habitat selection showed similar results. Most probable moose prefer older forest classes in summer, due to better food quality in the scrub level (Hjeljord et al., 1990; Kardell, 1979; Nikula et al., 2004).

Age class 0, which consists of unproductive forest, mire, open low/up land and rural areas, showed a negative relation with the moose pellet probability. Within this group mire had the largest proportion (44%) and therefore expected to be the main driver of this negative relationship. Moose tends to avoid mires during the summer season (Ball et al., 2001; Nikula et al., 2004).

Higher elevation showed a higher probability for finding moose pellets. I did not find much research on summer elevation and moose probability, however Cederlund et al. (1987) described that moose tends to migrate to higher elevations during spring. This probably due to better food quality in higher elevations (Andersen, 1991; Riley & Skjelvåg, 1984). Another partial migrator in Norway, the red deer (*Cervus elaphus*), is also moving to higher elevations during summer by following the green wave of plant development along the temperature gradient (Bischof et al., 2012). At higher latitudes, plants develop slower and therefore offer nutrient-rich food for ungulates over a longer period (Albon & Langvatn, 1992).

In winter the probability of finding moose pellets was negatively related with the elevation, i.e. high probability in the lowlands and low probability at higher elevations. Other studies suggest a similar relation with the elevation during winter (Cederlund et al., 1987; Gervasi et al., 2013). The distance to private roads showed a hump-shaped relation, at ± 700 metres distance from the road there is the highest probability to find moose pellets. Similarities has been found in the study from Eldegard et al. (2012), though this study looked at major roads. The hump-shaped relationship may be due to a trade-off between access to winter food and human disturbance. The roads in my study were often unploughed private roads, and we lack data about which roads were ploughed.

Among the vegetation types, pine forests had the highest probability of moose pellet occurrence. This is comparable to other studies which describe the importance of pines as winter browsing for moose (Histøl & Hjeljord, 1993; Månsson, 2009; Nikula et al., 2004; Van Beest et al., 2010).

There seems to be a higher moose pellet probability in area with higher densities of cabins, however the relation with distance to cabins is positive, which results in higher probability further away from cabins. I did not find literature which looked directly into this relation. However a possibility is that in areas with high cabin density moose feeding stations are near, which can attract more moose and increases the probability of finding moose pellets (Van Beest et al., 2010). As another possibility moose can use the cabin areas as a wolf avoidance technique (Stephens & Peterson, 1984). Wolves tend to avoid high human activity areas (Lesmerises et al., 2012), in contrast however, studies within Fenno-Scandinavia did not find predator avoidance behaviour in individual moose (Eriksen et al., 2011; Gervasi et al., 2013; Nicholson et al., 2014; Sand et al., 2006).

4.2. Limitation of the results

Over time moose pellets will decompose and vegetation will overgrow the pellets. This process is halted during the winter due to freezing temperatures. However during summer pellets will decompose faster, partly due to higher air temperatures, and partly because moose pellets contain less woody remains (Persson, 2003). The summer data of my study might therefore be less reliable due to this higher decomposing rate of the summer pellets. In addition, due to the high vegetation in late summer, pellets can be hard to detect. As a result, the summer data can be underestimated. However, I did not compare the summer and winter in a direct manner, e.g. comparing the absolute counts of both seasons, I compared the predictions which resulted from separate models. Therefore, I expect the general trends to be a reflection of the reality, even though the summer predictions might be underestimated.

According to Gundersen (2003) and Ball et al. (2001) moose starts migrating when the snow depth is between 30 to 50 cm. However, I chose to use the elevation as predictor, instead of snow depths, due to the correlation between the variables. Other studies used elevation (Gervasi et al., 2013), snow depths (Ball et al., 2001) or snow days above certain threshold (Månsson, 2009; Månsson et al., 2012). I did not test the models with the snow data due to the collinearity issue and the coarse resolution of the snow data. The snow depth data used for this was estimated by the NVE and are based on multiple variables, which includes elevation, daily precipitation, forest density, snow accumulation and evaporation (Lussana et al., 2018). The snow depth estimation has a scale of 1 by 1 km, though the elevation data has a scale of 30 by 30 metres (U.S. Geological Survey, 2018).

5. Conclusion

5.1. Conclusion

Which habitat types are preferred in winter compared to summer?

The winter model showed a preference for pine forest compared to other types. In summer, it is likely, that mires are avoided. Therefore, the hypothesis is partly supported, due to the higher probability of finding moose pellets in pine forests during the winter. However, the summer distribution does not look more uniformly distributed, in both summer and winter the $\pm 50\%$ of the total area had a probability more 0.5.

Does elevation and snow depth relate to seasonal movement in the winter?

Elevation and snow depths are related with each other, therefore I used the elevation in the models. The winter showed a negative relation with the elevation, which conforms my hypothesis, however, in summer the elevation is positively related with moose pellet probability. Therefore this hypothesis is partly supported, because of my expectation that the elevation would not have an effect in the summer.

What is the average distance to roads and settlements for moose in winter compared to the summer?

In winter there seems to be an optimum around 700 metres from private roads, and it is likely that cabin areas affect the moose habitat choice. In summer, I did not find a relation between the distance to roads and moose pellet probability, nor between houses and cabins.

How does moose habitat use change between summer and winter in Slettås research area?

Eventually, I can conclude that moose habitat use in summer results in higher elevations and likely avoidance of mires. In winter the lower elevation is preferred, together with a preference for pine forest. Most likely their habitat use is also influenced by human settlements, therefore moose might move also closer to human settlements in winter for feeding stations or as a wolf avoidance strategy.

5.2. Recommendation

Within this study I tried to form a basis for moose pellet prediction, which can be used for different research and management goals, e.g. population estimates, population management decisions, moose-wolf interaction, etc. I recommend to continue a study on moose predictions, with a focus on the relation between the snow depths and elevation, and the relation between cabins/houses and feeding stations. Furthermore, a comparative study of radio collared moose and moose prediction based on pellet counts like this study, will gain more insight into the reliability of the used methods.

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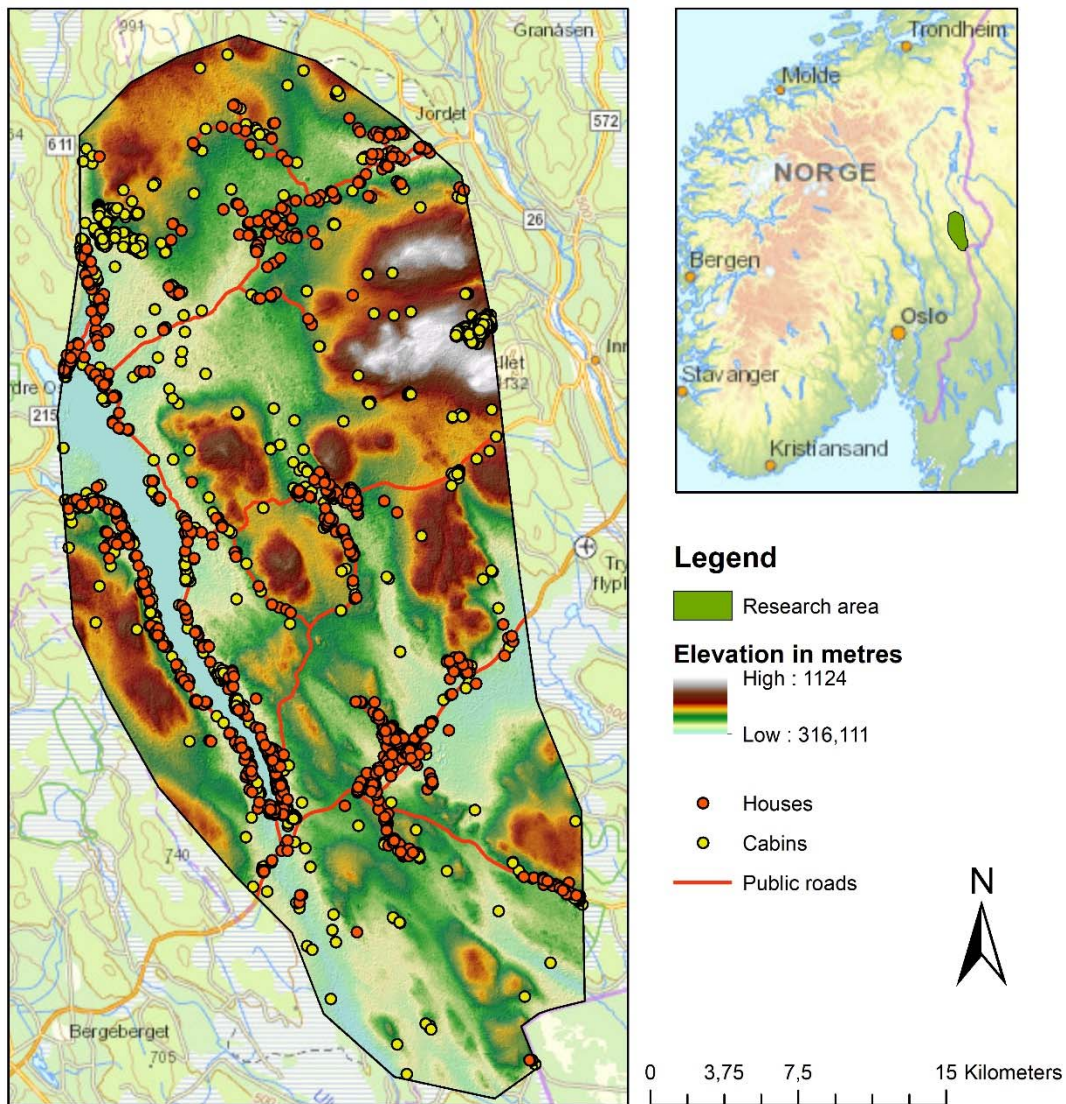
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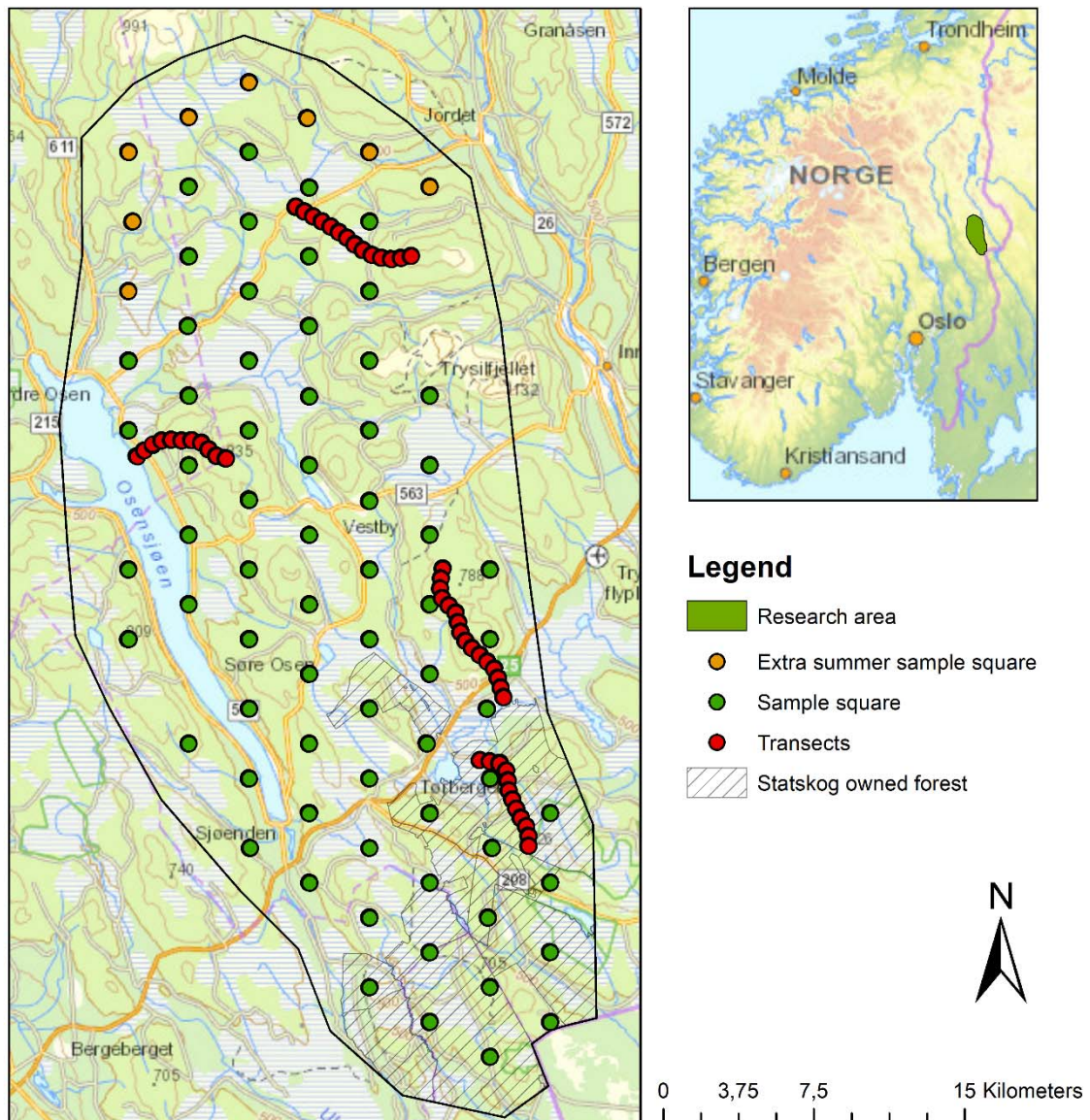
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Appendix 1 (Elevation and human settlements)



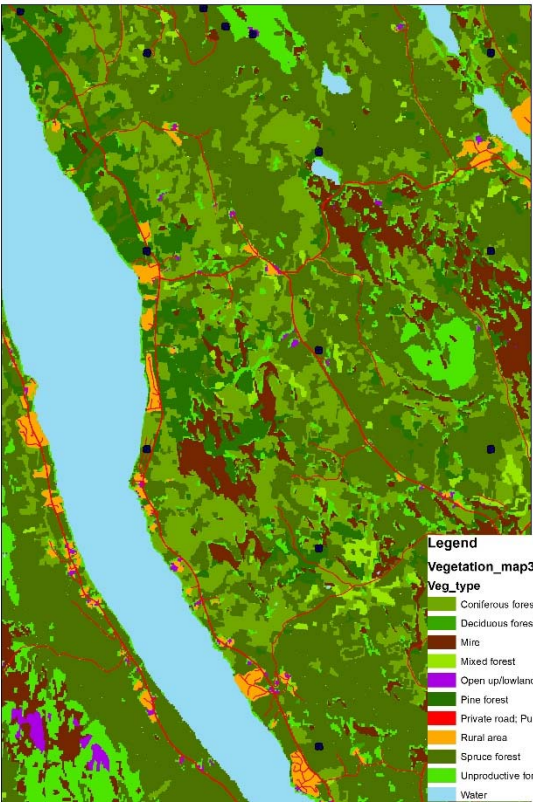
Appendix 2 (Overview of the sample square locations)



Appendix 3 (Vegetation types and age classes)

Main tree species		Description
Pine forest		Volume of pine is more than 50% of the total volume
Spruce forest		Volume of spruce is more than 50% of the total volume
Coniferous forest		Volume of pine and spruce together is more than 75% of the total volume
Deciduous forest		Volume of birch and other deciduous trees are more than 50% of the total volume
Mixed forest		Volume of pine, spruce and deciduous are all less than 50%, and the volume of pine and spruce together is less than 75%
Unproductive forest		Forests without stand data about species, ages and volumes
Other land uses		Description
Mires		All areas with mires, bogs and wetland conditions
Open up/lowland		Areas with tundra vegetation, or open (grassy) areas on lower elevations
Rural areas		Areas heavily modified by humans, like agriculture and areas with high density of houses and cabins
Roads		All the public and private roads in the study area, with a buffer of 12 metres and 8 metres, respectively, from the centreline of the road.
Water		All water bodies bigger than 30 by 30 metre
Age classes	Class ID	Description
<30	1	less than 30 years old
30-59	2	between 30 and 60 years old
60-89	3	between 60 and 90 years old
>90	4	more than 90 years old
Unknown	0	Unknown age class or non-forest area

Appendix 4 (Working steps for GIS Analyses)

Vegetation: <u>Forest data:</u> - Download data from Norsk institutt for bioøkonimi (NIBIO, 2018) - Clip and combine data for research area - Transform ('project') coordination system to projected WGS 1984 UTM zone 33N - Update average age to age class (<30, 30-60, 60-90, >90) - 'Dissolve' on Treslag (dominant tree species) and age class <u>Vegetation data (Johansen et al., 2009):</u> - Extract all non-forest types for the research area - Transform to projected coordinate system - Extract the raster data to polygon <u>Combine maps:</u> - Union maps together - Mark unknown areas as unproductive forest - Add new layer (polygon) - Add satellite image from kartverket wms-server (Kartverket, 2018b) - Look and draw polygons where new human activity is visible (high density of cabins and houses) - Create a 'buffer' for private roads (8 m) and public roads (12 m) to avoid that roads are marked as unproductive forest - Union all layers and update treslag layer if it is rural area or road. - Dissolve on treslag and age class - Translate treslag to dominant tree species Do a 'spatial join' with the vegetation map and the winter and summer plots to add the vegetation information to the plots for later analyses.	 Sample vegetation map
--	--

Distance to roads and settlements

For the roads the N50 Kartdata is used, which is available for downloading (Kartverket, 2018a).

Selection criteria

For houses:

- N50_BygningsPunkt
- BYGGTYP_NBR: 111 – 159

For cabins:

- N50_BygningsPunkt
- BYGGTYP_NBR: 161 – 171

For public roads:

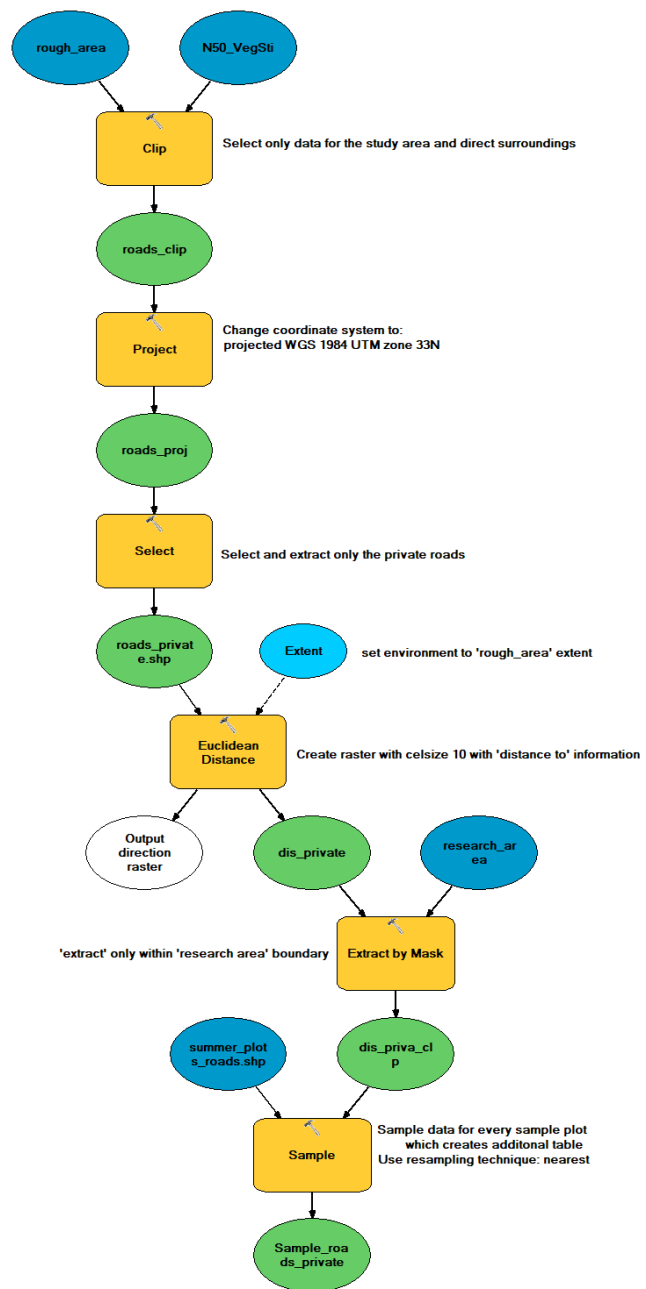
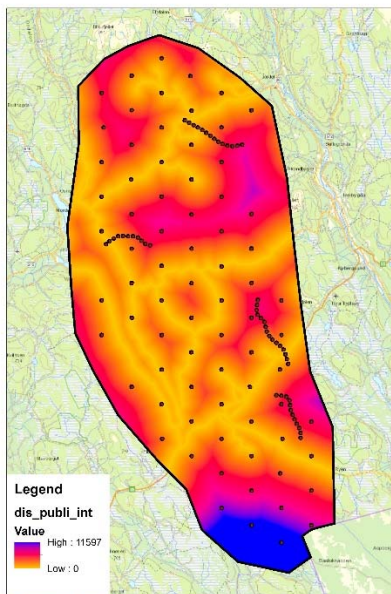
- N50_VegSti
- VEGKATEGORI: E, F, K, R

For private roads:

- N50_VegSti
- VEGKATEGORI: P

The model on the right is used for all four 'distance to' maps. The four samples are joined with the winter and summer plot data with the 'join field' tool.

See below a sample of the distance to public roads raster map:



Elevation, aspect, slope and snow depth

Maps/data used:

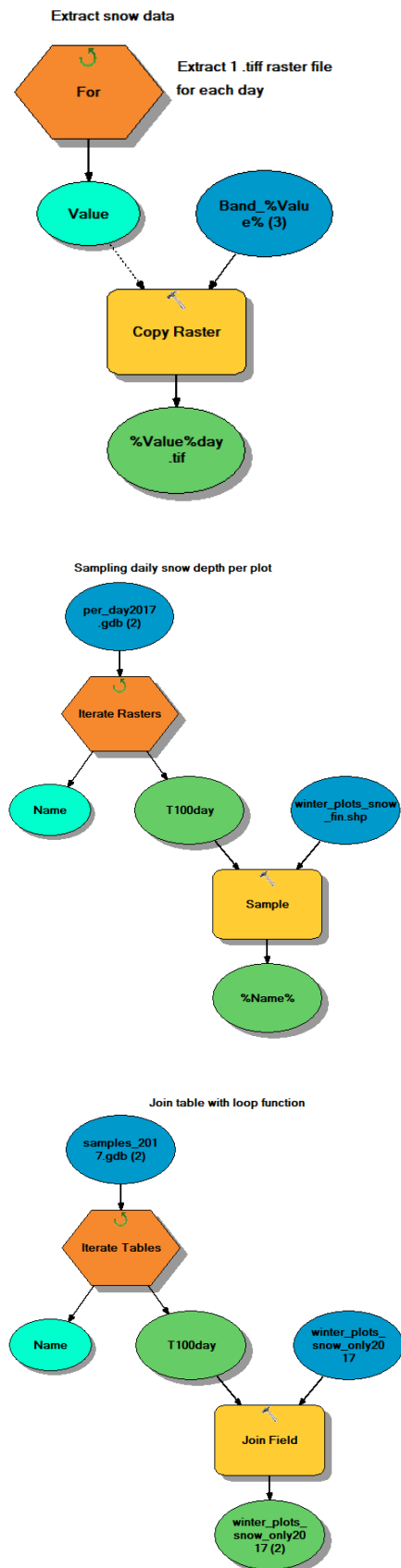
- Elevation (U.S. Geological Survey, 2018)
- Snow depth data as a NetCDF file provided by the NVE (Lussana et al., 2018)

Steps for elevation, aspect and slope:

- Add elevation map
- 'Extract by mask' to select on research area
- Use 'Aspect' tool to create aspect map
- Use 'Slope' tool to create slope map in degrees
- 'Sample' plots and 'join tables' to create final data sheet

Steps for snow depth:

- Add NetCDF with 'Make NetCDF raster layer' tool
- When done add in properties time as dimension, this creates a different band for every day
- Export data with as requirement the current view of the research area, to reduce the size of the raster file
- Add the exported data to the map and perform the models on the left:
 - o Extract snow data: makes a separate tiff file for every band (one tiff file with snow depth per day)
 - o Sampling daily snow depth per pot: this creates a table for every day and shows the snow depth for that day per plot
 - o Join tables with loop function: selects every table and joins the table with the plot data.



Appendix 5 (Tested models)

	Biotic		Abiotic			Anthropogenic				
Mod	Veg_type	Age_class	Aspect	Elevation	Slope	Dis_cabin	Dis_house	Dis_private	Den_house	Den_cabin
1	+	+	+	+	+	+	+	+	+	+
2	+		+	+	+	+	+	+	+	+
3	+			+		+	+	+	+	+
4	+			+					+	+
5	+			+		+	+	+		
6		+		+		+	+	+	+	+
7		+		+					+	+
8		+		+		+	+	+		
9	+	+		+	+	+	+	+	+	+
10	+	+		+					+	+
11	+	+		+		+	+	+		
12	+	+		+		+	+			+
13	+	+		+		+	+	+		+
Extra summer models										
7_1		+		+						
Extra winter models										
9_1	+			+	+	+	+	+	+	+
9_2	+			+		+	+	+	+	+
9_3	+			+		+	+	+		
9_4	+			+		+		+		