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MASTER'S THESIS IN ARCTIC NATURAL RESOURCE MANAGEMENT

The Relative Effects of Farm Management versus Climate on Lamb Autumn Weights

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May, 2008

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Abstract

In this study I ask if farm management have such large effects on sheep (*Ovis aries*) production that climatic studies could be improved by taking it into account. The relative effects of climate and farm management on autumn live weights of lamb were studied in Troms, northern Norway. A mixed method approach was used, including analyses of multiple databases, as well as qualitative, semi-structured interviews with sheep farmers. The results combine the farmer's statements with the quantitative data on production and climate. A total of 30 farms in three climatic areas (coast, fjord and inland), were selected from the Norwegian Sheep Recording System's (NSRS) database, which was based on the highest contrasts in autumn live weights. In the climatic analyses 34 831 free ranging lambs were studied over a ten year period. Spring and summer temperature and precipitation, and the Arctic Oscillation (AO) index were used as climatic parameters. Interviews on farm management included general treatment, feeding, outdoor and socioeconomic factors. The results indicate that both climate and farm management is important for autumn live weights. The main climatic effects were captured by the AO index for July/August, while the effects of temperature and precipitation did not show any clear pattern. Grazing at cultivated pastures in spring and herd size had negative effects, while the length of the grazing period had a positive effect on the weights. As effects size for management and climate were of similar magnitude, I suggest that the accuracy of climatic studies could be improved by taking into account some of the farm management variables.

Key words: *Ovis aries*, lamb autumn weight, climate, Arctic Oscillation, farm management, Troms.

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Introduction

In Norway lambs spend about 70 percent of their lifetime unmanaged on rangelands, which makes environmental conditions in the summer season particularly important for the production output. Summer climate could therefore have an influence on production through quality and quantity on foraging plants, insect nuisance and parasites. The animals can also be directly affected by the climate through thermoregulation and altered behaviour. Equally important may be farm management, as the sheep are intensively managed while kept indoors, and access to outdoor resources may vary between farms. Studies on the relative effects of climate and farm management practices is therefore important for assessing potential impacts of climate change on livestock production. Previous studies have found that sheep have the same response to large scale winter climatic patterns, acting through indirect effect on the quality and quantity of forage in spring and summer, as wild ungulates, such as red deer (*Cervus elaphus*) (Mysterud et al., 2001b). This indicates that they can be influenced by the same factors, either directly or indirectly. Despite these general relationships there are large local variations in the lamb weights (Steinheim et al., 2004). The deviating pattern could be explained by differences in farm management, which vary due to available time and resources, experience, feeding, parasite treatment and predation risk. Spring pastures of high quality are especially important for the lamb growth and autumn weights (Garmo and Skurdal, 1998). However, local variations in the environmental conditions may also be important. The topography in Norway varies considerably, which results in large variation in climate and growing conditions, even on a very small scale (Moen, 1999). Variable topography, resulting in an extended period of new emerging nutritious forage, has been found positively related to body weight of red deer (Mysterud et al., 2001a). In addition, southern sun-exposed slopes allow early access to nutritious herbs and grasses in northern regions.

The NSRS is a national register for sheep production data which contains high quality, detailed information about sheep production and performance. Data for each individual animal is registered, as date of birth, litter size, sex, autumn weight and age when weighted. The database has been extensively used to explore climatic effects on different life history parameters, especially body weights (Mysterud et al., 2001b, Steinheim et al., 2004, Weladji et al., 2003). However, there are no data available on management practice at farm level. Indeed, the database could also be used for a mixed method approach, which combines the data on production with interviews of sheep farmers about farm management. The combination of quantitative and qualitative approaches provides a unique possibility to study the importance of farm management on production, and to address questions which cannot be approached by a singular method.

Few studies have attempted to quantify the effects of farm management on production, and as far as I know, no previous studies have compared the relative effects of climate and farm management. One reason could be the statistical difficulties as many of the farm management variables are highly correlated, as experienced in another study on farm management conducted in southern Norway, which was based on questionnaires (unpublished; pers comm. Synnøve Vatn). In order to select uncorrelated variables of importance, it could be advantageous to use mixed methods approach which allows sheep farmers to identify the most important factors for production. By using both closed– and open ended questions, interviews could be used both to distinguish actual farming practices and to understand the relationship between different production factors.

I studied main effects of climatic and farm management on lamb autumn weights. I aimed to answering the following question: Does farm management have such high effect on sheep production that it would improve the accuracy of climatic studies? To answer this question I compared how climate fluctuations affect production relative to variation in production that could be linked to management practices.

Material and methods

STUDY AREA

The study was carried out in the county of Troms, situated in northern Norway (Figure 1). Troms lies within the boreal zone (Moen, 1999), and is strongly influenced by the Gulf Stream. The snow cover normally disappears during May, and the spring pastures are dominated by birch (*Betula pubescens*). Troms lies north of the Polar Circle, with continuous daylight from mid May to the end of July. The mild climate combined with continuous daylight give favourable growth conditions for plants and foraging species during a rather short period of vegetative growth. In the summer, most of the sheep graze in the alpine and sub-alpine zone (Lind and Eilertsen, 2004).

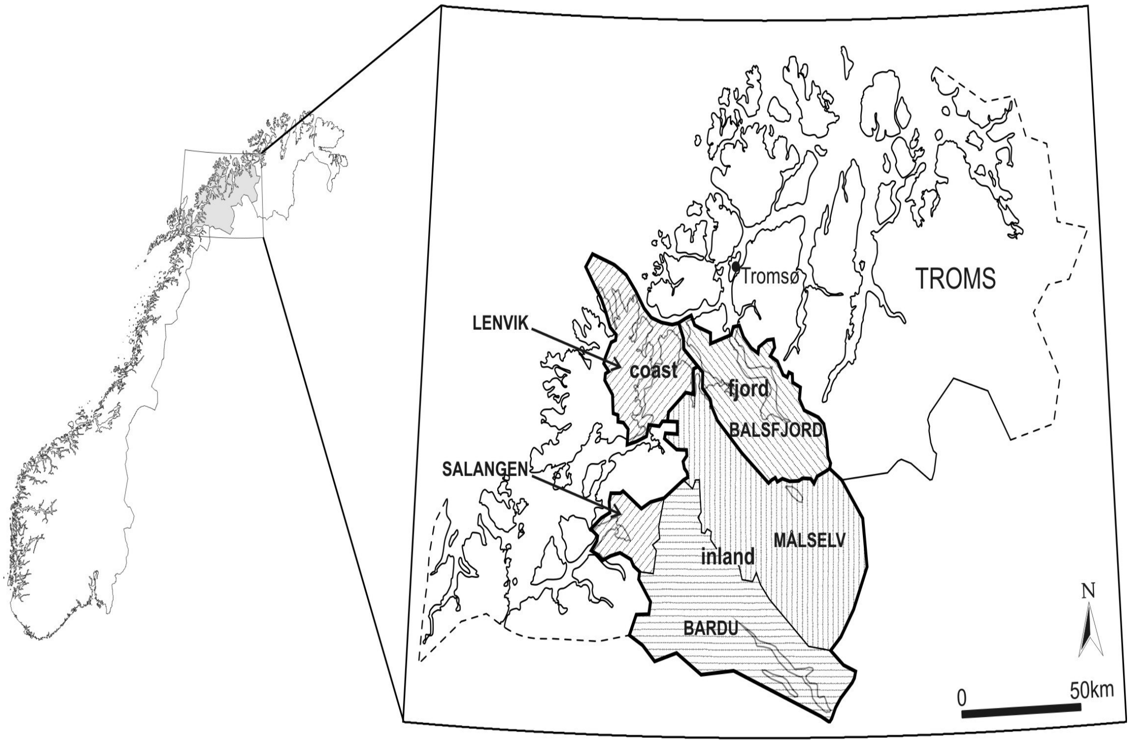

Figure 1. Map of the study area in Troms displaying the coast (Lenvik), fjord (Balsfjord) and inland (Bardu, Målselv and Salangen) area.

Three regions were sampled along a coastal–inland gradient, which consists of five municipalities; the coast area (Lenvik), the fjord area (Balsfjord) and the inland area (Målselv, Bardu and Salangen) (Figure 1). The average temperature and precipitation from May to August for the period 1994-2003 are presented in Table 1, which show that the largest differences between these regions is amount of precipitation, but there are also differences in temperature.

Table 1. (a) Mean monthly temperature (˚C) and (b) mean monthly precipitation (millimeter) for the coast, fjord and inland area for the months May to August in the period 1994-2003. The inland area experiences the highest mean temperature, and lowest mean precipitation. For details about the localisation of the weather-and precipitation stations, see Appendix 1.

	(a) Temperature				(b) Precipitation			
Area	May	June	July	August	May	June	July	August
Coast	5.58	10.72	13.13	12.38	53.58	46.09	64.14	91.57
Fjord	5.61	10.66	13.17	12.10	40.99	41.66	71.90	83.44
Inland	5.79	11.38	13.79	12.51	33.07	36.41	60.10	72.81

The bedrock in Lenvik consists mainly of gneiss and granites, which is low in nutrient. In Balsfjord, Bardu, Målselv and Salangen the bedrocks consist mainly of phyllite and mica schist, which is generally rich in nutrients (Moen, 1999). Plant composition and diversity of vascular plants in Troms are found to be higher on calcareous mica schist than on other substrates (Arnesen et al., 2007). This may indicate higher summer rangeland quality in the fjord and inland areas as compared to the costal area.

SHEEP HUSBANDRY PRACTICE

Sheep are fed indoors during winter (usually from October to late May or early June) and the diet consists mainly of ensilage, and some hay. Most farmers give concentrates to the lambs (less than 1 year old) during the whole indoor season, while one and a half year olds usually get slightly less than the lambs, and most of the ewes are fed concentrates only for periods; during the rut and before and after lambing take place. According to Steinheim *et al.* (2004), feeding and care are stable over years. However, the composition of the diet can differ between years due to new feeding and/or roughage shortage due to unfavourable climatic conditions or occasional winter damage.

Peak lambing generally takes place in May, and the lambs are released together with the ewes shortly after they are borne. Some practice grazing on cultivated pastures, while others release the sheep directly on rangeland. Sheep which have been kept on cultivated pastures in spring are released or transferred to rangeland. Normally the grazing season range from early June to mid or late September. The diet consists mainly of grasses and herbs, but they also eat sedges and woody plants (Garmo and Skurdal, 1998). Although sheep are free-ranging during the grazing season, they usually spend the summer within a restricted range (Skogland, 1984, Garmo and Skurdal, 1998) and, according to sheep farmers; they usually graze with a minimum overlap between neighbouring herds. It is a common practice to place salt lick on selected places at the pasture, which to some degree influence the use of the grazing area. The lambs are weighed shortly after they are gathered from the summer pastures (Mysterud et al., 2001a). Due to predators, especially wolverine (*Gulo gulo*), some farmers gather the herd already in late August. All farmers practiced conventional meat production.

SHEEP DATA AND STUDY DESIGN

The study was designed to cover the distribution of sheep farms along a coast – fjord – inland gradient, to include the local variation in climate and edaphic conditions. For the farmers' interviews, 30 farms were selected (10 in each region) according to the following criteria; 1) highest contrast in productivity (highest and lowest live autumn weights), 2) recordings from 1994 to 2003 and 3) on average more than 30 sheep. To achieve similar vegetation type, climatic regime and geology, farms situated close together were preferred. Because only 24 of the farms met all the selection criteria, I had to include 6 farms with less than 10 years of records.

Only lambs from the long–tailed breeds Dala, Steigar and Norwegian White Sheep were included, as most of the farms have mixed herds of these breeds. Hand reared lambs are excluded from the study. The difference between live spring weights, the weight prior to release to pasture, and the live autumn weights reflect growth during the free ranging period best. However, few data of spring weights exist as relatively few farmers' practice spring weighting, and these data were not used in this study. As the lambs spend most of the time on the pasture, the live autumn weight reflects the lamb growth during the free ranging period. The final material includes a total of 34 831 lambs over ten years (Appendix 5).

Mixed methods design

Mixed methods design, which consists of two different epistemological traditions, qualitative and quantitative approaches, has become more popular in social sciences in recent years (Creswell, 2003). It allows exploration of questions which cannot be addressed by either of the approaches alone. In biological sciences it is commonplace to combine quantitative and qualitative data in one statistical analysis, but mixed methods could introduce an additional dimension by allowing non-experts to present their understanding of ecological phenomena. The ecological "problem" can be seen in a new light, and the qualitative information can be used to discuss, explain or strengthen the findings/conclusions of the traditional quantitative data. In cases such as sheep farming, where there have been few previous studies about what controls lamb production, it could strengthen the scientific analysis to include the farmer's suggestions about the most important production factors.

Procedure

The quantitative and qualitative data were analysed separately, using a sequential strategy (Creswell, 2003) (Figure 2). Qualitative variables for quantification, were selected through ordination and farmer's statements. Finally the results from the two analyses were compared.

Farmer's statements and interpretations were used as part of the results. In addition to the qualitative data, some quantitative information describing the farm management is included.

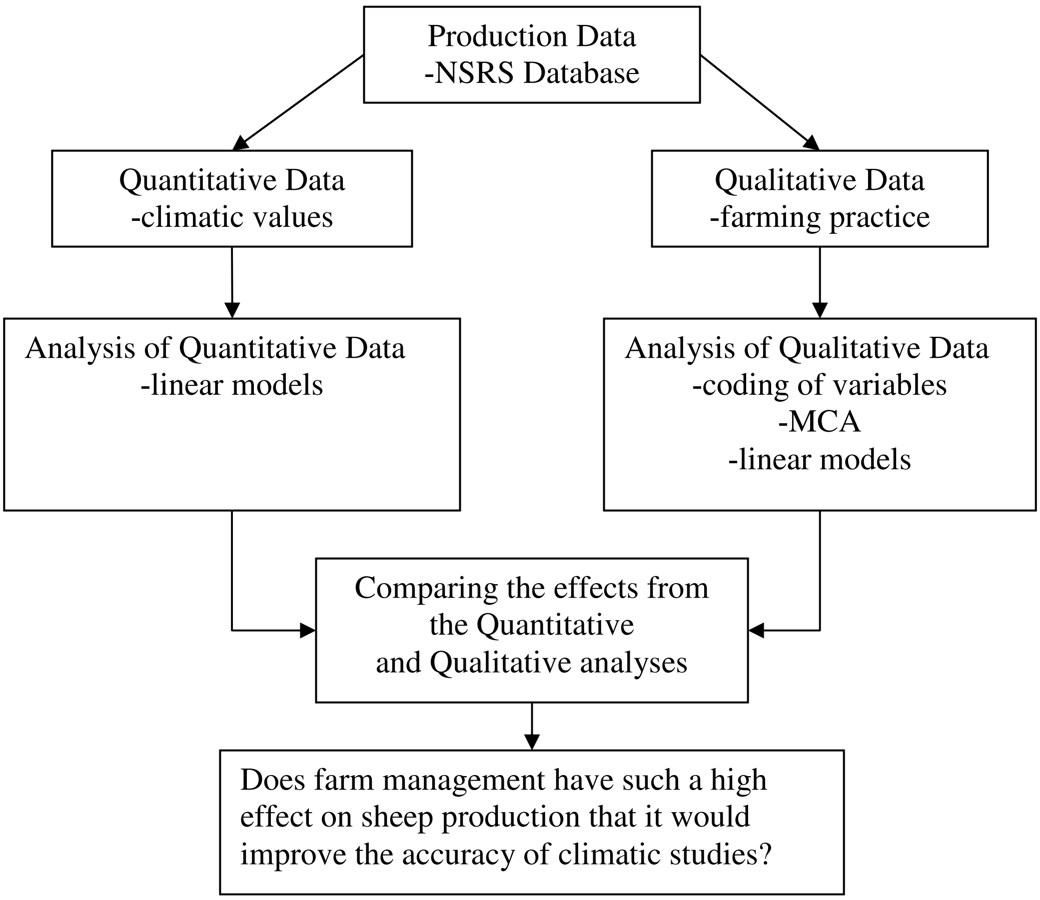

Figure 2. The strategy when Mixed Method design is used. Quantitative and qualitative data are used to explain differences in production data, and they are analysed separately.

Interviews are very informative if little research has been done on the subject, and the informants statements could be used as a guide in the analysis of quantitative data (Kvale and Brinkmann, 2008). Personal interviews were used rather than questionnaires, as it gives the opportunity for follow-up questions. Semi-structured interviews took place in the period 1st of August to 15th of November 2007. An interview guide was used to get information about factors concerning farm management that could impact autumn live weight of lambs on each farm. The interview guide was made in cooperation with researchers and key-informants. For quality assurance and ethical consideration key informants and agricultural organisations was contacted for discussion and improvement of the interview guide. Graphs and simple statistics for each farm were presented to help the farmers remember back in time. The questions for data analysis were close-ended factorial, but a few were open-ended for reflection and analysis. Coding of the questions was done prior to the interview. Norwegian Social Science Data Service (NSD) made a general consideration, and found the study ethically acceptable. Most farmers were positive to participate in this study. Out of 36 contacts, one had to be excluded from the analysis; four farmers were not available during the interview period of this study and one refused to participate. To ensure the anonymity of the sheep farmers, their identity is coded according to the area they belong to: fjord (F), coast (C) and inland (I).

The *qualitative data* obtained from the interviews was organized for statistical analyses; each variable was divided into two or tree levels, based on their distribution. Data from the interview was grouped in four categories:
1) *General treatment*: treatment against intestinal parasites, sorting of the herd, the use of new technology (insemination, ultrasound, analysis of roughage quality). 2) *Feeding regime*: feeding for the different age classes (lambs, one and a half years old and more than two years old), roughage (ensilage or hay), periods giving concentrates and amount of concentrates. 3) *Outdoor season*: Kind of pasture, grazing on cultivated pastures in spring and/or autumn, number of weeks at rangeland. 4) *Socioeconomic factors*: age, education, work beside the farm, experience. Personal interviews were preferred as the farmers were used as experts and open ended questions gave insight of the most important factors affecting lamb weights.

Data on sheep production was extracted from the NSRS. In 2007, there were 651 sheep farms in Troms (Statistics Norway, 2008), 161 of these were members of the NSRS (Norwegian Sheep Recording System, 2007).

METEOROLOGICAL AND CLIMATIC DATA

Monthly average temperature, monthly precipitation and AO-index were used as climatic parameters. Temperature and precipitation are local weather parameters, while AO measures the fluctuations in sea level pressure centred over the Arctic, and it reflects natural, large scale climatic patterns in the Northern Hemisphere (Wallace, 2000, Overland and Wang, 2005).

In recent years, there has been more attention towards the effects of large scale climatic indices on ecological processes (Hallett et al., 2004, Stenseth et al., 2003). The mostly used climatic indices in the Northern Hemisphere are the North Atlantic Oscillation (NAO), while the less used AO index is a different interpretation of the same pattern (Wallace, 2000). These climatic indices are a package for temperature, precipitation, snow depth, cloud cover and wind speed and direction (Stenseth and Mysterud, 2005), and have frequently been used to study the effect of weather patterns in winter on ecological processes and population parameters. For the western parts of Scandinavia, high positive winter AO index gives mild winters with much precipitation (Yoccoz et al., 2002), and are dominated by westerly winds (Moritz et al., 2002). The summer AO index partly reflects the same pattern as the AO winter index (Serreze et al., 1997, Serreze et al., 2000), but it has to a lesser extent been used to study the effect of summer climate on ecological processes and production parameters (Aanes et al., 2002).

Temperature and precipitation data were obtained from Norwegian Meteorological Institute (DNMI), and AO indices were obtained from the National Weather Service website (http://www.cpc.ncep.noaa.gov/products/precip/CWlink/daily_ao_index/ao.shtml). To get complete temperature and precipitation series, different weather and precipitation stations had to be combined, and months with missing data had to be estimated (Appendix 1). Temperature and precipitation series for the period 1994-2003 were used in the regression analysis to analyse the climate effects on lamb autumn weights. Since the height differences between weather stations are small, no correction was done according to general temperature lapse. The temperatures between stations are likely to differ on the warmest days during summer and coldest days during winter, but the calculation of monthly averages minimises these differences and there is therefore no need for correction (pers comm. Stein Eines).

To understand the relationship between AO, temperature and precipitation, 50 years time series (1950-1999) of temperature and precipitation data from Tromsø and AO index, for the months May to August, were analysed using principal component analysis (PCA) (Figure 3). The analysis shows that the AO index, temperature and precipitation in May and June (spring) are positively correlated (Figure 3), which is also the case for winter (December-March) (Yoccoz et al., 2002). AO and precipitation in July and August (summer) are positively correlated, but negatively correlated to temperature (Figure 3). As the AO indexes, based on PCA analysis, follow the same pattern for the months May/June and July/August, the average AO index for these months are used.

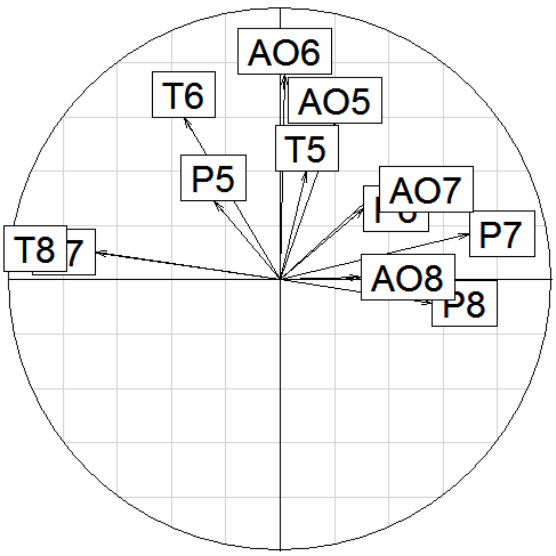

Figure 3. PCA of AO index, temperature (T) and precipitation (P) for the months May (5), June (6), July (7) and August (8) in the period 1950-1999. The figure shows that AO is positively correlated with both temperature and precipitation for May and June (PCA Axis 2). In July and August, AO index is positively correlated with precipitation, but negatively correlated to temperature (PCA Axis 1).

The climatic pattern for May and June is similar; the same is for July and August. The pattern for May and June is different from the same climatic parameters in July and August, indicating that there is a shift in the climatic expression of AO during the summer. A high AO index for May and June (AO56) is associated with a relatively mild and wet spring, while high AO index for July and August (AO78) is associated with a cool and humid summer. These spring and summer patterns appear to be relatively uncorrelated to each other as associated to the two first PCA axes, which are uncorrelated by construction.

STATISTICAL ANALYSES

The analyses were done at two different levels. Farm management variables is the dominant management practices over a ten year period, thus the statistical analysis is at farm level for the coast, fjord and inland area. The climatic analyses, which include variation in production in the ten year period, are based on data from the selected farms (n=30), within their respective climatic area.

Correction of autumn weight

Generalized additive model was used to decide the linearity of lamb growth, which showed a rather linear growth and a constant variance structure for the period 100 to 150 days, thus the dataset was restricted to lambs between 100-150 days of age when weighed. The lamb autumn weight (kg) was not log transformed for any of the statistical analyses, as the variance was rather constant. The intention was to select farms according to highest difference in live autumn weights, but because few farms met the selection criteria, it could not be done.

Data were analyzed using linear models. Corrected lamb autumn (CLA) weights were calculated for the whole sample and for each area (coast, fjord and inland area). The covariates were known from other studies to affect live autumn weights (Mysterud et al., 2002, Steinheim et al., 2004, Weladji et al., 2003), and included year, litter size (from one to five lambs in spring), lamb sex (male or female), age of the lamb (days) and age of the ewe. The relationships between the covariates and CLA weights are illustrated in Appendix 4. Age of ewe has a non linear effect, whereas date of birth and age of the lamb are linearly related to CLA weights. Weight and age of lamb are treated as continuous, while year, litter size and sex are treated as categorical; all the variables are treated as fixed. Litter size in spring explains more of the live autumn weights than do litter size in autumn. Date of birth do have a linear negative effect on the CLA weights, but is not corrected for at this stage, as it is an important aspect of the farm management. The differences in CLA weights within and between regions, are presented in Figure 4.

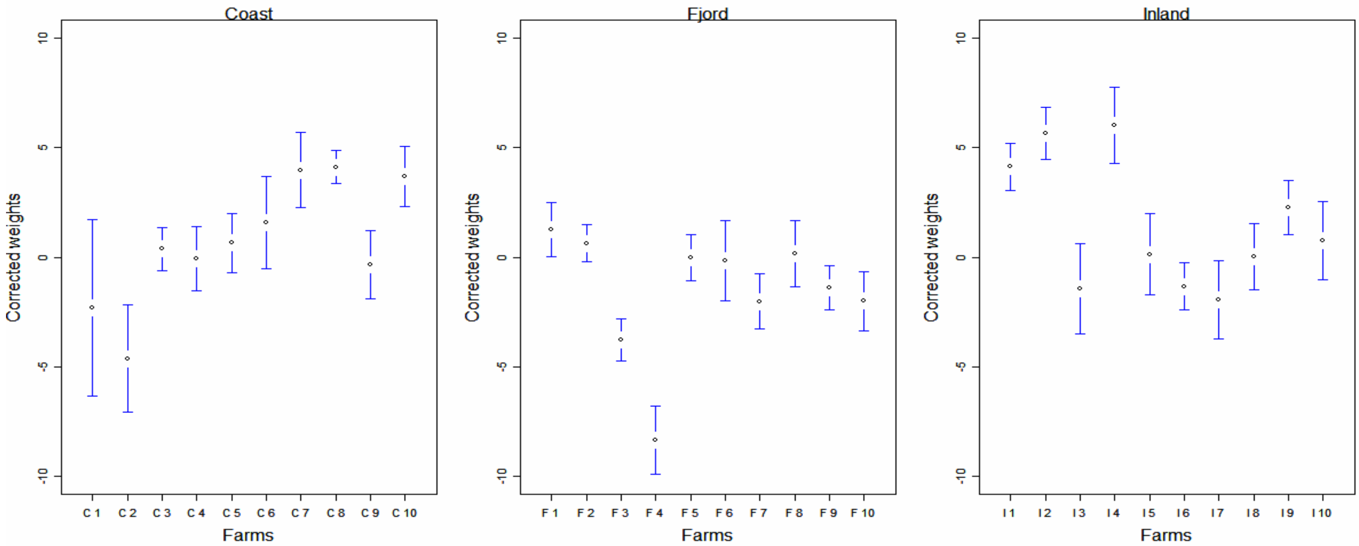

Figure 4. Predicted live autumn weights for the coast, fjord and inland area for the period 1994-2003. The bars show the 95% CI for the mean values for each farm. The lamb autumn weights are corrected for year, age of ewe (3 years old), litter size, sex and age (days) when weighted.

As the data about farm management are the dominant management practice for a ten year period, the dataset on farm level is relatively small (n=30), and only a few variables can be tested. Multiple correspondence analysis (MCA) was used to select two variables from each of the four groups (Appendix 2); the first based on differences on the first (horizontal) axis, the second based on differences on the second (vertical) axis. These factors reflect the main structures of the management variables, and uncorrelated variables within each group of variables could be selected. In cases where two or more variables showed the same pattern, the one assumed to be the most important variable was selected. As feeding is thought to be of high importance and highly influenced by the farmer, it was treated as one group, and two feeding variables were selected. For the analysis, the average residuals for all ten years were used.

Partial residuals were used in linear models to test the effects of climatic variables on the live autumn weights. The effects due to variation between years are kept, in order to test the climatic parameters against the corresponding year. The climatic variables were standardized (mean=0, s.d=1) to facilitate the interpretation of climatic effects. Calculation of all residuals is based on CLA weights. In the analyses of production, we used both qualitative (binary) and quantitative predictors. For the quantitative variables, each regression coefficient from the linear regression was rescaled by multiplying it by two, which make these scaled coefficients comparable directly to effect estimates obtained from the binary predictors (Gelman and Hill, 2007).

As the dataset was rather small, it was not practical to test the interactions between climatic factors and management practices. I also focus on effect size (Nakagawa and Cuthill, 2007), not so much on the statistical significance per se, as it is the quantitative effects which matter (i.e. variation in kg). Standard errors of parameter estimates were used to assess if lack of statistical significance was due to low effect size or high uncertainty. Both data from NSRS and interview data were analysed using linear models. All the statistical analyses were carried out in R (R Development Core Team, 2006).

Results

The most important factors influencing production on sheep farms were AO index for the climatic variables, whereas use of cultivated pastures in spring, herd size and length of the grazing season were the most important farm management variables (see model selection, Appendix 3). The effect sizes of the AO index and farm management variables are of rather equal importance. The climatic effects of AO78 are 6.81 kg (95% CI 2.04, 11.59, s.e.=2.40) for the coast, 2.94 kg (95% CI -1.38, 7.25, s.e.=2.17) for the fjord and 3.30 kg (95% CI -1.53, 8.12, s.e.=2.43) for the inland area (Table 4). The management variables also had large effects; grazing on cultivated pastures in spring had an effect of -2.56 kg, (95% CI -4.46, -0.65, s.e.=0.93), herd size -2.11 kg (95% CI -4.07, -0.15, s.e.=0.96) and length of grazing season 1.90 kg (95% CI -0.94, 387, s.e.=0.97) per lamb. The results are mostly supported by farmer's statements, which is presented below together with the results from the statistical analysis.

Relationship between farm management and lamb weights

Sheep farmers regard outdoor resources as very important for lamb weights. From the interviews, the most frequent factors claimed to affect lamb autumn weights are related to rangeland and grazing conditions, but also feeding and care through winter are thought to be important (Table 2).

Table 2. Sheep farmers ranking of important management factors affecting lamb weights (n=30).

Rangeland quality	13
Spring grazing	9
Feeding and care through indoor season	9
Autumn grazing	3

Not all the management factors could be directly explored by the statistical analysis, but in a broad sense the statistical analysis supports that factors related to outdoor resources are important (Table 3; see Appendix 3 for model selection). Negative effects on lamb weights were found for herds grazing on cultivated pastures in spring and herd size, while the length of the grazing season had a positive effect on lamb weights (Table 3). Rangeland quality mainly reflects vegetation type and heterogeneity in the grazing area, while spring grazing is most often referred to as the quantity of forage in early spring, either on cultivated pasture or rangeland. According to farmers, the grazing conditions on rangeland are often of high quality in spring (I10 and C9). Even if green plants can not be seen, farmers claimed that sheep find newly emerged buds under the litter (I10 and C4). However, this may not be the case for all farms, as this can depend on local conditions, such as rangelands of very high quality or especially favourable sun-exposed slopes. Due to limited herbage quantity in early spring, some farmers find it preferable to divide and release the herd onto rangeland in small groups (C6, C7 and I1). It was not asked specifically about the length of the grazing season, but it was a general understanding that a prolonged grazing season, due to early grazing start in spring, was an advantage. The importance of autumn grazing is mainly associated with grazing cultivated pastures to improve weight gain for lambs that are too small to be slaughtered.

Feeding and care through indoor season, however, was not found to have any effect on CLA weights, neither did any of the socioeconomic variables or date of birth.

Table 3. The effects of farm management variables. FS>70=average flock size of more than 70 ewes GCPS:1=practise grazing on cultivated pastures in spring prior to release to rangeland and WG:2=lambs spend more than 14 weeks at rangeland. Intercept is FS<70= average flock size less than 70 sheep, GCPS:0=does not practice grazing at cultivated pastures in spring and WG:1=lambs spend less than 14 weeks at rangeland. Statistically significant results (p<0.05) is given in bold.

	Estimate	Std.Error	95% CI	
Intercept	2.084	1.016	0.004	4.172
WG:2	**-2.108**	**0.955**	**4.072**	**0.145**
GCPS:1	**-2.556**	**0.928**	**4.463**	**0.649**
NS>70	1.896	0.968	0.094	3.886

Climatic influences on lamb weights

To most farmers, the best climatic conditions for high autumn weights of lambs are relatively cool and moist summers, while warm and/or dry summers have the most negative effect on lamb autumn weights. The farmers also suggest that the weather at the time of release is important, and the weather should be mild and fair (C5, C6 and C9). In the statistical analysis of climate effects on lamb weights, the AO index was found to be most influential on CLA weights. The AO index in summer (AO78) had clearest effect on the live autumn weights. It was positively related to CLA weights for all areas, with the largest effect for the coast (Table 4). As high AO78 is associated with cool and moist summers, it supports the statement that cool and humid summers give the highest lamb weights. At the same time, the effect of the AO index in spring (AO56) on CLA weights was weaker and not consistent, with high standard errors relative to effect size (Table 4).

Table 4. The effects of the AO index for the periods May/June (AO56) and July/August (AO78) for the coast, fjord and inland area. Statistically significant results ($p<0.01$) is given in bold.

						Rescaled (x2)			
		Estimate	Std.Error	95% CI		Estimate	Std.Error	95% CI	
Coast	Intercept	0.032	0.375	-0.714	0.776	0.064	0.750	-1.428	1.552
	AO56	-0.797	0.670	-2.217	0.533	-1.594	1.339	-4.434	1.066
	AO78	**3.407**	**1.202**	**1.020**	**5.794**	**6.815**	**2.404**	**2.040**	**11.588**
Fjord	Intercept	-0.416	0.333	-1.076	0.244	-0.832	0.666	-2.152	0.488
	AO56	0.618	0.593	-0.560	1.795	1.235	1.186	-1.120	3.590
	AO78	1.468	1.087	-0.691	3.626	2.935	2.174	-1.382	7.252
Inland	Intercept	0.098	0.366	-0.630	0.826	0.195	0.732	-1.260	1.652
	AO56	-0.457	0.655	-1.759	0.844	-0.914	1.310	-3.518	1.688
	AO78	1.647	1.214	-0.765	4.059	3.294	2.428	-1.530	8.118

The temperature and precipitation were positively correlated with the AO index in May and June (Figure 4), but no statistically significant relationships to lamb autumn weights were detected in the linear regressions. There were no clear patterns and the coefficients had high standard error. Furthermore, neither snow depth in the months April and May nor winter AO index (December to March) had any effect on live autumn weights.

Regional differences in lamb weights

There were regional differences in lamb weights with inland farms having the highest weights, while the lowest weights were found in the fjords. The main regional differences in climate were the amount of precipitation (Table 1), with the highest precipitation at the coast and the lowest amount of precipitation in the inland region. There were also some differences in the farm management, with inland region having most of farmers that did not use cultivated pastures in spring (Appendix 2c). Furthermore, coast area has highest proportion farms with flock sizes less than 70 sheep, while the fjord area has the largest proportion flocks with more than 70 sheep (Appendix 2a). The farmers were not directly asked about the reasons behind regional differences, but some of the farmers indicated possible reasons for lower production, such as spruce planting, locally high sheep density, fencing and increased cabin building in the grazing area (F10 and I10).

Discussion

How could farm management influence production?

There are strong indications that outdoor resources affect lamb weights, particularly in spring. This is supported by sheep farmers (Table 2) and the statistical analysis (Table 3). Lamb autumn weights were negatively related with grazing on cultivated pastures in spring and herd size, and positively related to length of the grazing season, thus quality and quantity of the foraging plants appear as highly important with regard to lamb autumn weights.

The lamb's potential for weight gain is highest in spring (Høberg et al., 2002). To maximize the lamb's high potential for weight gain in the spring, high milk production of the ewe, which is dependent on the quality and quantity of spring pasture, are important (Gjefsen, 1999). Spring grazing (Table 2) was considered by farmers as important independent of whether it was on cultivated pastures or at rangeland. The negative effect for those practising grazing on cultivated pastures in spring could be due to differences in quality and/or quantity of forage compared to rangeland pastures. Most cultivated pastures consist of relatively few plant species, mainly grasses, while rangeland provides a higher diversity of foraging species. However, it is a general understanding that quantity (available forage) rather than quality of foraging plants is the most limiting factor in spring (C4, C9, F6 and I10), as both protein and energy content are generally high at this time (Gudmundsson, 1993).

An alternative explanation for the negative effect of grazing cultivated pastures in spring could be due to gastrointestinal infections, which commonly can reduce weight gain of lambs during grazing period (Gjerde, 2005). The same cultivated pastures are often grazed in spring and/or autumn, and are often used year after year. Some parasites survive the winter at pasture and grazing at infected pastures in spring may lead to re-infection or higher loads of intestinal parasites (Gjerde, 2005).

The reason for the negative effect for large herds (>70 sheep), might be due to density dependent factors. The negative effect of herd size is supported by Simensen and Hauge (2003), who also found a negative relationship between herd size and live autumn weights. They argued that it could be due to reduced resources, particularly on the spring pasture, which can be a limiting factor for large herds. Some farmers claim that it is best to release small groups spread out on favourable places in the rangeland to ensure enough food (C6, C7, C10, F7 and I1). This may indicate that density dependent factors are important, and particularly in spring when the amount of forage can be low. Density dependence in foraging behaviour, at the scale of diet choice, are found for sheep (Kausrud et al., 2006). Thus, in larger herds, there might be competition for the best foraging plants during the whole grazing period, or the plant composition might alter due to high grazing pressure (Austrheim et al., 2005). Furthermore, high stocking rate at pastures may lead to higher infection of nematodes for grazing sheep (Thamsborg et al., 1996).

The length of the grazing period on rangeland had a positive effect on the lamb weights. The database does not tell if the herd starts grazing early in the spring, or if the grazing period is prolonged in the autumn, which makes it hard to interpret. The length of the grazing season depends on location and condition of the rangeland, and usually lamb growth decrease when the nutritive value of forage drops in autumn (Gudmundsson, 1993, Høberg et al., 2002). It is therefore most likely that the positive effect of the grazing period is associated with early grazing on spring pastures. However, in some areas they gather their herds already in August due to predation risks, which may influence autumn weights. Some farmers also claimed that autumn grazing at cultivated pastures are of importance for production.

Which climatic indices could best explain differences in production?

Of the climatic factors, the AO index was the factor that best could explain the differences in lamb weights, and the effect was largest on the coast. The relationship between climate in summer (AO78) and lamb weights is strong, and exhibits the same pattern for all areas. July and August are the warmest summer months, and high AO78 means cool and moist climate for these months. Reduced temperature, due to a high AO78, might slow down the growth and development of foraging plants, and hence plants of high quality will be available for a longer period (Albon and Langvatn, 1992). On the other hand, low AO78, is likely to give more wind from East/Southeast (as during low AO winter index) (Moritz et al., 2002), leading to warmer and dryer weather, which is claimed by the farmers to be the worst climatic conditions for lamb autumn weights. Under warm and dry weather conditions, the sheep alter their behaviour; they graze less than they normally do, and get stressed by insect harassment (Garmo and Skurdal, 1998). Furthermore, the development of nematodes is sensitive to climatic conditions (van Dijk and Morgan, 2007). Climatic conditions that give lower lamb autumn weights may also give faster development of parasites and higher infection rates.

In the coast and inland area the relationship with AO56 was negative, but more uncertain. High AO56 is associated with relatively “mild” and wet spring weather conditions. It is a common understanding that it should be relatively mild and fair weather at the time of release to pasture. Cold and wet weather at the time of release, normally in early June, can give an abrupt reduction/stop in the growth of lambs (C6). Sheep can alter the behaviour during heavy rainfall; they seek shelter and eat less.

Regional differences in lamb weights

It is likely that the local and regional differences in CLA weights (Figure 5) are due to differences in access to outdoor resources, which may be related to topography, local climate, edaphic conditions, predators or human inventions in nature. Even if it was not a specific question during the interview, there are some indications of why these differences exist. Spruce (*Picea abies*) is not a native species. However, especially in the fjord area, spruce planting has been intensive, and are claimed to degrade the important spring pastures. As the spruce patches mature and alter the natural vegetation the grazing quality at these pastures decline (Dyrlie, 2005). Cottage building can result in loss of valuable rangeland, and combined with disturbance, it may result in reduced growth (F10 and I10). Predators present in the grazing area will most probably result in loss of sheep and lambs (Warren et al., 2001), and also disturb the sheep (Høberg et al., 2002). These factors may also explain effects on production which cannot be explained by general climatic variables. The effects of these variables could not be explored with the databases used in this study.

Local climatic parameters versus climatic indices

Local measures of temperature and precipitation did not show any clear pattern and was not able to explain the variation in live autumn weights, such as the AO index did. It has been found that large-scale indices are better predictors than local climate, which do not capture the complexity of the climate effects on ecological processes (Hallett et al., 2004). The climate does not act through a single climatic variable, but through interactions between different climatic variables. Aanes et al. (2002) found that the AO summer index could explain ecological effects of climate. In a study on Svalbard they found that high AO summer index (June to September) had a negative effect on the growth of *Cassiope tetragona* and a delayed negative effect on growth rate of Svalbard reindeer (*Rangifer tarandus platyrhynchus*).

The relationship between the summer AO index and local weather parameters differ in space, and it is stronger in north Norway than in south Norway, a pattern opposite to the winter AO index (Yoccoz, unpublished data).

Reliability and validity

Due to the use of mixed method design, which includes personal interviews of the farmers, the sample is limited both in size and space. The study is expected to be valid for members of NSRS in Troms, which perhaps do not vary as much in their farming practices compared with farmers that are non members. Furthermore, if the sample size had been larger, other factors might have been investigated, such as ecological farming practice. This study has shown that farm management has a large effect on lamb autumn weights, and it provides a basis for further studies on the importance of farm management. By using questionnaires, based on the results form this study, the external validity could be improved.

I studied the main effects of climate and farm management on lamb autumn weights over a ten years period. The analysis of the climatic effects on lamb autumn weights could be made more reliable by using longer time series for the AO index, temperature and precipitation. However, due to the parallel analyses of farm management, there had to be a trade off, as the farm management should be relatively stable over the study period. Furthermore, if local climatic parameters only have substantial effect during years of extreme, the short time series of this study will not be able to detect the effects of the local climatic parameters (Skogan, 2000). There are also large differences in lamb autumn weights within each climatic region (Figure 4), and there might be confounding effects between region, climate and farm management. For instance, the use of cultivated pastures in spring was a dominant farming practice in the inland, and could be a confounding pattern. To reveal these relationships, it has to be a larger sample on a larger spatial scale.

According to the sheep farmers, feeding and care through winter is important (Table 4), and makes up the basis for the live autumn weights. It is stated that high birth weights, good milk production and generally good health conditions are necessarily for an effective utilizing of the rangeland resources. Even though feeding through winter, especially before and after lambing, is assumed important, the statistical analysis was not able to show any effect of feeding strategy. The lambs spend most of their time outdoor, but the lack of effect could also be related to difficulties of identifying the actual farming practices by interviews.

Conclusion

This study has identified some farm management variables affecting lamb autumn weights in a restricted sample of sheep farms in Troms. The results indicated that variation in farm management could have as high influence on production as climatic fluctuation, thus the accuracy of climatic studies on sheep production may be improved by including/correcting for variation in farm management. Further studies are needed in order to test if these factors are of importance for other areas, and they should include larger sample sizes and cover a larger geographic area.

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Appendix

Appendix 1

The different weather- and precipitation stations used for the climatic series for the coast, fjord and inland. Temperature and precipitation series (May, June, July and August) from Tromsø in the period 1950 - 2006 was used in the PCA analysis with AO index for the same period. Temperature and precipitation for the period 1994 - 2003 are used in the linear regression model for the climatic effects on live autumn weights.

Area	Station name	Station number	Meter asl	Geographical location	Period	Weather parameter	Temperature data missing	Precipitation data missing
Coast	Senja - Grasmyrskogen	88920	50	69,29 N; 17,77 E	Jan 1994 - Jun1997	temp and prec	Jul and Aug 1997 [1]	Jul and Aug 1997 [2]
	Senja - Laukhella	88200	9	69,23 N; 17,90 E	Sept 1997 - Dec 2003	temp and prec	Jul 1998 [1]	
	Tromsø - Langnes	90490 [5]	8	69,67 N; 18,91 E	May 1996 - May 1999	temp		
	Bardufoss	89350 [5]	76	69,60 N; 18,54 E	May 1996 - May 1999	temp		
	Tranøybotn - Nystad	88340 [5]	36	69,21 N; 17,58 E	May 1996 - May 1998	prec		
Fjord	Storsteinnes i Balsfjord	90200	27	69,25 N; 19,23 E	Jan 1994- Dec 2003	prec	Jan 1994 - Dec 2003 [3 & 4]	
	Tromsø - Langnes	90490 [5]	8	69,67 N; 18,91 E	Jan 1994- Dec 2003	temp		
	Oteren	91300 [5]	12	69,25 N; 19,87 E	Aug 1994 - Dec 2002	temp	Jan 2003 - Dec 2003	
Inland	Bardufoss	89350	76	69,60 N; 18,54 E	Jan 1994 - Dec 2003	temp and prec		

Notes:

[1] Temperature are estimated 1˚C above temperature at Tromsø Langnes (90490).

[2] Precipitation are estimated to be 10 millimeter below precipitation in Tranøybotn (88340).

[3] Temperature data are from Tromsø Langnes (90490), and Kvesmenes (91330) / Oteren (91300), and it is corrigated ¾ against Kvesmenes/Oteren.

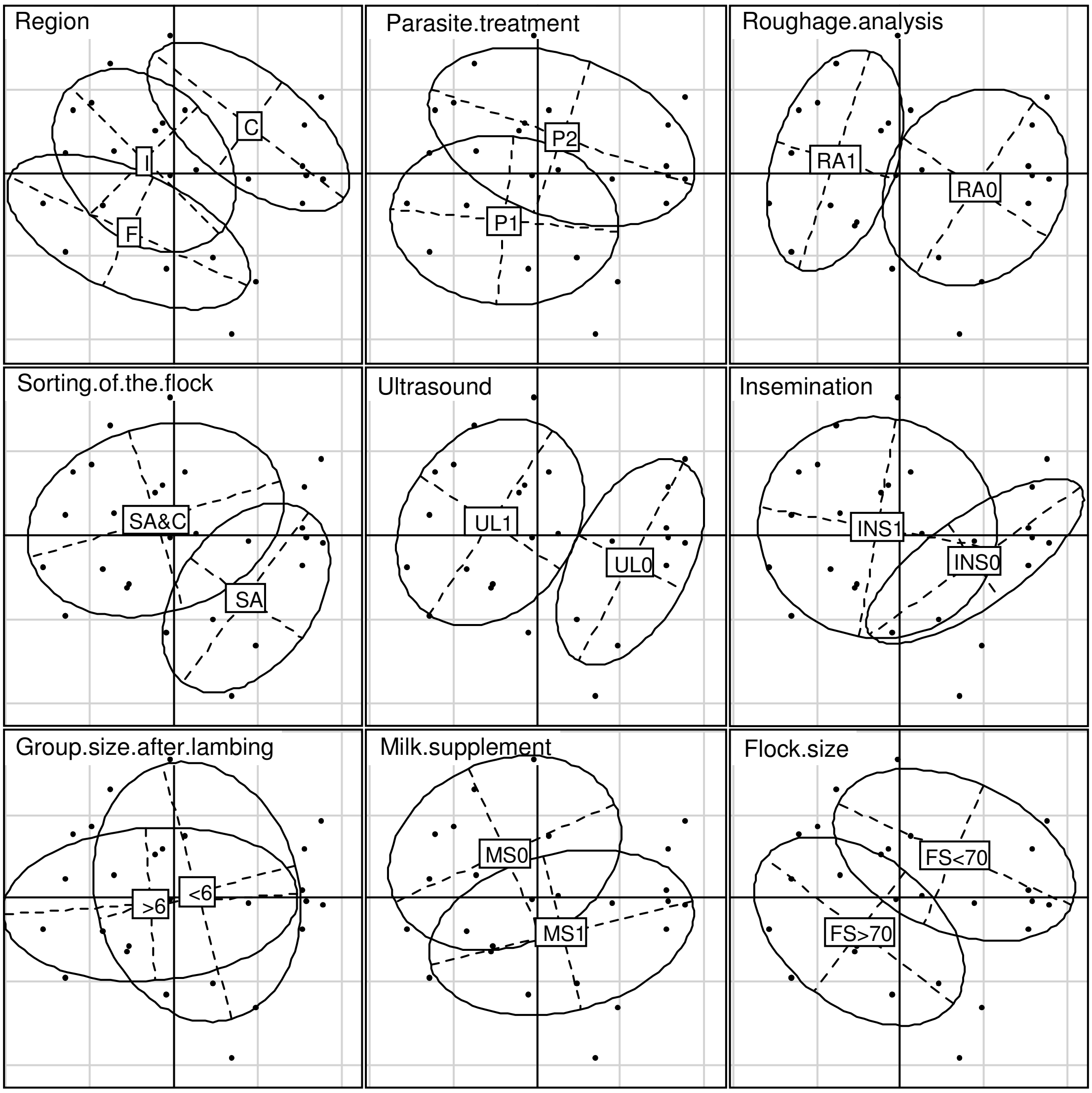
[4] Temperature data for 2003 are reconstructed, based on the temperature series from Tromsø Langnes and Oteren.

[5] Stations used for estimation and/or reconstruction of missing data.

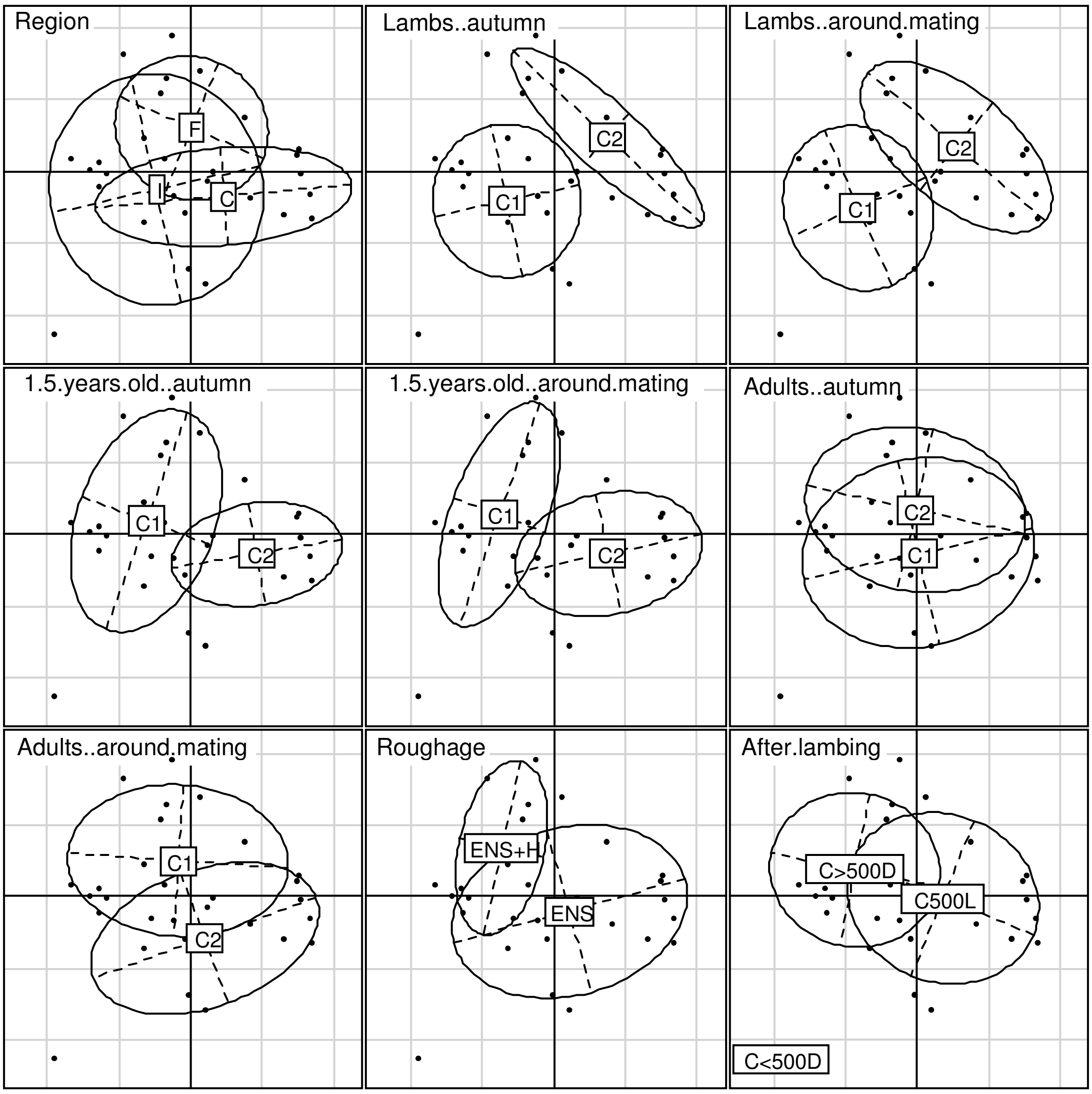
Appendix 2

MCA of the management groups; (a) general treatment, (b) feeding regime, (c) outdoor resources and season and (d) socioeconomic factors. MCA allow selection of uncorrelated variables within each group. For description of variables, see Table 5.

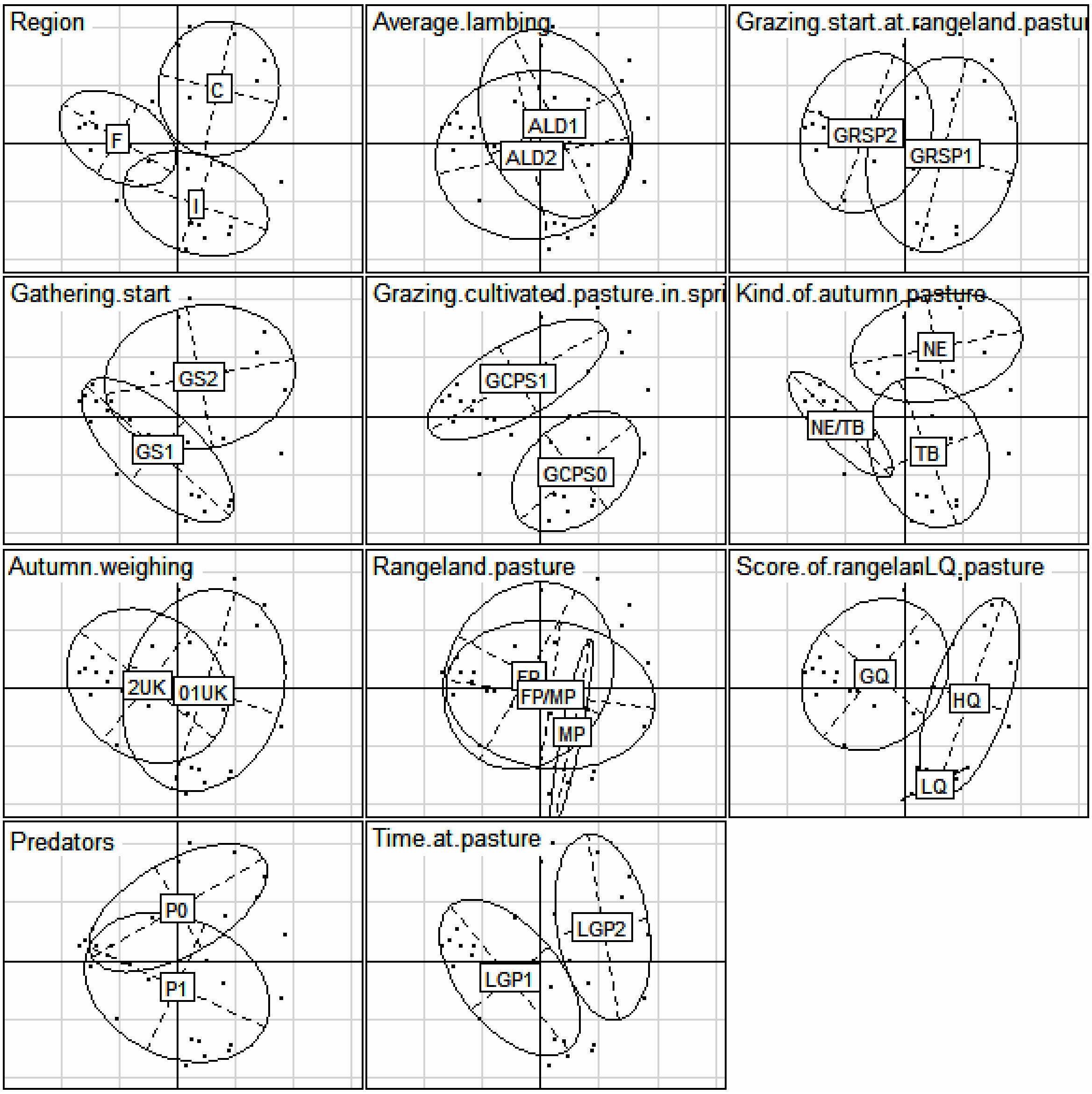
(a) General treatment.



(b) Feeding


Region
F
I
C
Lambs..autumn
C2
C1
Lambs..around.mating
C2
C1
1.5.years.old..autumn
C1
C2
1.5.years.old..around.mating
C1
C2
Adults..autumn
C2
C1
Adults..around.mating
C1
C2
Roughage
ENS+H
ENS
After.lambing
C>500D
C500L
C<500D

(c) Outdoor season



(d) Socioeconomic factors

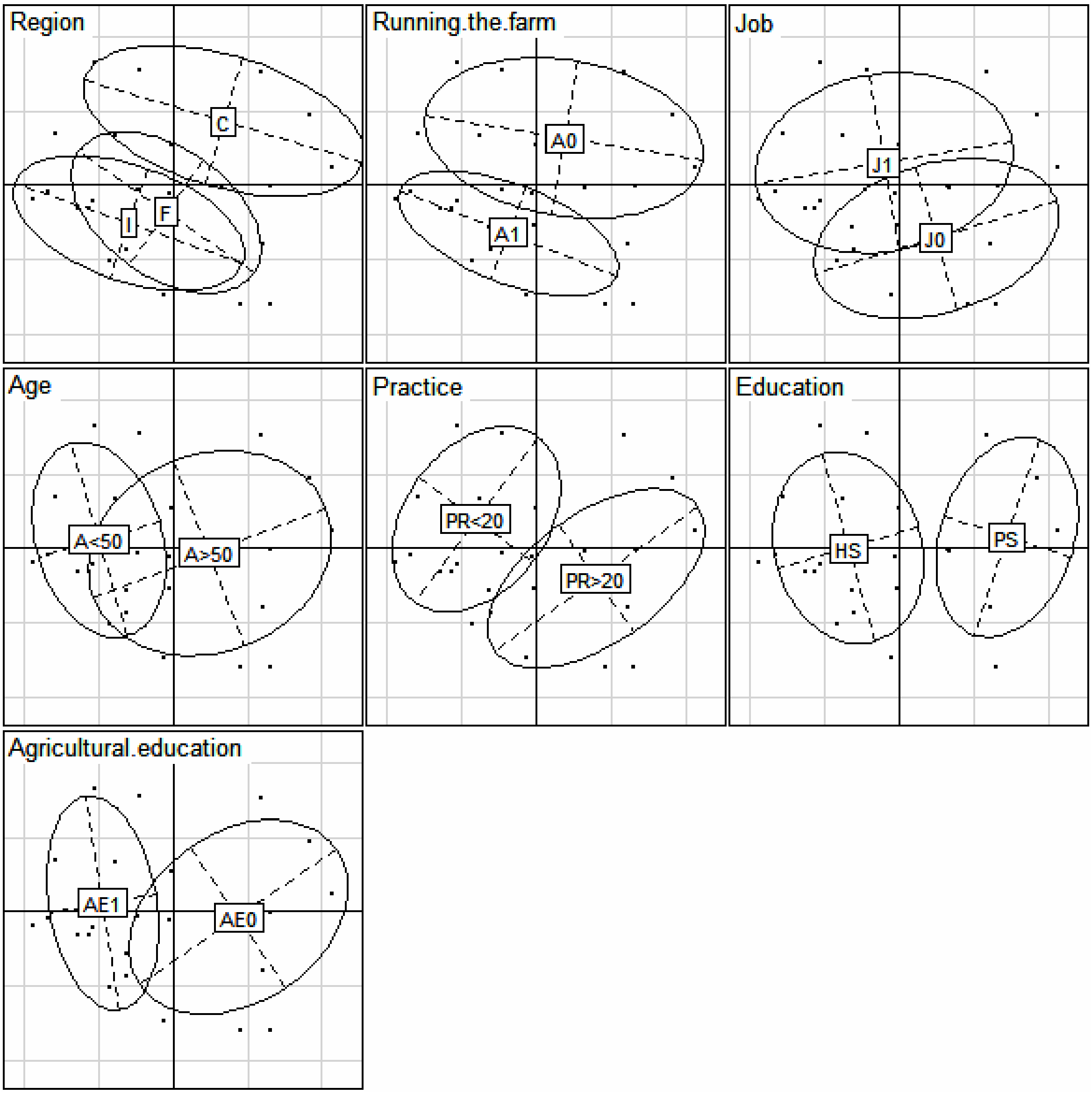


Table 5. Codes and description for the variables used in the MCA for Appendix 2a-d.

(a) General treatment	Code	Description
Region	C	Coast area
	F	Fjord area
	I	Inland area
Parasite treatment	P1	One treatment against intestinal parasites each year
	P2	One to two treatments against intestinal parasites each year
Roughage analysis	RA0	Never used roughage analysis
	RA1	Have used roughage analysis one or more times
Sorting of the flock	SA	Sorting the flock only after age
	SA&C	Sorting the flock after age and condition
Ultrasound	UL0	Do not use ultrasound
	UL1	Have used ultrasound more than one year
Insemination	INS0	Do not use insemination
	INS1	Have used insemination more than one year
Group size after lambing	<6	Less than six ewes and their lambs
	>6	More than six ewes and their lambs
Milk supplement	MS0	Does not give milk supplement to the lambs after lambing
	MS1	Do give milk supplement to the lambs after lambing
Flock size	FS<70	Average flock size of less than 70 ewes
	FS>70	Average flock size of more than 70 ewes

(b) Feeding		
Region	C	Coast area
	F	Fjord area
	I	Inland area
Concentrate feeding: Lambs in autumn	C1	≤ 400 gram concentrate per day
	C2	> 400 gram concentrate per day
Concentrate feeding: Lambs before/after mating	C1	≤ 450 gram concentrate per day
	C2	> 450 gram concentrate per day
Concentrate feeding: 1.5 years old in autumn	C1	≤ 200 gram concentrate per day
	C2	> 200 gram concentrate per day
Concentrate feeding: 1.5 years old before/after mating	C1	≤ 350 gram concentrate per day
	C2	> 350 gram concentrate per day
Concentrate feeding: Adults in autumn	C1	0 gram concentrate per day
	C2	> 0 gram concentrate per day
Concentrate feeding: Adults before/after mating	C1	≤ 250 gram concentrate per day
	C2	> 250 gram concentrate per day
Roughage	ENS	Only ensilage
	ENS+H	Ensilage and/or hay
Concentrate feeding: after lambing	C<500D	Less than 0.5 kilograms per day per ewe after lambing
	C>500D	More than 0.5 kilograms per day per ewe after lambing
	C500L	0.5 kilogram per lamb per day

(c) Outdoor season		
Region	C	Coast area
	F	Fjord area
	I	Inland area
Average lambing date	ALD1	Average lambing date at or before May 14th
	ALD2	Average lambing date after May 14th
Grazing start at rangeland pasture	GRSP1	Grazing start at rangeland pasture before June 4th
	GRSP2	Grazing start at rangeland pasture after June 4th
Gathering start	GS1	Gathering start before September 12th
	GS2	Gathering start after September 12th

Grazing cultivated pasture in spring	GCPS0	No grazing on cultivated pastures in spring
	GCPS1	Grazing on cultivated pastures in spring
Kind of autumn pasture	NE	Cultivated pastures with native species
	TB	Timothy pastures
	NE/TB	Cultivated pastures with native species/Timothy pastures
Autumn weighing	01UK	Autumn weighing 0-1 week after gathering
	2UK	Autumn weighing 1 or more weeks after gathering
Rangeland pasture	MP	Mountain pasture
	FP	Forest pasture
	FP/MP	Mix between forest and mountain pasture
Score of rangeland pasture	LQ	Low quality
	GQ	Good quality
	HQ	High quality
Predators	P0	Predators not present in the rangeland
	P1	Predators present in the rangeland
Time at rangeland pasture	LGP1	14 weeks or less at rangeland
	LGP2	14 weeks or more at rangeland

(d) Socioeconomic factors

Region	C	Coast area
	F	Fjord area
	I	Inland area
Running the farm	A0	Running the farm with help from the family
	A1	Running the farm alone
Job	J0	No job beside the farm
	J1	Job beside the farm
Age	A<50	Farmers age less than 50 years
	A>50	Farmers age more than 50 years
Practice	PR<20	Less than 20 years practice as sheep farmer
	PR>20	More than 20 years practice as sheep farmer
Education	PS	Primary and secondary school
	HS	High school/upper secondary school
Agricultural education	AE0	No agricultural education
	AE1	Agricultural education

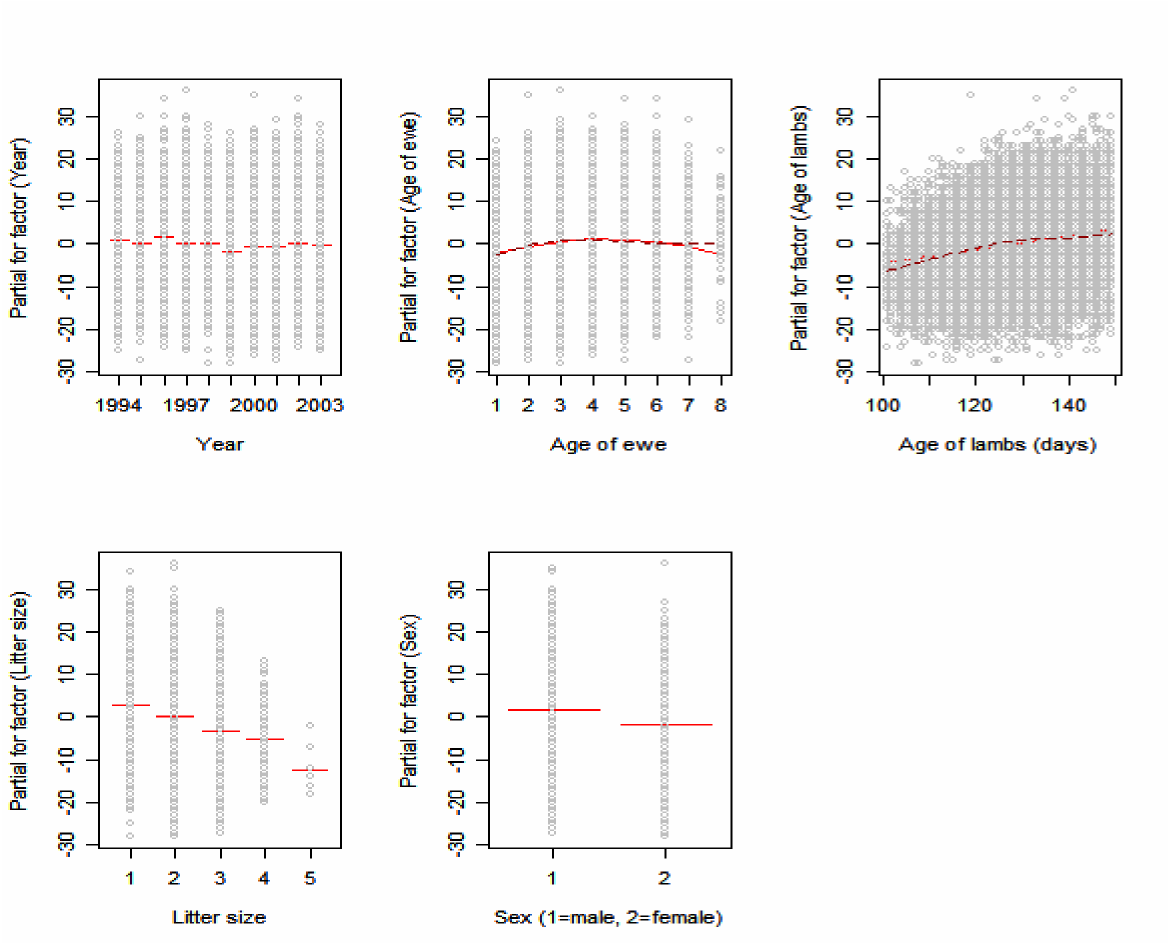
Appendix 3

Model selection for the selected farm management variables. FS= flock size, MS= milk supplement to the lambs, CFAL= concentrate feeding for lamb in autumn, CFA1.5= concentrate feeding for 1.5 years old in autumn, GCPS= grazing cultivated pastures in spring, LGP= length of the grazing period, PR= years of practice and RF= runs the farm.

(int.)	NS	drevet	driver	gh	GCPS	merst	ph	WG	k	R.sq	Adj.R.sq	RSS	AIC	AICc	dAICc	akaike.weight
2,0840	**1**				**1**			**1**	**5**	**0,4156**	**0,3482**	**156,6174**	**144,7146**	**147,2146**	**0,0000**	**0,1386**
3,0665	1				1				4	0,3294	0,2797	179,7157	146,8417	148,4417	1,2271	0,0750
0,6255					1			1	4	0,3061	0,2547	185,9574	147,8659	149,4659	2,2514	0,0450
2,5721	1				1	1		1	6	0,4272	0,3356	153,4953	146,1105	149,7627	2,5481	0,0388
3,6979	1				1	1			5	0,3621	0,2885	170,9430	147,3403	149,8403	2,6257	0,0373
1,8384	1	1			1			1	6	0,4206	0,3279	155,2806	146,4574	150,1096	2,8950	0,0326
3,5393	1				1		1		5	0,3547	0,2802	172,9410	147,6889	150,1889	2,9743	0,0313
2,2599	1				1		1	1	6	0,4169	0,3236	156,2716	146,6483	150,3004	3,0859	0,0296
2,2293	1		1		1			1	6	0,4169	0,3236	156,2799	146,6498	150,3020	3,0874	0,0296
2,0148	1			1	1			1	6	0,4158	0,3224	156,5559	146,7028	150,3550	3,1404	0,0288
2,6233	1	1			1				5	0,3421	0,2662	176,3080	148,2674	150,7674	3,5528	0,0235
3,2883	1			1	1				5	0,3334	0,2564	178,6559	148,6642	151,1642	3,9497	0,0192
1,6779	1								3	0,1927	0,1639	216,3472	150,4069	151,3300	4,1154	0,0177
3,0821	1		1		1				5	0,3294	0,2520	179,7124	148,8411	151,3411	4,1266	0,0176

Appendix 4

The covariates effect on lamb autumn weights. There are differences in lamb autumn weights due to year, while age of ewe has a nonlinear effect. Litter size is negatively related to the weights and there are weight differences between sexes. Age (days) when weight is rather liner related to the weights for the period 100-150 days.



Appendix 5

The number of lambs for each area and year (1994-2003), and the total for the ten year period.

Area	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Total
Coast	994	961	993	1013	1010	956	1149	1055	1080	1182	10393
Fjord	1177	1237	1281	1369	1369	1512	1469	1665	1723	1651	14453
Inland	626	984	879	879	912	950	1038	1084	1238	1395	9985