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Analysis

Livestock management at northern latitudes Potential economic effects of climate change in sheep farming

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ABSTRACT

We study the economy and ecology of sheep farming under future climate change scenarios. The analysis is at the farm level and includes two different categories of the animals, ewes (adult females) and lambs with a crucial distinction between the outdoor grazing season and the winter indoor season. The model is formulated in a Nordic economic and biological setting. During the outdoor grazing season, animals may experience growth constraints as a result of limited grazing resources. The available grazing resources are determined by animal density (stocking rate) and weather conditions potentially affecting the weight, and hence, the value of lambs. Because empirical evidence suggests that climate changes, e.g., increased temperature, have contrasting effects on lamb weights depending on the location of the farm, the spatial effects of such changes are analyzed.

1. Introduction

IPCC projections indicate that mean annual temperatures will increase and the increase will be strongest at higher latitudes (Solomon et al., 2007). However, summer temperatures are expected to increase more in southern Europe, while winter temperatures more in the north (Alcamo et al., 2007). Climate change is a major challenge to food and agriculture (FAO, 2009) and has become a key issue for The Food and Agriculture Organization of the United Nations (FAO) (see: http://www.fao.org/climatechange). In particular, a slight warming in seasonally dry and tropical regions is expected to reduce crop yield, while the effect of elevated temperatures on pastoral systems in temperate regions is expected to be positive, at least up to a 3 °C increase (Easterling et al., 2007). These projections indicate that Nordic sheep farmers will face novel climate conditions in the future. Nielsen et al. (2012) showed that in southern Norway increased spring temperature would have contrasting effects on lamb autumn body mass, depending on the location of the areas where the animals are kept during the outdoor grazing season. This indicates that any attempt to include weather conditions and climate change in optimization models for individual farmers has to be site specific. To illustrate the effect of the spatially inconsistency in climate effects, we include in our theoretical and numerical model two areas where the effect of increased spring temperature has been shown to have opposite effect. Our aim is to show how climate change may alter the body weight and the slaughter value of the animals, and how this will affect the stocking rate and profitability of the farmers.

Our sheep farming study is carried out with a crucial distinction made between the outdoor grazing season (spring, summer and fall) and the indoor winter feeding period, and between different categories of animals (lambs and ewes). Lambs are born in early spring, just before the outdoor grazing season starts, which is the typical situation found in many strongly seasonal environments at northern latitudes, such as in the Nordic countries, and at high altitudes in continental Europe, such as mountainous areas in France and Spain. The analysis essentially relates to the economic and biological setting found in Norway, but should also have relevance for sheep farmers in Iceland and Greenland, and possible also in mountainous areas in France and Spain. The problem analyzed here is to find the optimal number of animals to be fed and kept indoors during the winter season for a given farm capacity (i.e., farm size). A corollary of this problem is to find the effect that summer grazing sheep density has on vegetation productivity and hence on per-animal meat production. The problem is analyzed under the assumption that the farmer aims to do it 'as well as possible,' represented by present-value profit maximization.

The animal growth model presented in this paper builds on Skonhoft (2008). Skonhoft et al. (2010) extended this model to include a relationship between vegetation availability and lamb weight. Here we develop this relationship further by allowing lamb weights and slaughter values to be affected by weather and outdoor grazing conditions. Balancing the number of animals and weight of animals is indeed seen as a crucial management problem in the Nordic

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countries as well as other places (e.g., Mysterud and Austrheim, 2005; Olafsdottir and Juliusson, 2000).

In the natural resource and agricultural economics literature, there is an increased focus on the potential effects of climate changes and weather uncertainty. Diekert et al. (2010), analyzing the Barents Sea cod fishery, assume that climate changes are channeled through a temperature variable affecting the recruitment of the cod stock, and where a higher temperature improves the recruitment. Hannesson (2007) also studies a situation where climate changes are materialized through sea temperature. His analysis is dealing with potential effects on the migration pattern of fish between the exclusive economic zones of different countries. Quaas and Baumgärtner (2012) study optimal livestock management in semi-arid rangelands with uncertain rainfall. Rainfall has no direct effect on livestock growth in their model, but affects the grazing capacity of the rangeland. They solve for the optimal stocking rate and demonstrate how it is influenced by the degree of risk aversion and amount of rainfall.

The present study differs from the above contributions in two ways. First, we consider climatic factors (i.e., temperature) as having no direct impact on animal recruitment as in Diekert et al. (2010), but as detrimental to lamb slaughter weights and hence, the per animal market values. Furthermore, we present and analyze an age-specific model consisting of adult animals and lambs. Second, along with empirical findings, we consider increased spring temperature as having a positive or negative effect on lamb slaughter weights depending on the specific site of consideration; that is, the spatial pattern and the location of the farm play a role. We focus on two mountain ranges and two scenarios; the Northern scenario, exemplified by Forollhogna in Trøndelag and the Southwestern scenario, exemplified by the western side of Hardangervidda, where increased spring temperature has been shown to have a positive and negative effect, respectively, on lamb growth over summer (Nielsen et al., 2012). See Fig. 1. We analyze how temperature changes may alter the optimal slaughtering composition (lamb and ewes), the stocking rate, and profitability of the farmers. We therefore distinguish between the direct effect of a temperature change; that is, the effect on lamb weights, and the indirect effect which reflects that farmers may adapt to temperature changes by adjusting the size of the sheep population. This distinction adds new insight of potential effects of climate change on farm economy as climate studies usually focus only on the direct effect. No climate uncertainty is considered in the main modeling, but some possible effects of taking uncertainty and risk aversion into account are included in Appendix A.

This paper is organized as follows. Section 2 describes briefly the Nordic sheep farming system. Section 3 provides information about sheep animal growth and presents the biological model. While animal population growth is unaffected by potential climate effects, weight growth per animal is affected and this relationship is discussed in Section 4. The revenue and cost functions follow in Section 5. The stocking problem of the farmer is then solved in Section 6, while Section 7 provides numerical results. Section 8 summarizes our findings.

2. The Nordic Sheep Farming System

There are approximately 16,000 sheep farms in Norway, all family farms. Because there are around 2.1 million animals during the outdoor grazing season, the average farm size only accounts for some 130 animals during the summer. Norwegian farms are located either close to mountain areas and other sparsely populated areas or along the coast, with a means to transport sheep to more distant alpine areas for summer grazing. The main product is meat, which accounts for about 80% of the average farmer's income. The remainder comes from wool, because sheep milk production is virtually nonexistent today (Nersten et al., 2003). On Iceland, there are about 450,000 winterfed and 1.2 million outdoor grazing animals today. Meat is also the most important product from sheep farming here. On Greenland, the available land for sheep grazing is much more restricted, and the population of ewes and outdoor grazing animals in 2007 was estimated at 25,000 and 65,000, respectively (Austrheim et al., 2008).

Fig. 1. Norway and the focal areas. The Northern scenario (Forollhogna) and the Southwestern scenario (Hardangervidda) are presented in white, encapsulated with solid lines. The two other areas referred to in the text (Setesdal in the south and the eastern side of Hardangervidda) are presented in dark gray, encapsulated with dotted lines.

Housing and indoor feeding are required throughout the winter because of snow and harsh weather conditions (Fig. 2). In Norway, winter feeding typically consists of hay grown on pastures close to farms (80%), with the addition of concentrate pellets provided by the industry (20%) (Skonhoft et al., 2010). The spring lambing scheme is controlled by the farmers because of the In Vitro Fertilization protocol used to time the lambing to fit current climatic conditions. In late spring and early summer, the animals usually graze on fenced land close to the farm at low elevations, typically in the areas where winter food for the sheep is harvested during summer. When weather conditions permit, ewes and lambs are released together into rough grazing areas in the valleys and mountains. In Norway, most sheep (about 75% of the total metabolic biomass) graze in the northern boreal and alpine region (Austrheim et al., 2008).

The outdoor grazing season ends between late August and the middle of September. The length of the outdoor grazing season is relatively fixed, partly because of local climatic conditions but also, at least in certain areas, because local traditions and historical reasons play a role in the timing. In general the outdoor grazing season does not exceed 130 days. Throughout the outdoor grazing season, lamb growth is affected by climate conditions, both directly and indirectly through climate effects on the vegetation (Nielsen et al., 2012).