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Research Paper

Farm level approach to manage grass yield variation under climate change in Finland and north-western Russia

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Cattle feeding in Northern Europe is based on grass silage, but grass growth is highly dependent on weather conditions. If ensuring sufficient silage availability in every situation is prioritised, the lowest expected yield level determines the cultivated area in farmers' decision-making. One way to manage the variation in grass yield is to increase grass production and silage storage capacity so that they exceed the annual consumption at the farm. The cost of risk management in the current and the projected future climate was calculated taking into account grassland yield and yield variability for three study areas under current and mid-21st century climate conditions. The dataset on simulated future grass yields used as input for the risk management calculations were taken from a previously published simulation study. Strategies investigated included using up to 60% more silage grass area than needed in a year with average grass yields, and storing silage for up to 6 months more than consumed in a year (buffer storage). According to the results, utilising an excess silage grass area of 20% and a silage buffer storage capacity of 6 months were the most economic ways of managing drought risk in both the baseline climate and the projected climate of 2046–2065. It was found that the silage yield risk due to drought is likely to decrease in all studied locations, but the drought risk and costs implied still remain significant.

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1. Introduction

The global mean temperature rose by 0.76 °C between 1906 and 2005 (IPCC, 2007), and in Finland the mean annual temperature has increased by 0.3 °C per decade during the last 150 years, which is more than twice the rate for global annual temperature for the same period (Tietäväinen, Tuomenvirta, & Venäläinen, 2010). The growing season in Finland has lengthened, especially in spring (Carter, 1998; Kaukoranta & Hakala, 2008). However, the expected further lengthening of the growing season is likely to be realised more in the autumn in the future (Peltonen-Sainio, Rajala, Känkänen, & Hakala, 2014). Longer and more frequent spells of mild weather, with increased precipitation during winter will also occur in northern latitudes (IPCC, 2013). Over the history of systematic observations, extreme weather events such as long spells of decreased precipitation have been relatively rare in north-eastern Europe including Finland (Hohenthal, Venäläinen, Ylhäisi, Jylhä, & Käyhkö, 2014). However, in some regions, dry spells of considerable length are already affecting crop production today, and the frequency and intensity of dry spells is expected to increase as part of climate change. For example, a summertime drought period of 40 days duration occurred in Jokioinen every 10 years between 1959 and 2006 (Venäläinen et al., 2009).

Grass-based dairy and meat production constitutes the economic backbone of agriculture in Northern Europe including Finland. Timothy (*Phleum pratense* L.) and perennial ryegrass (*Lolium perenne* L.) are currently the most important forage grasses in the Nordic-Baltic area. In this region, grazing is often restricted to 2–3 months per year due to the short growing season caused by low temperatures. The largest part of the forage grass grown on Nordic farms is therefore stored as silage and consumed gradually over the cattle's long in-house period. However, weather-driven inter-annual variation in the quantity and quality of grass yields may lead to substantial variation in the economic output of forage-based dairy production. Nordic dairy farmers aim for relatively high milk yields per cow (>8 t cow^{-1} yr^{-1} in Finland), which requires stable feeding based on sufficient quantity and quality of grass silage (hereafter simply "silage") supplemented with cereal-based feed concentrates (Kuoppala, Rinne, Nousiainen, & Huhtanen, 2008) where the silage-concentrate ratio depends on the relative prices of the feed types within limits set by their feed quality, animal health and production factors. Farmers try to minimise the risk of silage deficit as there is most often no market for silage. Since silage is of high water content, transporting silage over long distances is not economically feasible. Such deficits will also increase the need to use expensive feed concentrates to maintain high milk yields. To avoid silage deficit in years of low grass yield and quality, farmers typically cultivate grass on a larger area, and store more silage than needed in the years of average grass yields. This is possible since livestock density at Finnish dairy farms has been low for decades and adjusting the share of grassland out of the total farmland area has imposed little additional costs. Thus, while the quality of silage can be partly controlled by timing of the grass harvest, the risk of drought implies the use of surplus grass area and storage to minimise the risk of economic loss.

Most dairy farms harvest silage twice per year, in two separate cuts. In practice, there is an option to adjust the fertilisation and hence the amount of silage after the first cut, based on the grass yield of the first cut. This means that a smaller amount of fertiliser (often injected slurry manure) can be applied if the yield of first cut was high, while a high amount of fertiliser can be applied if the quality and/or quantity of the first cut was poor. However, drought events will decrease the yields irrespective of the amount of fertiliser applied. Irrigation of grassland is rarely an option on Nordic farms due to high costs relative to the value of the reduced risk of yield loss resulting from this practice. Furthermore, purchasing silage is not usually an option in the case of drought years, since drought implies scarcity of silage in the entire region. In summary, farmers consider silage deficit a significant threat to their economy, and they use different strategies to minimise the risk of deficits.

There is a strong need to evaluate the economic cost of managing drought risk, and how it develops over time as the climate changes. Risk management has become a central part of many climate change assessments, particularly in the light of projected increases in extreme weather events like drought (Kalaugher, Bornman, Clark, & Beukes, 2013). There is a need to quantify not only average yield changes but also the potential frequency of major losses (Yakushev, 2009).

The objective of this paper is to evaluate the cost of drought risk management in silage production under current and future climatic conditions at two locations in Finland (Jokioinen in south-west Finland and Kuopio in middle-eastern Finland) and one in Russia close to Finland (the Leningrad region surrounding St Petersburg). A model was developed for evaluating the economic cost of strategies intended to reduce the risk of silage deficit. The strategies involved different combinations of cultivated field area and storing capacity for silage. The model was applied to a dataset on grassland yield and yield variability for the study locations under current and mid-21st century climate conditions from a previously published simulation study (Höglind, Thorsen, & Semenov, 2013).

This paper proceeds as follows. In the next section we present the main findings in the literature on grass growth under future climatic conditions in northern Europe and the most important implications for milk production and cattle husbandry, which are dependent on grass forage and in particular at high latitudes where silage maize is too risky or infeasible an option. In section 3 we present the data and the calculation method. In section 4 we provide the main results, which are discussed in section 5. The most relevant and important results, in terms of their significance for the farms' economy in dairy milk production and cattle husbandry, are summarised in the conclusions.

2. Key findings in the literature on grass growth in climate change in northern Europe

Elevated atmospheric CO_2 has been shown to result in increased grass production and enhanced water/nutrient-use efficiency (Körner, 2000). Higher temperatures during the