Assessment of Harvest Security of Timothy under Climate Change Condition Using a Set of Simple Criteria

Tomas Persson
Norwegian Institute for Agricultural and Environmental Research, Norway

Mats Höglind
Norwegian Institute for Agricultural and Environmental Research, Norway

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Tomas Persson and Mats Höglind

Norwegian Institute for Agricultural and Environmental Research, Grassland and Landscape Division, 4353 Klepp Stasjon, Norway, www.bioforsk.no

Contact email: tomas.persson@bioforsk.no

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Introduction

According to climate change projections, the conditions for forage grass production in Northern Europe, including Norway, will change dramatically during the 21st century. The projected changes in climate in this country include increased average annual air temperature as well as increased precipitation both during the summer and winter season (Hansen-Bauer *et al.* 2009). In previous studies, effects of projected climate change on the above-ground biomass production, winter survival and harvest security of forage grasses have been assessed (Thorsen and Höglind 2010; Höglind *et al.* 2013). For example, Persson and Höglind (2013) showed a decreased dry spell period and an increased accumulated precipitation at the time of optimal harvest quality of timothy (*Phleum pratense* L.) at a few locations in Norway due to climate change. These results suggest increased difficulties to harvest forage grasses under future climate conditions. However, more knowledge is needed to better assess the risk of forage harvest failure due to increased rainfall and changed rainfall patterns.

In this paper, we present a first attempt to quantify the risk of harvest failure of timothy grass given certain climate change scenarios, weather data downscaled from general circulation models (GCMs), and harvest management strategies.

Methods

To be able to quantify changes in the risk of harvest failure, we defined simple and practically applicable criteria for harvest security of timothy based on harvesting practices for northern Europe. The criteria were the following: (1) Three consecutive days with no rainfall after cutting; and (2) not more than 50 mm of rainfall the seven days preceding the day of grass cutting. These two criteria allow for harvesting a crop that is dry enough for successful conservation with minimal storage losses. Harvesting under these criteria would also minimize the risk of unnecessary soil compaction by the harvesting machinery. We evaluated the impact of climate change on the harvest security in two production systems with different biological harvest windows that were based on forage quality criteria. As the forage quality decreases with increasing maturity of the crop, the length of the harvest window is set by the tolerance for deviation between the pre-planned and obtained forage quality. The first production system represented a harvest window of four days from the day when the timothy reached the early-heading stage, which represented high forage quality requirements in intense dairy production systems. The second production system with a harvest window of 14 days from the day of early-heading stage onwards represented low forage quality requirements in extensive cattle production.

To determine the date of early-heading stage, we applied the LINGRA model (Höglind *et al.* 2001), which dynamically simulates timothy growth and development as a function of weather, soil and management factors with a time step of one day. Daily weather data for the simulations, which represented projected climate change conditions for the greenhouse gas emission scenario A1B from the Special Report on Emission Scenarios (SRES) (Nakićenović *et al.* 2000), were downscaled from 12 GCMs, using the LARS-WG tool (Semenov 2008). Two future periods 2046-65 and 2080-99, and a baseline period with weather representing the 1961-90 climate, and four locations, Apelsvoll (60°42'N; 10°52'E), Sola (58°53'N; 5°38'E), Tromsø (69°41'N; 18°55'E), and Værnes (63°27'N; 10°55'E), were included in the study. For each GCM and period, timothy growth and development were simulated for 100 single years.

Results and discussion

Preliminary results show that the risk of harvest failure of timothy in Norway is significantly higher under projected climate change conditions than under the baseline climate. The risks of harvest failure will increase especially for intensive dairy production, of which the forage quality requirements allow for only a short harvesting window. For example, for the short cutting window, at Vaernes, the number of years out of 100 where there were no dry spell period of three days or more after the first cutting increased from 38 in the baseline period to 46 in the in the 2046-65 period and 43 in the 2080-99 period, on average. Also at most other locations and both cutting managements, the risk that the dry spell criterion was not fulfilled was higher under climate change conditions than under the baseline climate. Similarly, the years when the criterion of maximum rainfall before cutting was not fulfilled tended to increase under climate change conditions. In general, the risk of harvest failure due to unfavourable weather was low in the 14 day window cutting system, as were the differences between climate conditions. However, there were large differences in harvest security between the different GCMs from which the daily weather data for the future conditions were downscaled.

This study reports results from a first attempt to quantify the risk of harvest failure in forage grass produced under northern European conditions due to frequent or excessive rainfall under climate change conditions. The results are a strong argument for an increased effort to adapt forage production to a changing climate. The lower risk of crop failure in systems, which allow for a longer harvesting period, suggests that breeding programs for grass cultivars, which retain their nutritive value for a longer period, could be one way of adaptation to climate change. However, more refined assessments of climate change impact on the harvest security of forage grass would further increase our understanding of the potential climate change impact on forage grass production. Such assessments could take into account *e.g.* the impact of soil factors, and different harvesting and conservation methods.

Conclusions

In conclusion, the results of this study showed a higher risk of harvest failure in timothy production under climate change conditions compared with current climate conditions. However, the effect of climate change on harvest security varied substantially among locations and among the GCMs from which the daily weather data representing future climate change conditions were downscaled.

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