Simulating grassland winter survival in high latitude regions using the BASGRA model

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Abstract

In high latitude regions, variability in weather and climate conditions during the winter season cause a considerable variation in forage grass productivity and animal feed supply between years and locations. Tools to estimate or predict winter survival and yield, such as ground registrations, satellite image analysis and process-based simulation models, can be combined in decision support for grassland management. In this study, we simulated grassland winter survival using the BAsic GRAssland (BASGRA) model. The model was initialized after the last cut in the autumn. Its performance to simulate ground coverage in the early spring, either assessed by on-site ground registrations or from Sentinel-2 satellite images, was evaluated. Grass fields at Malangen and Målselv in Northern Norway were simulated for the winter seasons 2020–2021 and 2021–2022. Model input including daily air temperature, precipitation, relative humidity and wind speed data were obtained from weather stations nearby the grass fields. The initial values of biomass, leaf area and tiller density in the autumn were based on ground registration in October. Preliminary results show considerable variation in both simulated winter survival and prediction accuracy of observed spring ground coverage between the locations and two winter seasons.

Keywords: forage grass, process-based models, remote sensing, winter kill, yield security

Introduction

Forage grass is the main component of ruminant feed in many world regions and production systems. In high latitude regions, variability in weather and climate conditions during the winter season cause a considerable variation in forage grass productivity and animal feed supply between years and locations. Early and accurate predictions or estimates of grassland winter survival can help farmers make decisions about reseeding, fertilisation regimes and procurement of extra feed, thereby reducing weather- and climate-related risks and increasing the production stability. However, predicting and estimating winter kill in grass fields is a difficult task. The hardening and dehardening processes in plants are regulated by weather and plant genetics and determine the lowest temperature a plant can survive. Besides snow cover, ice encasement and soil frost conditions modify the conditions the plant is exposed to (Rapacz *et al.*, 2014). Moreover, assessments of winter kill early in the spring can result in the misrepresentation of non-green but still living plants as dead plants, thereby overestimating the winter kill. More accurate information from later assessments might, on the other hand, come too late to be useful in decision making about reseeding and fertilizer regimes. Hence, in practice, early information about winter survival is often imprecise or inaccurate.

Recent development of remote sensing tools and process-based simulation models potentially opens new avenues to obtain earlier and more precise knowledge for winter survival. The goal of this study was to simulate grassland plant survival during autumn, winter and early spring using a process-based model and evaluate its prediction performance against information of winter survival and biomass production early in the growing season, obtained either from remote sensing images or from ground observations.

Materials and methods

Forage grass performance on 5 fields at Malangen (69.4° N, 18.9° E) and 4 fields at Målselv (69.2° N, 18.5° E) in Norway was simulated during the autumn, winter, and early spring 2020-2021 and 2021-2022 as a function of daily weather and soil data using the BASGRA model (Höglind *et al.*, 2016). Initial values of biomass, leaf area and tiller density in the autumn, which are needed to run the model, were set according to ground registrations. Plant parameter values were calibrated against a combination of ground registrations and satellite-sensed data from Northern Norway. Ground cover from satellite images was derived using a machine learning model that used unmanned aerial vehicle (UAV) images as a reference measurement to generate high-resolution training data for the model. Daily weather data used as input to the BASGRA model were obtained from the Norwegian Meteorological Institute or the AgClimate network of the Norwegian Institute of Bioeconomy Research. The model performance was first evaluated against observations of spring ground cover, which was either determined visually by the human eye or by a satellite-based classification of the percentage of living plant material. The ground cover is not directly simulated by the BASGRA model. Therefore, we assumed that the ratio between the simulated number of tillers per area and the number of tillers per area in a dense stand with no gaps (which was previously assessed in controlled field trials in Norway) corresponds to the percentage of living plants. The model performance was evaluated against the first registration of above-ground plant biomass by destructive samplings in late May or early June.

Results and discussion

There was no correlation between the simulated tiller density and the estimated share of ground area covered by living plants when assessed either by the human eye or from satellite images (Figure 1a,b). However, it is difficult to know if this lack of correlation was due to a misprediction of ground cover by the BASGRA model, by incorrect estimations of winterkill in the field, or by a combination of these two factors. However, the fact that covered ground area differed between the field observation methods indicates that these results are uncertain, and we do not know which of the methods gave the most accurate assessments. The observed above-ground biomass at the first registration as assessed by destructive samplings was simulated with a higher accuracy than the area of plant coverage (Figure 1c).

In total, these results suggest that there is a need for more reliable estimations of winter kill early in the season. A temporal mismatch between the start of the growing season, and the observation days is one possible source of error. Remote sensing tools enable more frequent area imaging than measurements that

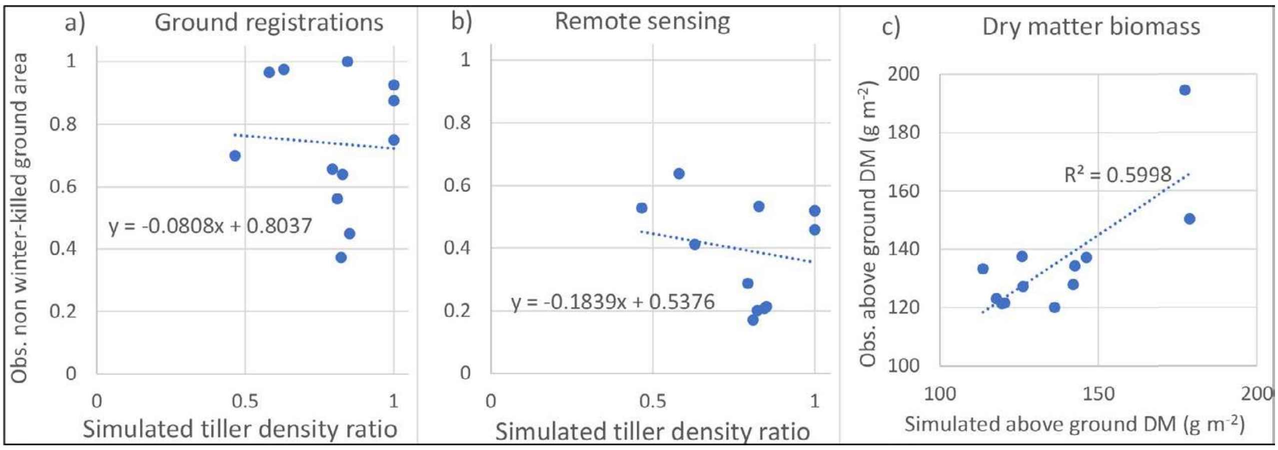

Figure 1. (a, b) Observed share of ground area (*y*-axis) covered by living plants based on ground registrations (a), and by satellite sensing (b), versus the share of maximum number of living tillers simulated by the BASGRA model. (c) Observed versus simulated above-ground plant biomass dry matter in late May–early June.

can be done practically by traditional ground-based tools. One way forward could be to first use satellite or drone mounted cameras together with detailed weather data to identify the visual character of fully survived fields at the start of the growing season, and assess winter damage related to images of the fully survived field. Such an approach would probably benefit from including images from regions and fields that include a diversity in winter harshness.

Conclusion

The prediction of the estimated share of ground area covered by living plants in the spring by the BASGRA model was poor, while the prediction of the first cut dry matter yield was better. Future research should include the development of methods to determine more accurately the coverage of living plant material at the start of the growing season.

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