Simulating the effects of water stress on grassland dynamics – a challenge for current grassland models

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Introduction

Grasslands cover the majority of the world's agricultural area and provide the feedstock for animal production (Whitehead, 1995). Assessing their response to climate change and shift in the occurrence of extreme events is of paramount importance for securing grassland functioning and productivity. Grassland models can help identifying crucial aspects and therefore understanding grassland dynamics under altered environmental conditions.

Grasslands are particularly sensitive to water stress (Knapp et al., 2001). While to some extent grassland models are able to account for the effects of drought on productivity, in general their performance is far from being satisfactory. The purpose of this contribution is to review existing problems and discuss possible solutions.

Materials and Methods

We examine the performance of two state-of-the-art grassland models in simulating the effects of summer drought on herbage production. Results of recent field experiments conducted in Switzerland (Ammann et al., 2009; Deléglise et al., 2015; Meisser et al., 2015) and related monitoring activities (Mosimann et al., 2012) are used as reference. One of the models (PROGRASS; Lazzarotto et al., 2009) was originally developed to simulate the seasonal and inter-annual dynamics of grass/clover mixtures. The other model (MODVEGE, Jouven et al., 2006) was developed to predict herbage quantity and quality in productive systems on the basis of a grassland functional group classification.

Results and Discussion

Results indicate that both models can reproduce the seasonality of growth across sites. But while the effects of water stress on growth are correctly predicted in some years (e.g. 2003), they are overestimated in others (e.g. 2006) (Fig. 1). Compared to the baseline runs, tests with alternative formulations of the response of net assimilation to water stress show no significant improvement in model performance. This suggests an inadequate representation of processes contributing to drought avoidance (changes in the allocation of assimilates, enhanced root dynamics, compensating effects from species interactions in mixtures, altered nutrient cycling, including symbiotic nitrogen fixation, etc.).

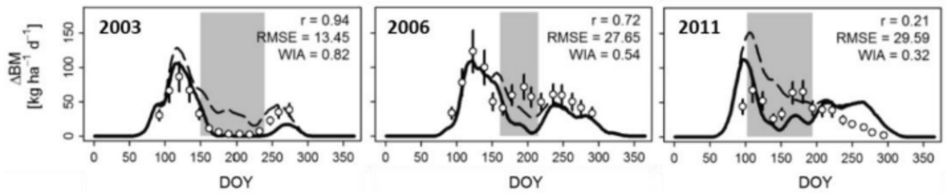

Figure 1. Observations (points and error bars) and simulations (lines) of daily herbage growth (ΔBM) at Changins (western Switzerland, 6°13' E, 46°24' N, 400 m a.s.l.) in (left to right) 2003, 2006 and 2011. Shown are simulations with (continuous lines) and without water stress (dashed lines). The period with significant water stress is highlighted in grey. Performance metrics (r: correlation coefficient; RMSE: root mean square error; WIA: index of agreement) are included in the upper right corner.

Contrasting the simulation of summer drought effects, we find the effects of spring drought to be underestimated by the models (Fig. 1). In this case, the problem is partially related to an inaccurate prediction of the start of the growing season.

Conclusions

In spite of recent advances, there is still room for improving the performance of grassland models regarding the simulation of the impacts of drought on grassland ecosystem functioning. As grasslands usually involve multiple species, ways to better account for community dynamics under water stress have to be examined. A firmer hold on root dynamics is also required, even though experimental results are still open to diverging interpretations (Prechsl et al., 2015). Finally, there is necessity for a more realistic description of grassland phenology. This is a difficult question that, to our knowledge, has yet to receive the necessary attention by the modelling community.

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