Observing and simulating temperate grasslands in Central Europe

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Abstract. This presentation summarises recent activities to observe grassland features using remote sensing and uses this data to feed mechanistic simulation models for temperate grassland vegetation in Central Europe, in order to assess underlying processes that are difficult to observe. Public interest has recently focused on grassland ecosystem services, such as carbon stocks, nitrate retention and greenhouse gas emissions; variables that in principle can be simulated using models. However, current grassland models suffer from the fact that species dynamics in grasslands are very active, and may change in response to water supply and management. As different species come with different traits, a uniform representation of grassland in models is often not wise. This contribution highlights the potential of remote sensing in this problem space and gives an overview of where we stand now when aiming at predicting grass biomass yields and quality features in heterogeneous landscapes of temperate climate.

Introduction

Managed perennial grasslands in central Europe are often composed of highly competitive grasses and herbs. Frequent mowing, grazing and additional nitrogen dosages to increase the yield influence the species composition, but above all, the supply of water governs the spatiotemporal pattern of species composition and related yields. There is a great interest to predict fodder yields within the season, but also beyond, e.g. for climate change impact studies, as the recent drought episodes in Central Europe have resulted in massive shortages of fodder for livestock production and a consequent increase in soybean protein imports from overseas. These incidences have raised the awareness that fodder production from grasslands has a similar importance for the agricultural commodities market as the food crops, especially in a regional context, and revealed at the same time that grassland research has moved out of sight in recent years. Here, I present the current stage of using simulation models to predict yields of managed grassland in Central Europe, and of using remote sensing data to inform such tools.

Simulation models for managed grassland ecosystems

Mechanistic simulation models for grasslands have not been as intensively developed as models for food and fodder crops, such as wheat (*Triticum aestivum*) and maize (*Zea mays*). Even though one of the first mechanistic models that contained soil and plant processes in a manner to represent the full soil-plant-atmosphere continuum was a model for grasslands (Seligman and van Keulen 1980), crop growth models received much more attention in the late 1990ies and early this century. Consequently, the Agricultural Intercomparison and Improvement Project (AgMIP, Rosenzweig et al. 2013) did not initially include grassland models. Furthermore, within the European MACSUR project (Rötter et al. 2013), where grassland and livestock models were dealt with in their pillar (LiveM; Kipling et al. 2016), scientists found themselves in fewer numbers (Korhonen et al. 2018) and far less prepared in comparing and improving their models as a community as the parallel acting crop modelling community (CropM). In the following years, which included some heavy drought years with much-reduced grass yields, grassland science experienced a revival, and more modelling groups turned to simulating grasslands with their process-based models (Pogacar and Bogataj 2018; Kamali et al. 2022; Ruelle et al. 2022).

Remote sensing of managed grassland

With the advent of high-resolution and high-frequency remote sensing platforms (Sentinel 1 and 2, Landsat 7 and 8, etc.) information retrieval for use in agricultural science was pushed. Crop-type mapping based on dense time series resulted in the first large-area wall-to-wall products, in which also grassland area was included (Griffiths et al. 2019). Yet underexplored as a biophysical system, management detection soon became available (Griffiths et al. 2020; Schwieder et al. 2022) and served as a first indicator to assess grassland use intensity (Gómez Giménez et al. 2017; Lange et al. 2022; Potočnik Buhvald et al. 2022). First attempts exist in which the species composition of grasslands is analysed via remote sensing (Magiera et al. 2017, 2018). However, satellite remote sensing is still far away from mapping individual grassland species to inform species competition models.

Grassland yield response to water supply

In a bid to predict grass yields for fodder production over an area as large as Germany, remote sensing can, so far, inform about the location of grasslands, its use intensity, and to a certain extent on the species composition. However, grassland performance depends a lot on water supply, and it is known that grassland vegetation shifts in response to water availability (Tello-García et al. 2020). In lowland grasslands, with shallow groundwater tables, grasses dominate that tolerate seasonal flooding and translate their access to ample water resources into vigorous growth. However, in secular multi-year drought periods, the composition of the vegetation shifts rapidly towards a more drought-tolerant set of species (Figure 1; Khaledi et al. 2023). This, however, comes with a lesser biomass productivity. Growth models for grassland species employ only a single parameterisation, either for one single or for a bulk of species (Kamali et al. 2022). For a stable composed species community, these models are able to predict biomass growth in response to year-to-year variability in weather. However, they fail as soon as the vegetation composition becomes dynamic. Khaledi et al. (2023) have demonstrated that biomass growth and species composition are the two dominant processes that constitute the response of grassland vegetation to water supply patterns. Using data from lowland lysimeters whose water tables were managed differently over more than 10 years, they were able to separate the two processes and could then employ a growth model to reproduce the soil moisture-to-biomass response. The remaining pattern – as they suggest – could be captured by a species competition model, of which some have been presented already (e.g. Taubert et al. 2020).

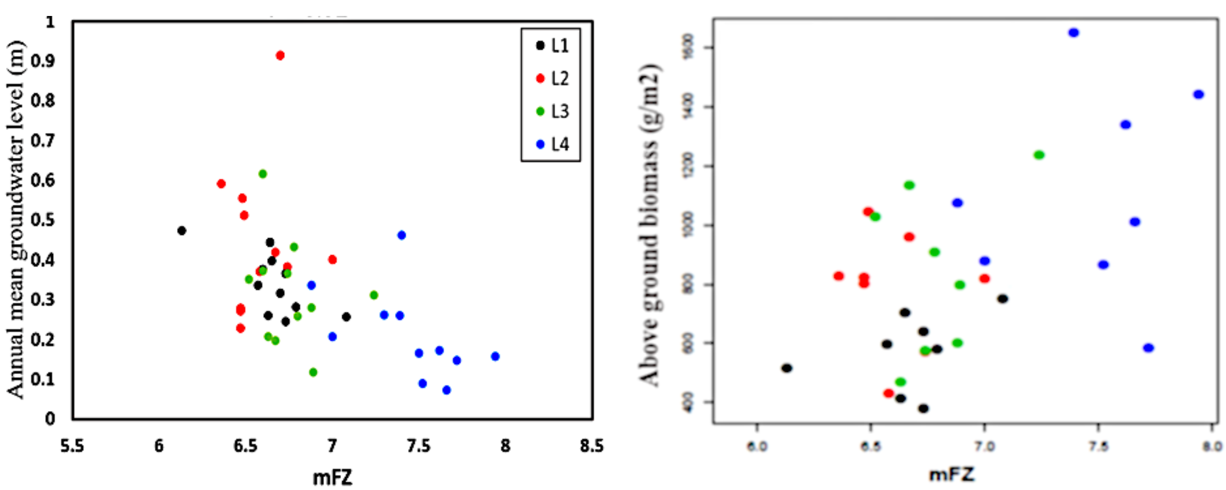

Figure 1: Relationship between the species composition in a grassland lysimeter and its groundwater level (left) and between species composition and grassland aboveground biomass (right). Species composition is represented by the Ellenberg indicator of soil moisture *mFZ* (Ellenberg and Leuschner 2010). The graphs were reproduced from Khaledi et al. 2023.

Conclusions

Perennial grasslands in Central Europe are an important source of fodder production, and the prediction of its production is still difficult. While process-based models advance rapidly towards closing methodological gaps, appropriate data products to drive them at larger scales are still missing. For lowland grasslands with a connection to the capillary fringe, the dynamics of the groundwater table is a piece of essential information to explain aboveground biomass dynamics. For capturing long-term biomass in the growth models, the response of the species composition to changes in water availability needs to be considered. Species competition models are at hand to explain this part of the system dynamics.

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