Impact of drought stress and climate change on yield and forage quality of grassland

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Abstract

Climate change puts many grassland areas and their associated livestock farms under increasing pressure. Increased frequency and intensity of droughts will also adversely affect those climatic regions currently still favoured. To assess the impact of climate change on the overall grassland ecosystem, we compare the ambient climatic situation with future climate scenarios on permanent grassland. Therefore, we use a multifactor, multilevel approach on 54 plots with three cuts per year and standardized fertilization *(ClimGrass)*. It was established in 2014 and combines elevated temperature, CO_2 enrichment, and rainout shelter for drought stress simulations. The results of two drought experiments show a significant decrease in water availability during drought periods. We observe a reduction in yield under drought conditions for all treatments. The simulation shows a more severe drought effect under future climate conditions, resulting in a yield reduction of about 20% compared to the current climatic conditions. Research findings of this experiment serve as a basis for adaptation strategies for resilient grassland management.

Keywords: grassland, drought, climate change

Introduction

With grassland management adapted to site-specific environments, efficient land use is feasible in productive regions and Areas Facing Natural or other Specific Constraints (ANCs). However, the water requirement of grassland is comparatively high, so the annual precipitation in grassland marginal areas needs to be at least 700 to 800 mm (Forstner *et al.,* 2021). Climate change affects future weather, e.g. through a rise in temperature and more uneven rainfall, the risk of severe droughts increases, especially in already dry regions. Due to the comparatively poor water use efficiency of grassland, traditional grassland regions with sufficient rainfall in the past will be more vulnerable in the future (IPCC, 2014). The results of the field experiment *ClimGrass* at AREC Raumberg-Gumpenstein (47°29'38.2' N 14°06'03.0' E, 695 m a.s.l.; 8.5 °C, 1,077 mm; deep cambisol), where the impact of climate change on the grassland ecosystem is studied, show significant effects of climate change on plant composition, yield, phenological development and soil water balance (Pötsch *et al.*, 2019). In this paper, we present selected results of two drought experiments conducted on *ClimGrass* where we show how severe drought events affect yield and forage quality in comparison of current and future climate conditions.

Materials and methods

The sward on all *ClimGrass* plots consisted of about 85% grasses, 10% herbs, and 5% legumes. Dominant grass, legume, and herb species were *Dactylis glomerata, Trisetum flavescens, Arrhenatherum elatius, Festuca pratensis, Trifolium repens and Taraxacum officinale.* On 54 plots, each 16 m^2, of a free-air CO_2 enrichment (FACE) experiment the impact of the current climate is compared to a simulation based on the factors temperature and CO_2 concentration. In the middle of each plot, there is a fumigation ring on a height-adjustable frame, which supplies ambient air enriched with CO_2 at the canopy height and infrared radiators, which heat the irradiated surface. The CO_2 concentration measured on several reference plots (C0) is increased by +300 mg l^{-1} (C2), the reference temperature (T0) by +3.0 °C (T2) (treatments C0T0 and C2T2). While the temperature is applied all year when the snow cover is below a thickness of 10 cm, CO_2 is only added during the day within the growing season. On 12 plots equipped with dynamic rainout shelters controlled by rain sensors, water stress can be generated in combination with current and future climate (C0T0R and C2T2R). In the experimental years 2017 and 2020, we closed the rainout shelter for the entire second growth of the three-cut system. A subset of 15 plots was selected to evaluate drought impact with four replicates for the treatments C0T0, C0T0R, and C2T2R and three replicates for C2T2. We analysed the influence of the drought, the year, and their interaction using the glimmix procedure in SAS (Version 9.4, SAS Institute Inc.). A generalized linear mixed model was used to take care of the correlation of the longitudinal data.

Results and discussion

Drought stress under future climate conditions leads to significantly lower yields on the studied permanent grassland stands. Figure 1 shows the development of the climatic water balance (precipitation – evapotranspiration according to Penman-Monteith) for current climate and drought simulation from the start of the growing season to the harvest of the second growth with the corresponding yields of the different treatments for the selected year 2017.

While the dry matter yield in Figure 2 demonstrates the impact of drought, there are minor differences between the treatments regarding forage quality (crude protein). However, our experiments show a significantly lower lignin content (acid detergent lignin; ADL) in the drought-stressed treatments, which correspond to studies by Sanaullah *et al.* (2014). Lower Leaf Area Index values (measured with AccuPAR LP-80) in the drought-stressed treatments correspond to lower yields and, concerning the lower ADL values, indicate more stocky grassland stands with a reduced stem fraction.

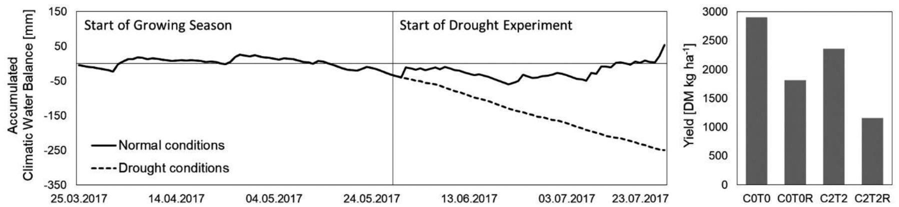

Figure 1. Accumulated climatic water balance for 2017 with corresponding yields of current (C0T0, C0T0R) and future climate (C2T2, C2T2R).

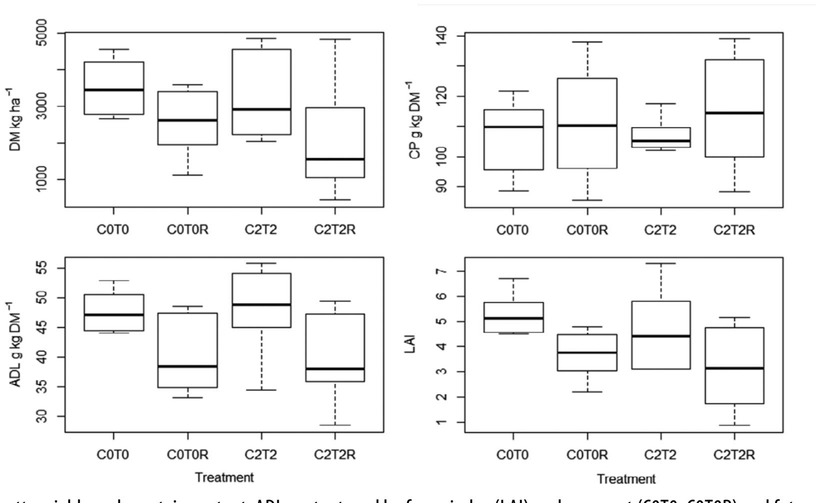

Figure 2. Dry matter yield, crude protein content, ADL content, and leaf area index (LAI) under current (C0T0, C0T0R) and future (C2T2, C2T2R) climate in comparison of ambient conditions and drought stress.

The simulated drought events in 2017 and 2020 are embedded in the long-term experiment that has been showing the effects of increased temperature and CO_2 concentration on permanent grassland since 2014. The results in this paper focus only on the direct effects of both drought events. However, we observed a general change of the sward in climate simulation treatments with a decrease of grasses in favour of herbs. This led to a reduction in aboveground biomass not only in the drought years but also in all other trial years, which is in the line of findings of Cantarel *et al.* (2013).

Conclusions

The increase in drought risk that comes with climate change leads to strong grassland yield fluctuations with significant regional differences. While forage quality remains stable even under dry conditions and digestibility may even be positively influenced due to the reduced lignin content, the decrease in yield results in a shortage of forage supply. Hence, timely adaptation strategies to climate change are crucial for preserving grassland management in particularly vulnerable regions. The adaptation of the species composition towards better drought tolerance as well as the use of a wider range of species are first steps to provide sustainable grassland yields under future conditions.

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