Modelling crop management adaptation to scenarios of declining precipitation sums in Upper Austria

Katharina Falkner[1], Hermine Mitter[1] and Erwin Schmid[1]

Abstract **– Changing climate conditions and declining precipitation sums can severely affect agricultural production and crop management adaptation. Moreover, crop management adaptation affects the agro-environment, such as groundwater availability and nutrient loads. We model effects of precipitation scenarios on agricultural production and crop management adaptation in Upper Austria. We employ regional precipitation scenarios, the bio-physical process model EPIC, and the bottom-up land use optimisation model BiomAT. The EPIC results show large regional differences in the effects of precipitation scenarios on crop yields, irrigation amounts and nutrient loads. Efficient crop management adaptation is modelled with BiomAT, which also allows to identify regional hotspots of effects and adaptation in Upper Austria. The model results inform regional land and water management planning under precipitation scenarios in Upper Austria.**

INTRODUCTION

In agriculture, rising temperatures and changing precipitation patterns combined with more frequent, longer lasting and more intense extreme weather events (e.g., droughts, dry spells, heat waves, late frosts) are already a challenge in many European regions including Upper Austria. This is evident by the events in the years 2017 to 2019. In Upper Austria, fruit and field vegetable production were particularly affected with yield losses of up to 30% compared to a long-term average (Grüner Bericht OÖ, 2020). Currently, crop management adaptation to changing and declining precipitation sums, such as the installation of irrigation systems, is only discussed for a few crops and in a few regions in Upper Austria (Statistik Austria, 2018). However, crop management adaptation is expected to gain in importance in the upcoming decades, even in regions where production conditions are comparably favourable, for example due to deep and fertile soils with large water holding capacities.

Previous studies for Upper Austria mainly focussed on the future availability of (ground)water resources for irrigation, but disregarded alternative crop management adaptation options to precipitation scenarios. Therefore, we aim to (i) model the regional impact of scenarios with declining precipitation sums on crop production and crop management adaptation, and (ii) inform land and water management planning in Upper Austria.

METHOD

We applied an integrated modelling framework (IMF) consisting of the agronomic model CropRota (Schönhart et al., 2011), the bio-physical process model EPIC (Williams, 1995), and the bottom-up land use optimisation model BiomAT (Stürmer et al., 2013) at 1 km spatial resolution in Upper Austria. The IMF is employed in context of three precipitation scenarios (Strauss et al., 2013), which are: a reference scenario (SDRY1) where precipitation sums and distribution resemble the past, a moderate (SDRY2) and extreme (SDRY3) scenario with declining annual precipitation sums and more frequent and longer lasting drought periods. CropRota is applied to derive typical crop rotations using IACS (Integrated Administration and Control System) land use data at municipality level. The typical crop rotations per municipality are allocated to the 1 km cropland pixels according to their relative shares. The typical crop rotations, climate, soil, topographical, and crop management data are used in the bio-physical process model EPIC to simulate many agro-ecological processes (e.g., crop growth, evapotranspiration, runoff, nitrification, mineralisation, soil erosion). In particular, rain-fed and irrigated crop management with conventional and reduced tillage are simulated with and without cover crops. EPIC calculates daily stress indices for water, temperature, nitrogen, phosphorus, aluminium toxicity, and aeration using the most limiting value to reduce actual plant growth and crop yield. Irrigation is automatically triggered in EPIC such that 90% of the crop growth period is water-stress free until a total limit of 250 mm per annum is reached. A single irrigation activity is limited to 20 and 50 mm. EPIC is used to calculate – inter alia – crop yields, crop water stress days (i.e., the number of days on which water stress occurs in a crop growth period), irrigation amounts, and nutrient loads for each crop and crop management practice per precipitation scenario at 1 km spatial resolution and a 30 year period. The EPIC outputs are used in BiomAT to model efficient crop management adaptation strategies by precipitation scenario including changes in irrigation, tillage, and crop rotations at 1 km spatial resolution. Moreover, BiomAT accounts for revenues and costs of crop production. Therefore, EPIC output (i.e., dry matter crop yield) and data on crop commodity prices, variable crop production costs, annuities of irrigation equipment costs, and CAP (Common Agricultural Policy) payments are used in the calculation of the revenues and costs of crop production in Upper Austria. Hence, cropland qualities and endowments at 1 km spatial resolution are considered in BiomAT.

[1] Falkner, K., Mitter, H., and Schmid, E. are from the University of Natural Resources and Life Sciences Vienna, Institute of Sustainable Economic Development, Austria (corresponding author: katharina.falkner@boku.ac.at).

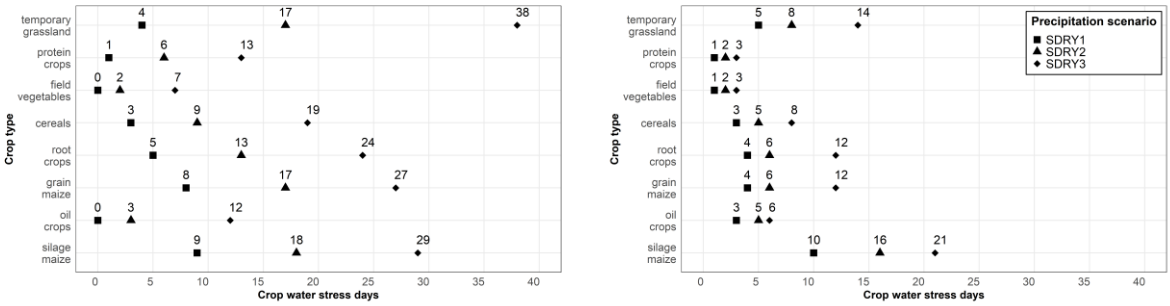

Fig. 1: Crop water stress days by crop type for cropland in the region a) Machland and b) Welser Heide under rain-fed crop production conditions with conventional tillage for three modelled precipitation scenarios

RESULTS

We present selected EPIC results on the different effects of crop management strategies and precipitation scenarios on crop water stress days (WS), irrigation amounts, and dry matter crop yields (DM) by crop type and regions, which are delineated on the basis of groundwater bodies.

The precipitation scenarios differ in the mean annual precipitation sum (PRCP) using a 30 year period. In SDRY1, PRCP amounts to 969 mm on cropland in Upper Austria. However, it varies spatially from 519 mm to 2,068 mm, and is between 815 mm (25%-quantile) and 1,101 mm (75%-quantile) for 50% of the cropland. In SDRY2, PRCP decreases by 16.9% to 805 mm, with a spatial variability from 455 mm to 1,681 mm. In SDRY3, PRCP decreases by 30.4% to 675 mm, with a spatial variability from 401 mm to 1,384 mm.

The effects of decreasing PRCP vary between regions and crop types. For example, in SDRY1 for cereals, 3 WS occur under rain-fed production conditions with conventional tillage in the regions Machland and Welser Heide (Fig 1). With an increase to 9 (19) days, the SDRY2 (SDRY3) has a greater effect on WS in the Machland compared to Welser Heide, where WS increase to 5 (8) days. Similar effects are seen for the other crop types. In SDRY3, the effect on WS is greatest for temporary grassland in Machland, while it is greatest for silage maize in the Welser Heide.

Maintaining rain-fed production but changing from conventional to reduced tillage has little effect on the regional, crop type-specific WS, i.e., WS decrease by a maximum of 1 day, regardless of the precipitation scenario. However, conventional or reduced tillage with cover crops can reduce WS by up to 3 days.

Irrigation can reduce WS for all crop types and regions below the WS level in SDRY1 under rain-fed production conditions, regardless of the precipitation scenario. Irrigation amounts increase with declining mean annual precipitation sums (SDRY2 and SDRY3) but vary considerably among crop types and regions. For example, in Machland, the annual irrigation amount for cereals is 87 mm in SDRY3 and almost twice as high for silage maize (167 mm). However, the annual irrigation amount for silage maize is 70 mm in the region Westliches Mühlviertel. A change in tillage has little effect on the irrigation amount.

Irrigation also results in higher regional DM for all crop types. For cereals, the increase in DM is highest (lowest) in the region Welser Heide (Zwischen Krems und Moosbachl) with +7.0% (+1.8%) in SDRY2 and +9.7% (4.1%) in SDRY3, respectively.

CONCLUSIONS

Changing climate conditions increase the need for informing regional land and water management planning, even in regions with currently comparably favourable cropping conditions. Our analysis shows the effects of precipitation scenarios on crop production, informing efficient crop management adaptation.

ACKNOWLEDGEMENT

This research was co-financed by the European Regional Development Fund through the Interreg Alpine Space Programme with the project ADO (Alpine Drought Observatory – Dürremanagement im Alpenraum, ASP940). This research was also supported by the project "Variability of Groundwater Recharge and its Implications for Sustainable Land Use in Austria (RechAUT)" funded by the Austrian Academy of Sciences within the Earth System Science Initiative.

REFERENCES

Amt der Oö. Landesregierung. (2020). Grüner Bericht 2020 über die wirtschaftliche und soziale Lage der oberösterreichischen Land- und Forstwirtschaft in den Jahren 2017-2019. Linz, Oberösterreich.

Schönhart, M., Schmid, E. and Schneider U.A. (2011). CropRota – A crop rotation model to support integrated land use assessments. *European Journal of Agronomy* 34: 263–277.

Statistik Austria. (2018). Agrarstrukturerhebung 2016 – Betriebsstruktur. Wien, Österreich.

Strauss, F., Moltchanova, E., Schmid, E. (2013). Spatially Explicit Modeling of Long-Term Drought Impacts on Crop Production in Austria. *American Journal of Climate Change* 02: 1–11.

Stürmer, B., Schmidt, J., Schmid, E., Sinabell, F. (2013). Implications of agricultural bioenergy crop production in a land constrained economy – The example of Austria. Land Use Policy 30: 570–581.
Williams, J.R. (1995). The EPIC Model. Computer Models of Watershed Hydrology: 909-1000.