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Assessing Savannah Grassland Intensification Impacts - Integrating Vegetation Community Functions into Physiological Crop Models

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Abstract

Economists see high potential to increase agricultural productivity in African savannahs through rangeland intensification and conversion into cropland. Ecologists however expect negative impacts on ecosystem services (ESS) such as soil and vegetation degradation, which threaten the ecological and economic sustainability of the system. Vegetation structure and its changes play a crucial role in this context and models have been employed to simulate long-term and probabilistic processes. Ecological vegetation models simulate plant type assembly dynamics, but usually based on empirical relationships, lacking processes behind takeover and suppression of different plant functional types. The mechanistic level of physiological crop models however allows exploring these processes, but rigid spatio-temporal pattern of growth and plant interaction limit its applicability for grassland simulation.

This study aims to provide a concept to integrate ecological grassland vegetation functions into process-based crop models. Two substantial limits of crop models were identified: (1) Plant interaction on plot level is defined by explicit or zonal canopy and rootstock overlaps due to homogeneous row arrangement, whereas savannah vegetation has a stochastic to patchy spatial structure. (2) Crop models are able to reflect major disturbance impacts via dry season/drought effects and simple grazing mimicking slash-and-remove functions, but they lack carbohydrate reserves supporting survival during and regrowth after disturbances.

To resolve these limitations, (1) on grassland plots, crop model's row geometry is dissolved to represent random plant arrangement, where spatially inexplicit interaction between plant types starts when total vegetation ground cover exceeds 100 percent. An additional clumping factor accounts for interactions occurring before 100 percent ground cover is reached, reflecting patchy vegetation. (2) The growth of carbohydrate reserves is supplied by excess assimilates which are not needed for plant growth when the latter is limited by phenological development. Reserves are remobilised to support regrowth after grazing and drought as well as to allow plant survival by compensating net respiration during dry periods.

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We developed and tested a ‘minimum-invasive’ concept of amending physiological crop models where two additional functions — heterogeneous plant arrangement and regeneration capacity - allow the mechanistic representation of major plant type assembly processes in savannah grasslands.

Keywords: Disturbance impacts, pasture regrowth, patchy vegetation structure, plant interactions, process-based modelling