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Grassland Functions Improve a Mechanistic Crop Model to Assess Savannah Crop Encroachment and Overstocking Impacts

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Abstract

In Ethiopian Borana rangelands, crop encroachment directly and indirectly influences savannah ecosystem functions. Plant cover is temporarily reduced and soil structure disturbed through tillage when pastures are converted to cropland. Indirectly, rangeland fragmentation inhibits traditional spatio-temporal herd mobility. Overstocking on the remaining continuously grazed pastures can cause rangeland degradation through declining surface cover and reduced soil organic matter formation. On poorly structured soils, intensification-induced soil organic matter loss diminishes water infiltration- and retention capacity. Reduced surface cover is main driver for soil erosion and vegetation degradation on sloping terrain. In summary, the vulnerability to degradation depends on soil characteristics and topography across a heterogeneous savannah landscape. Vegetation structure then regulates actual degradation, depending on pasture's capacity to recover from intensive grazing under certain site conditions.

We employ the mechanistic grid-based land use change impact assessment tool (LUCIA) to study the mechanisms described above. LUCIA's spatially explicit structure allows simulating crop encroachment and herd mobility patterns, which have not been described yet. We developed grassland functions and integrated them in a modular way into the LUCIA main program. Herd routes across the landscape follow patterns of pasture quality and availability, which govern intake and nutrient excretion. The grassland module adds functions to represent pasture plants' post-grazing rehabilitation capacities: (1) Short plants producing many side shoots retain more residual leaf area after grazing than erect morphotypes. (2) Preferential assimilate allocation to leaf-regrowth allows rapid canopy re-establishment. (3) Rejuvenation of foliage by investing in young leaves boosts regrowth through increased leaf area photosynthesis. (4) Enhanced nutrient demand to build young tissue can constrain regrowth. These functions regulate the impact of overgrazing on vegetation- and soil degradation.

By running scenarios, we can show that crop encroachment rate and the spatial distribution of cropping and overgrazing influence ecosystem processes, such as erosion, water retention, soil organic carbon storage and plant productivity. For future coupling of LUCIA with herd- and farmer's decision models, the grassland module functions as connection point.

We discuss process-representation improvements by implemented grassland functions and how model coupling is expected to enhance the understanding of major feedbacks within complex socio-ecological savannah systems.

Keywords: African savannah, ecosystem functions, land use change, pasture regrowth, spatially explicit modelling

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