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Assessing Impacts of Crop Expansion and Overstocking in Kenyan Savannah Rangelands Using the LUCIA Model

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Abstract

There is potential to increase agricultural productivity by converting Guinea Savannah rangelands to cropland on a large scale, but such land use change is expected to have negative effects on ecosystem functions. Conversion of pasture to cropland and tillage affect seasonal plant cover, soil organic matter replenishment, and soil water storage. Additionally, herd mobility becomes more limited and remaining pastures are overgrazed. This can cause shifts in vegetation composition towards higher plant cover and abundance of trees and bushes at the cost of grasses. Our aim is to assess the impacts of land use change in savannah rangelands on vegetation and soil as well as to investigate major processes involved. We studied a savannah watershed in Laikipia, Kenya, by simulating different crop expansion- and herd movement patterns using the mechanistic and spatially explicit Land Use Change Impact Assessment tool (LUCIA). In order to represent the processes described above, we amended the agronomic LUCIA model for functions on plant regeneration after grazing, as well as on tree seed dispersal and seedling recruitment depending on grass competition. The new functions allow simulating pasture degradation with growth reserve depletion, as well as bush encroachment due to enhanced seedling establishment under reduced grass competition. We, thus, build a bridge between agricultural modelling and simulation of plant community ecology, which allows assessing ecological sustainability of agricultural actions in landscapes. Scenario simulations show how ecosystem functions such as soil organic carbon storage, water retention, plant productivity, and fodder provision are affected by different cropping systems (e.g. inter-cropping,) and management regimes (e.g. zero tillage), as well as their expansion rates and -pattern into the savannah landscape. On rangelands, grazing intensity and timing affect biomass regrowth and grass productivity, which influence grass-tree competition and vegetation composition. We discuss model improvements representing important processes involved in land use change impact pathways in savannah ecosystems by newly implemented ecological model routines. We expect, that upcoming LUCIA coupling with livestock- and farmer's decision models will enhance the understanding of major processes and feedbacks within complex socio-ecological savannah systems that are under pressure of land use change and agricultural intensification.

Keywords: Ecosystem functions, pasture degradation, spatially explicit modelling