Agent-based modelling of subsistence agriculture and land cover changes in SW Madagascar

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The unique ecosystem in the Mahafaly region of SW Madagascar provides a range of services to local inhabitants, who mainly depend on subsistence agro-pastoralism for their livelihood. Food insecurity is a serious problem and most people partly rely on forest products to fulfil their daily needs. Due to the ongoing population growth, the highly variable and unpredictable climate and the low economic development, the pressure on natural resources increased drastically over the last decades and triggered land use and land cover changes (LULCC) with high rates of deforestation.

To explore the drivers of LULCC and gain insight on the complex interactions and feedbacks between land use activities and ecosystem services, a spatially-explicit simulation model was developed by using an agent based modelling approach (ABM). Our aims were (i) to simulate possible future trends of the land use system and the effects of these trends on the environment, household economy and food security, (ii) to explore small holder farmers' coping strategies to food insecurity and (iii) to evaluate LULCC and landscape fragmentation in space and time.

The model consists of four different submodules (household and crop production, livestock, climate, landscape). For the parameterization of entities, a wide range of data was used incorporating social surveys, high-resolution remote sensing and field-based validation data. Households represent the individual farm households characterized by their state variables, which capture the livelihood capital and assets derived from socio-economic surveys. The landscape is depicted by congruent land pixels corresponding to GIS-layers of institutional and biophysical spatial state variables extracted from field surveys and mapping campaigns. Forest patches are additionally characterized by spatial state variables related to the forest use potential (e.g. biomass stock, growth rate), which are parameterized based on remote sensing and forest inventory data.

The household decision making process was mainly simulated using a heuristic approach, which takes inputs from the household profile, its perceived landscape information, and information from other household agents. Simulations are performed along discrete time steps, following a yearly cycle, which includes sequential steps with patch-based processes and ends after 30 years. For each time step households may use different adaptation mechanisms to avoid food insecurity and increase household income through land-use activities. The effect on forests varies between different land-use activities, ranging from forest degradation to deforestation.

Crop yields were simulated based on production functions, which take into account management activities, soil quality and climatic conditions. Global variables were defined as driving forces that directly affect the state variables and household activities such as population dynamics, climate conditions and management strategy. During model initialization, the user can change global variables in the user interface at will to simulate multiple scenarios. Simulation outputs are spatio-temporally explicit land-use and land cover maps, which were used to analyse habitat fragmentation, changes in forest area and biomass stocks and basic socio-economic indices such as food security (food-self sufficiency), crop yields, household income, availability of fuel and construction wood and coping strategies.