Land pressure and agrarian mutation, spatial modelling of farming systems evolution from plot to regional scale in West Burkina Faso

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1 Introduction

The cotton region of West Burkina Faso has seen notable transformations these last two decades. In the 70's, the arrival and rapid extension of a cash crop, cotton, has led to a new agrarian organization, with new cropping practices and social patterns. At the same time, the development of the plough has permitted to increase the cultivated surfaces. Those mutations have been enhanced by the huge population increase since the 90's, principal driver of the cultivated area expansion at the expense of forest. The last 20 years have seen the progressive disappearance of fallows, the increase of livestock and the lack of fodder for all animals. The low lands, that were used to water the herds, have been colonized by crops, causing conflicts and bringing about the departure of many breeders. A good understanding of these mutations is required to guide the establishment of adapted public policies. However, the analysis of agricultural mutations and production trends faces important scale issues. Agrarian changes are the result of interacting processes occurring at different scales, which raises the issue of documenting the main trends without distorting the information when trying to upscale or downscale it. The dynamics at plot level are linked to cropping practices, whereas farmer strategy is made at the farm scale. Public policies, the evolution of food prices, and farmer organization will have an influence at the regional scale. Thus a multi-scalar approach is necessary to understand and monitor those dynamics, which takes into account the determinant processes (Veldkamp & Lambin, 2001; Verburg *et al*., 2013). In this study we experiment an approach integrating a crop model (Sarra-H: Baron *et al*., 2005) into a spatial dynamics modelling environment (Ocelet: Degenne *et al*., 2010) to analyse the main processes occurring in an area representative of the cotton region of West Burkina Faso during these last 15 years.

2 Materials and Methods

The study area covers about 6500 km² and is located in the Tuy province in West Burkina Faso (Fig. 1). About 150 plots pertaining to five villages (Koumbia, Gombeledougou, Boni, Dimikuy, Founzan) were followed during the 2014 growing season. Data collected on the plots were used to calibrate the crop model and to evaluate yield spatial variability. At farm scale, based on existing studies we identified three farmer group types (farmers, farmer-breeders, and breeders) and their corresponding strategies. Spatial analyses and expert knowledge have also emphasized essential elements as village organization, migration dynamics, impacting policies and prices variation. Remote sensing archive images (Landsat and Spot) gave information about the landscape and plot structure in the 2000's whereas a time series analysis revealed important land cover changes in the study area.

The model has been built by integrating the crop model Sarra-H into a spatial model, using the Ocelet domain specific language and model building environment. Sarra-H simulates the growth and potential yield of dry cereals (millet, sorghum and maize) in the Tropics. Three processes are simulated with a daily time step: water balance, carbon balance and phenology. Sarra-H uses three types of input parameters: soil, agricultural practices and meteorological (including rainfall) data. Ocelet is a simulation tool for landscape dynamics, based on interaction graphs. Graphs consist of entities, characterized by a set of properties, which are linked together by different kinds of relations (spatial, functional and hierarchical). The scenario contains a series of instructions which, when executed during a simulation, make the entities evolve according to their relations.

The spatialized Sarra-H model was built upon three types of spatial entities: Farm, Plot and Climate. Farm entities were defined according to the typology described in Marre-Cast and Vall (2013). Plot entities were defined their area, crop and soil types. Climate entities were defined as areas with the same meteorological (temperature, relative humidity, global radiation) and rainfall conditions. Plots are linked to the Farm entities to which they belong, where characteristics like surface area, maximum inter-plot distance and distance to the village are considered. Each Plot entity is also linked to a Climate entity of the same area. Each plot therefore has one crop variety (that changes every year) and belongs to one farm that, in turn, has a practice strategy and a Climate entity that defines the meteorological conditions. Moreover, soil characteristics are properties of plots. In this way, Sarra-H can simulate, for several years with a daily step, yield, LAI, biomass, etc. for each crop in each plot.

This model has been applied to the Tuy province in Burkina Faso, by simulating the annual crop production and the expansion of cultivated areas at the expense of forests, between the years 2000 and 2014. Three processes were taken into account when simulating the evolution of the cultivated area: farm expansion, farm division and migrant installation. Each of these three processes had an impact on forests. Clearing is modeled by ranking fallow lands according to soil quality, slope, distance to a road, and whether they belong to protected areas. For example, an expanding farm would acquire new plots one by one, the best available lands first, until reaching a certain surface. The attainable surface area can be parameterized according to farm type (farmers, farmer-breeders, and breeders) and strategies.

3 Results - Discussion

The simulation results are able to highlight both inter- and intra-annual changes like:
- The expansion of cultivated lands in the different sub-zones. For example, the model reproduces the rapid clearing of the forest in the West of the village of Koumbia, where many migrants settled these last years. In contrast, the area East of the Kapo Forest has seen a slower expansion of cultivated lands, as the zone was reserved for pastures and the lands were poorer (Fig.1).
- The difference in crop development between plots, according to their corresponding agro-ecological conditions. The total production of the zone is estimated, taking into account the new crops installed each year.

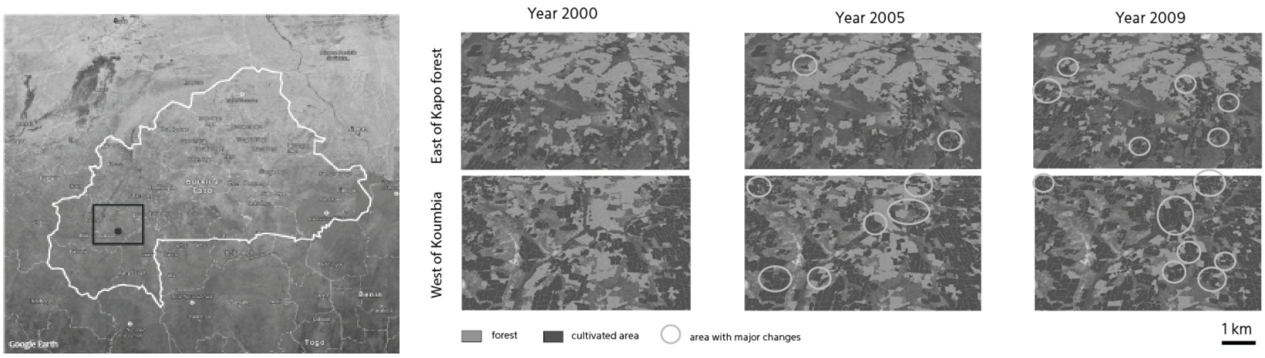

Fig. 1. Localization of the study area in West Burkina Faso, West Africa and results of the simulation of agrarian dynamics in the area of Koumbia.

4 Conclusions

Modelling with interaction graphs allowed us to link information at different scales, and to integrate and spatialize the Sarra-H crop model. The model could be forced with coarser scale processes (migration, farm life cycle) to simulate the annual expansion of cultivated areas, at the expense of forests, and also finer scale information (farm strategy, local agricultural practices) to simulate crop production every year during the last fifteen years. The model developed takes into account farmer strategies, demographic dynamics and spatial heterogeneities. It was able to reproduce the expansion of cultivated lands in the different sub-zones, although the expansion rate was slightly under-estimated.
Work is ongoing to use expert knowledge to better calibrate the model in order to obtain a rate of expansion that is confirmed by observations. The next step is now to extend the model to cotton, a major crop in the zone, to estimate the yearly total production.

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