Multi-Agent Simulation for Landscape Management

A Case around Wondo Genet: Ethiopia

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1. Introduction

Land is the foundation resource for nearly all-human uses. Human use of the land resources varies depending on the production objectives and the biophysical capability or suitability of the land itself. Land use, which is use of land by human for different purposes, is being shaped under the influence of two broad sets of forces – human needs (socio-economic) and environmental features and processes (biophysical). The interaction of the two forces, mainly governed by human actions, causes changes in the uses of land that occur at various spatial levels and at various time scales. The human actions, in turn, are the product of individual and group behaviors within specific socio-economic and environmental settings (Briassoulis, 2000). To take into account the complexity of land use change, modeling at individual level has been a focal area of interest (Turner, et.al, 1995). Nowadays, multi-agent system (MAS) is increasingly employed to model the complexity of processes that take place during land use changes (Ginot et al., 2002, Parker et al, 2001).

2. Objective

The objective of this study was to develop land use and land cover change model that simulate the interaction of land users (agents) and the environment by applying multi-agent system in Wondo genet , Ethiopia.

3. Study area

Wondo Genet is located from 5°30' N to 7° 20' N latitude and 37° 05' E to 39° 50' E longitude. The elevation ranges from 1680 to 3960 m.a.s.l. The major problem occurred in the study area are forest degradation, frequent changes in cropping patter especially from food crop to cash crop, land fragmentation, encroachment and population growth (Teshale, 2003, Tilay and Menfes , 1993).

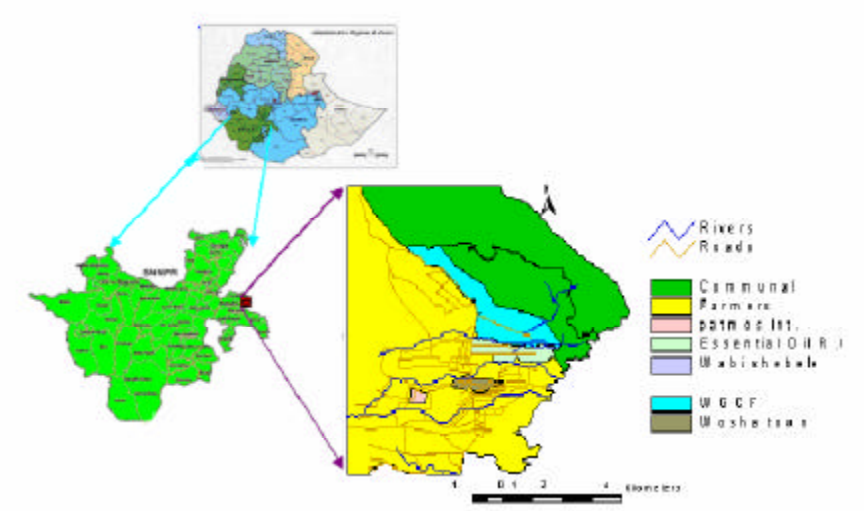


Figure 1 Study area

4. Methodology

4.1 Method

The complex LUCC processes of the study area were depicted as three components as "actor-market-environment" conceptual framework (Fig 2.). Its key focus is how actor decision-making affects the environment and how the environment and market influence this decision-making.

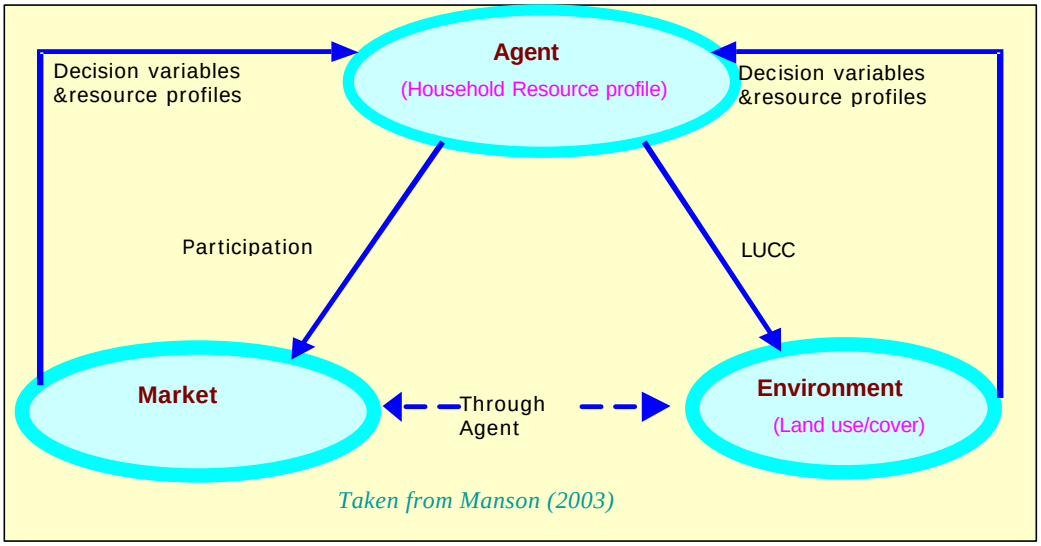


Figure 2. Conceptual Framework

Two basic methods were applied for analyzing the processes. Spatial variability of the biophysical process was introduced by analyzing suitability of the land for each land use type. Soil fertility was taken as dynamic. The socio-economic process was performed based on basic economic theory. The households were tried to maximize their utility from their plot and choose one of the land use type that gives them the highest price by reducing any cost.

The model was developed using JAVA and REPAST. All the spatial analysis was under taken in ArcINFO. The major input data were biophysical data (soil type, erosion hazard, rivers, elevation, slope, land form, land use and cover), socio – economic data (road, market place, population, household profile etc).

4.2 Model Attribute

The model includes temporal, spatial and human decision making attributes. Each time step in the model represents a year. During a step, all the processes that form the flow of the model are executed once and repeated again in the next step with new situation. The analysis was based on equal spatial resolution of 70m X70m raster cells. All the household exists in the landscape were responsible for the decision-making processes regarding to the land-use/management change in the plots of the study area. Each household was represented as an individual and autonomous agent and embeds his own rules of behavior while keeping track of his state.

4.3 Model Action

In each course of the simulation, different action was undertaken. Each agent allocates best land uses in their own plot based on the expected price of each land use that was determined by Market, soil fertility, biophysical condition of their plot, their household profile and availability of off-farm activity. These factors determine household income. If their income was positive, agents' decision would be either contentment (utilizing the fertility of their land as it is) or

innovation (applying fertilizer and use high yielding variety to enhance their production). If it was negative, agents were forced encroaching the forest or migrating from the study area (Fig. 3).

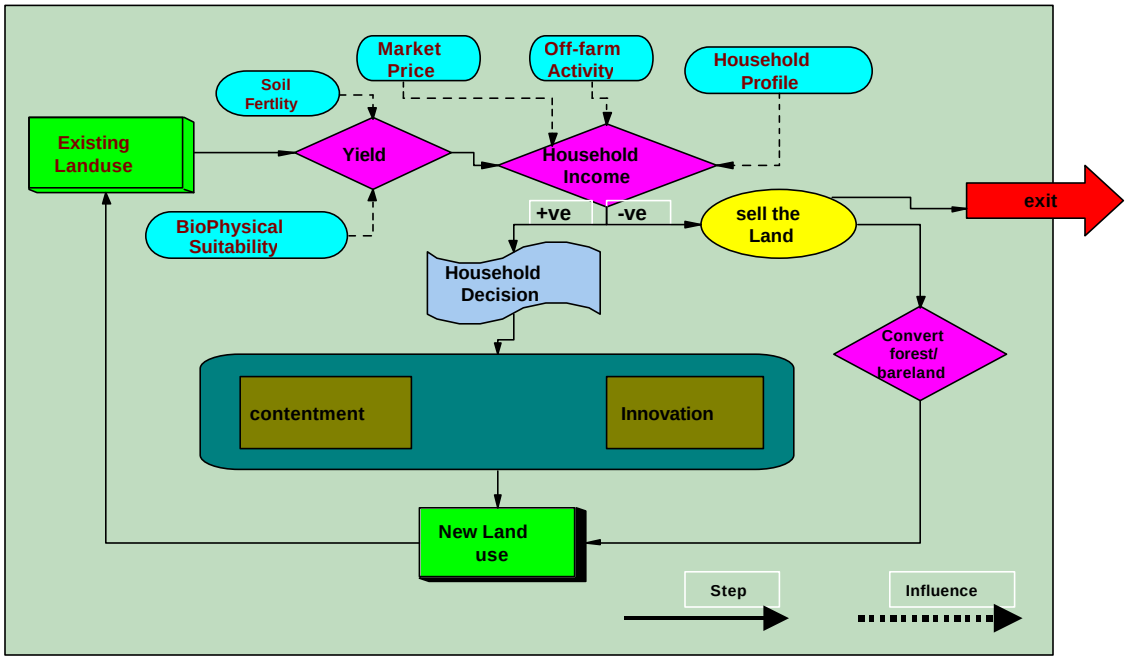


Figure 3: Process steps of Agent decision-making

4.5 Scenario Study

Three different scenarios were compared: Reference (1st), stabilization (2nd) and optimistic (3rd) scenario. The first scenario was taken as reference since it resembled to the existing situation (poor off-farm activity). The main difference in each scenario was allowing of household to sell or buy labor for engaging off-farm activity (second scenario) and also increasing demand of land use type by 50 % in addition to engaging in labor off-farm activity (third scenario).

5. Result

Even though at the start the choice of crop was intense in the first scenario, the choice of crops by the farmers is changing in each year. Four major crops – maize, sweet potato, chat and sugar cane dominates along the simulation years. Except sugar cane which show relatively smooth pattern the other three crops were dominated in an interchangeably fashion (Fig 4, 5). In the second scenario, the pattern of choice shows significant changes. Sugarcane more disturbed and a frequent replacement of sugarcane and chat was also observed. Sweet potato and potato are least favored as compare to the first scenario (Fig 6, 7). In the third scenario, as compared to the other two scenarios, a significant change on land use pattern was observed. Chat and sugarcane coverage increased smoothly with time as oppose to the other two scenarios (Fig 8, 9). In all scenarios inclination to choice of planting cash crops observed clearly as the population growth increases.

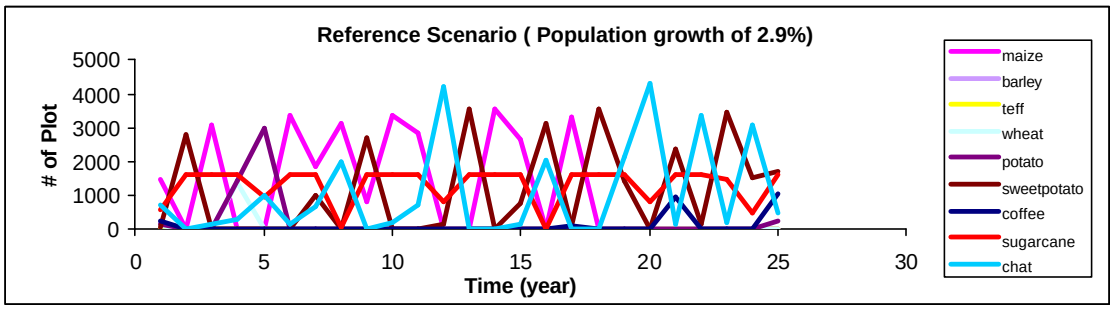


Figure 4 Scenario 1 land use trajectory

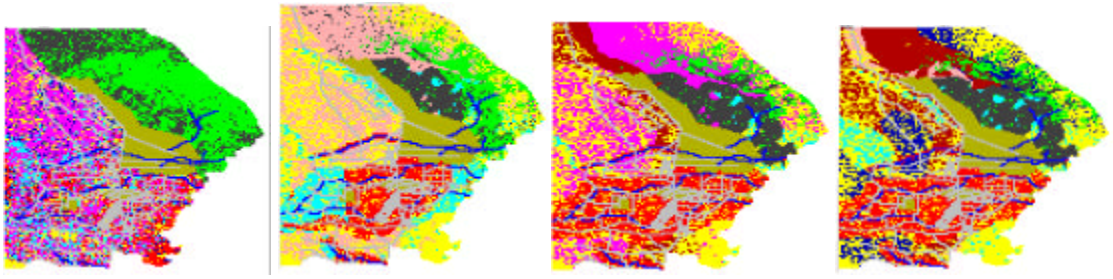


Figure 5 Scenario 1, simulation result for t_1, t_5, t_{15} and t_{25} (from left to right) of Land use and Land cover Changes

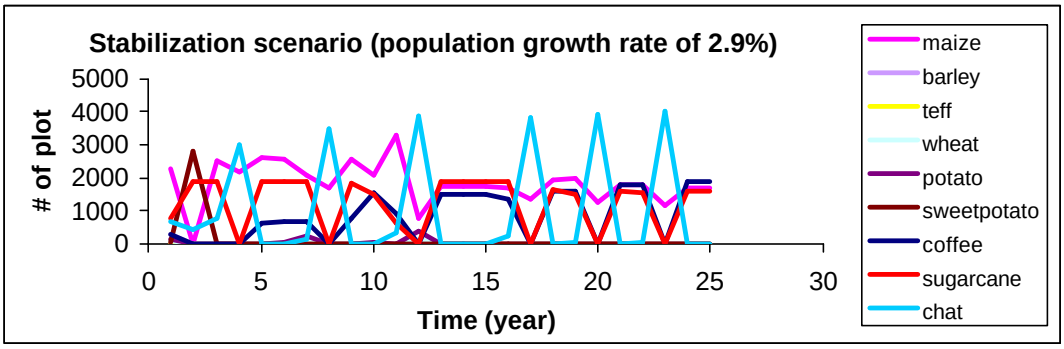


Figure 6 Scenario 2, land use trajectory

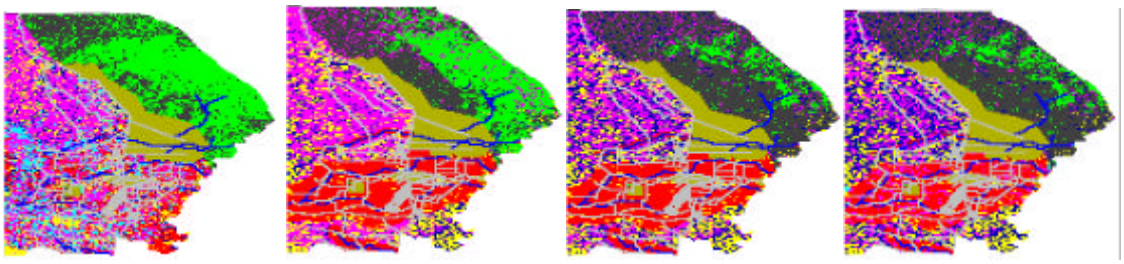


Figure 7 Scenario 2, simulation result for t1, t, t_{15} and t_{25} (from left to right) of Land use and Land cover Changes

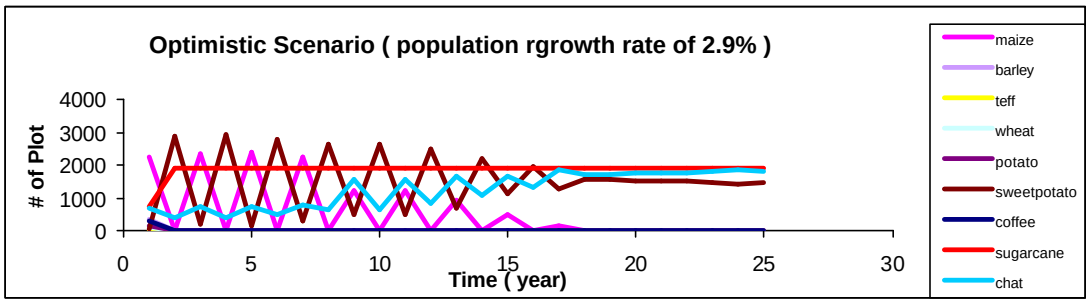


Figure 8. Scenario 3, land use trajectory

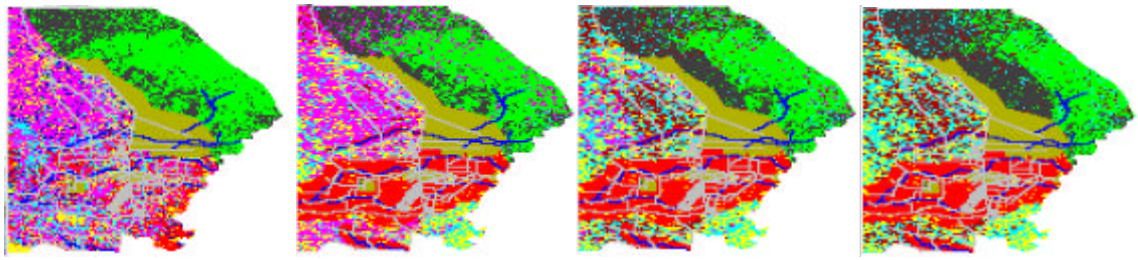
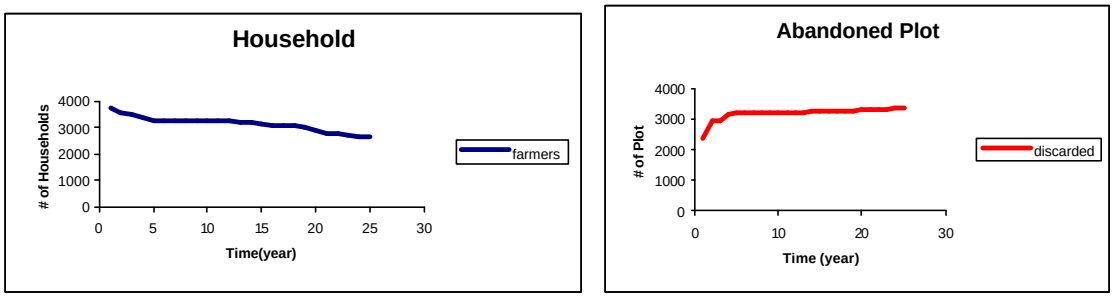


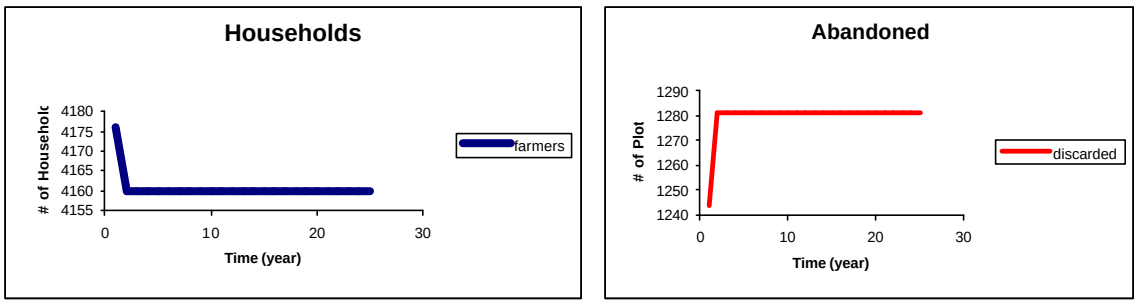
Figure 9 Scenario 3, simulation result for t_1, t_5, t_{15} and t_{25} (from left to right) of Land use and Land cover Changes

The population in these three scenarios, significantly changes has been observed. The number of people left from the area or encroached to the forest in the first scenario was high as compared to the other two scenarios (fig. 10). The stability of living in the second scenario achieved after the third year of the simulation (Fig 11) while in the third scenario (Fig 12), no migration was observed. The amount of natural forest (shrubs, scrub and forest) deforested dramatically increase in the first scenario as compared to the other two scenarios both for fuel consumption and encroachment (Fig 13, 14, 15 respectively).



(a) (b)

Figure 10 Trends in number of households (a) and abandoned plots (b) along time under scenario 1



(a) (b)

Figure 11 Trends in number of households (a) and abandoned plots (b) along time under scenario2

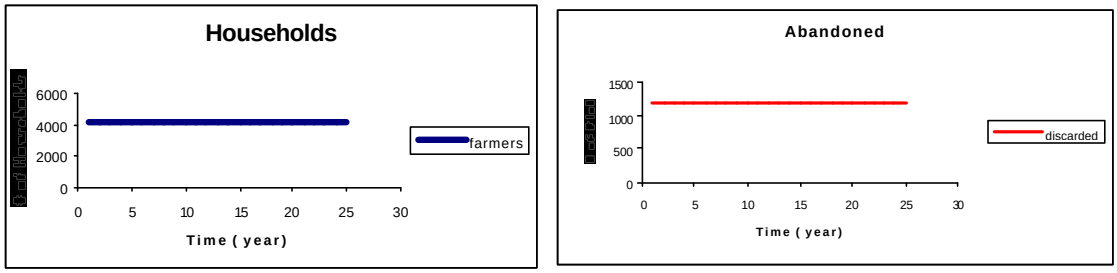
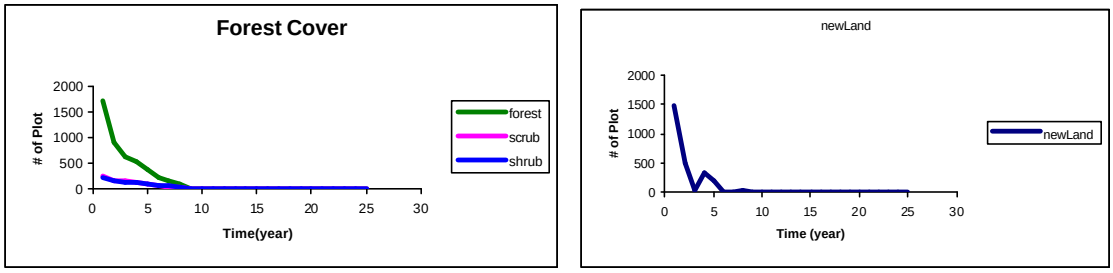
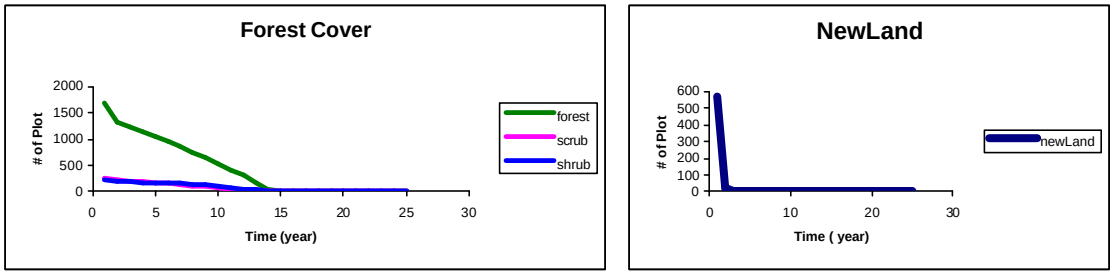


Figure 12Trends in number of households (a) and abandoned plots (b) along time under scenario3



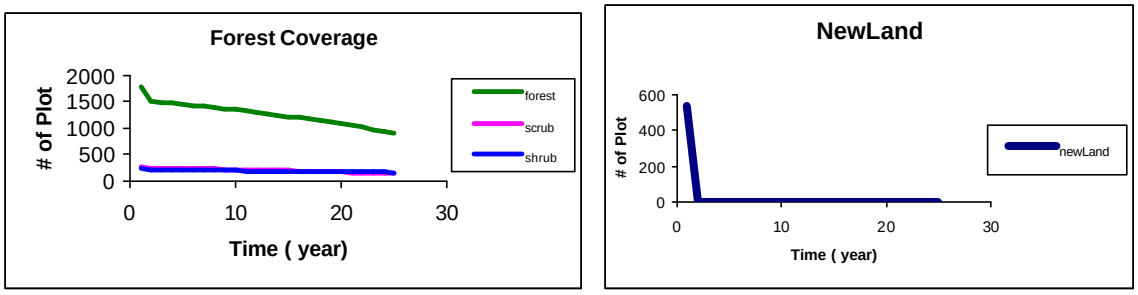
(a) (b)

Figure 13. Forest coverage decline (a) and new plots implemented (b) under scenario 1



(a) (b)

Figure 14 Forest coverage decline (a) and new plots implemented (b) under scenario 2



(a) (b)

Figure 15 Forest coverage decline (a) and new plots implemented (b) under scenario 3

6. Conclusion

Land use and land cover changes occur from complex processes that are result of different intricate and interwoven factors. The global land use and land cover changes that occurred in the study are the product of local decisions taken by each household. Population growth affects the existence of most households especially whose plot was less suitable than others. Generally, it can be seen from reference scenario is that unless other economic opportunities, such as off farm

activities (stabilization scenario) or creating of better market (optimistic scenario), the present economic situation is not sustainable. The expansions of agriculture and fuel wood collection from the existing forest could be considered as the major cause for increase deforestation rate in the study area. Application of MAS for the study of complex processes of land use and land cover provides great opportunity to link the different forces that are responsible for the cause of changes of land use and land cover.

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Acknowledgment

We would like to thank to the sponsor NUFFIC and Wageningen University for covering all the study costs.