Multi-agent simulation of deforestation: a subsistence farm-based decision making approach

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Introduction

Several parameters are recognized to influence agents of deforestation's decision making to deforest and in the tropics many of these parameters are agriculture-based. With the majority of the households engaging in charcoal production as a coping mechanism when they fail to produce enough food in the study area, we present an attempt to simulate deforestation trends of Dzalanyama forest reserve, Lilongwe, Malawi using a Java-based multi-agent approach.

The objective of the research is therefore to derive understanding of the underlying causes of deforestation in Dzalanyama and estimate the future of forest cover loss. Using a farming household as the main agent, this study simulated the inefficiencies of the agricultural crop production theories being practiced in the areas surrounding Dzalanyama forest reserve and how they translate into its deforestation.

Methods

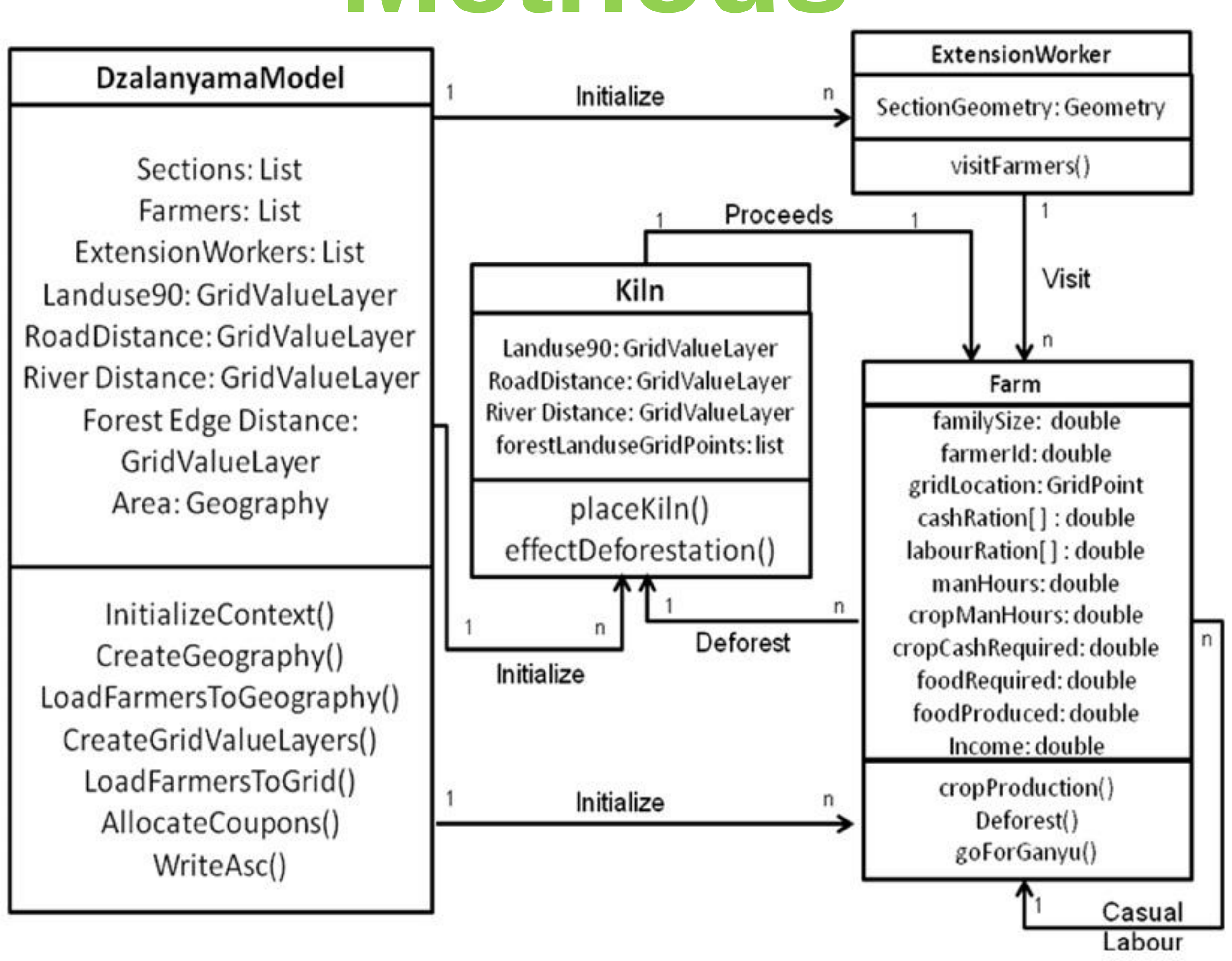

Figure 1 : Framework of the interactions and interrelationships of the entities Farm, Extension worker and Kiln agent

The simulation is an abstract representation of the forest reserve landscape, the smallholder farming households, and the processes and entities that link them (Figure 1). It is a spatially referenced simulation that is wholly written in Java with the Repast Simphony 2.0 toolkit .

A field survey was conducted to determine the main agricultural activities at the household level and how they influence the crop production. Figure 2 shows the household decision making structure in growing the crops. The field survey revealed that access to hybrid farm inputs (cash endowment), exposure to good farming methods (agricultural extension services) and access to subsidized hybrid farm inputs were the important factors that defined the household's capacity to produce enough food.

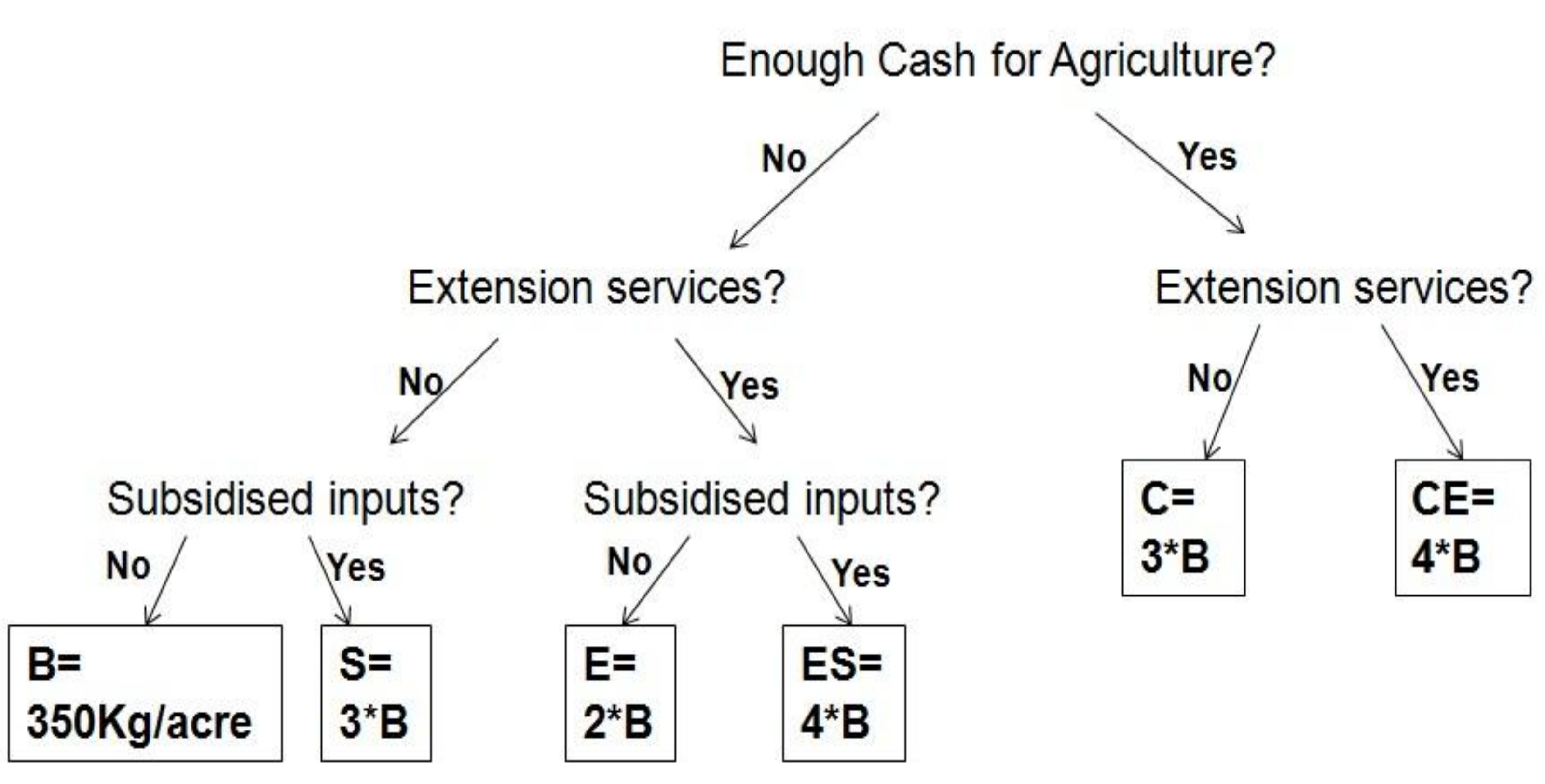

Figure 2: Farm household agent heuristic decision making structure to "Grow crops" (maize/corn)

Results

From 1990, 12,207 ha of forest were simulated as lost against 13,639 ha observed in 2000. The quantities accumulate to 19,459 ha simulated against 22,031 ha observed by the year 2010. Statistically, the simulation stands at a standard Kappa value of 0.731 and 0.629 when compared with the observed land cover map for 2000 and 2010 respectively. Using Map Comparison Toolkit, the simulation does explain some land cover change (KSimulation = 0.192), where 82 percent (KTransition = 0.815) of the individual class transitions are similar for both the observed and simulated maps in 2010 with 24 percent (KTranslocation = 0.235) of these transitions being correctly allocated spatially (Hits in Figure 3). Figure 4 shows the future estimates in business as usual scenario (S1) and an increased reward from charcoal production scenario (S2).

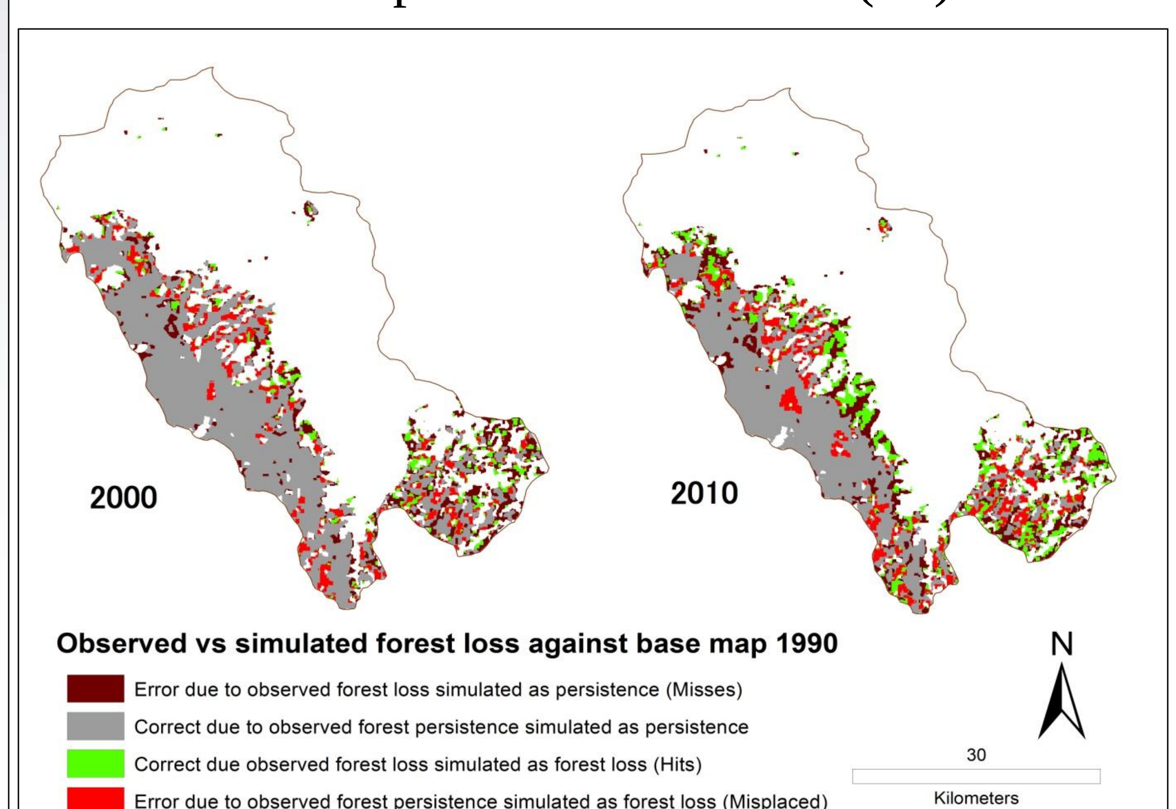

Figure 3 : Simulated versus observed forest loss spatial distribution against base map 1990

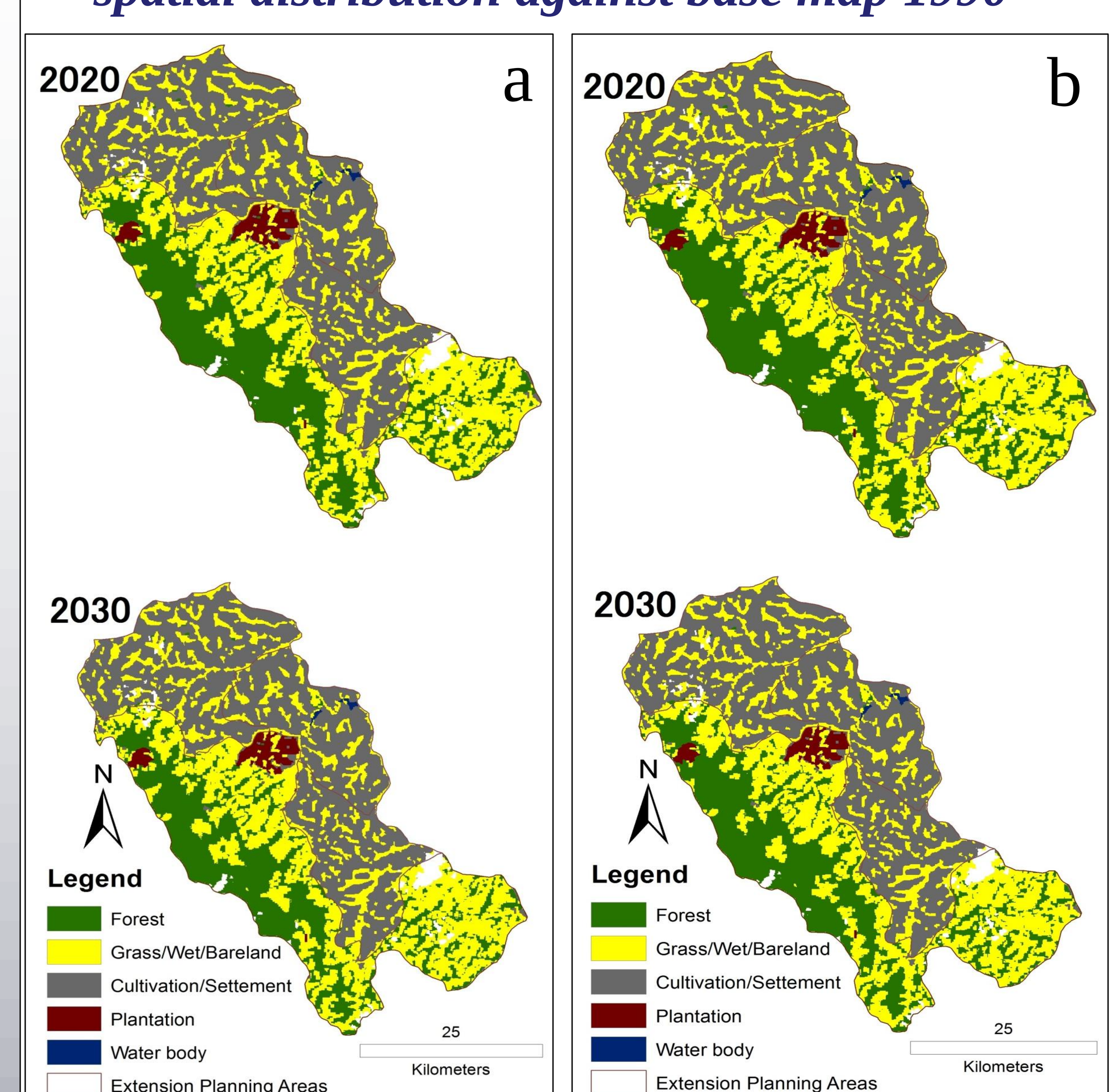

Figure 4: Predicted Land use/cover a) S1 conditions; b) S2 conditions

The S1 conditions predict forest loss of 23,100 ha by the year 2020, which accumulates to 26,721 ha in 2030. S2 conditions starting from the year 2010 reduces the predicted forest loss to 21,676 ha in 2020 and 24,060 ha in 2030 when compared to the respective S1 conditions. This means in S2 the accumulated forest loss decreased by 1,424 ha (~6%) in 2020 and 2,661 ha (~10%) in 2030. This reduction in forest loss represents an accumulated gain (or sustenance) of forest cover of 4 percent in 2030 which can only increase in the years beyond.

Conclusions

Inefficiencies in the smallholder farming system are the major driving factor of deforestation in Dzalanyama and the future looks bleak in the business as usual scenario.

As charcoal production is illegal in Malawi, the study proposes its formalization and introduction of ecosystem service payment programs. The former would allow introduction of taxing systems that would boost government revenue. Both would increase the households' accruing income from charcoal. With reduced dependency on charcoal as the households' productivity improves or reduced fuelwood wastage as the households invest in efficient charcoal production methods these interventions would go a long way in containing the deforestation.

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