METHODOLOGY FOR SIMULATING THE SPATIAL DYNAMICS OF LAND USE CHANGE IN FOREST FRINGES

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INTRODUCTION

Land use change is the result of the complex interaction between humans, the biogeophysical environment and the socio-economic and cultural context (Turner II et al. 1995). Understanding of these interactions helps us to better understand the underlying causes of continuing deforestation and is essential to properly design land use policies and alternative livelihood strategies to reduce the degeneration of forest resources in these areas.

The spatial dynamics of land use change on the forest fringe are not always explicitly taken into account in most sociological and ecological studies of deforestation. However, an increased understanding of the spatial dynamics of land use change can help to better relate the causes of deforestation and their effects on natural resources and feedbacks on the socio-economic system trough land degradation, biodiversity loss and the opportunities for alternative livelihood strategies. Spatial dynamics determine the fragmentation of the remaining forest, the vulnerability of areas towards degradation and the suitability of the land for agricultural purposes. In this paper we will discuss how spatially explicit methods of land use change can be used to study land use transitions on the forest fringe.

METHODS

Current and future changes in land use pattern are often simulated with dynamic models that capture the interaction between land use change and the characteristics of the biogeophysical and socio-economic environment. One of these land use change models in which the spatial dynamics are explicitly addressed is the CLUE model (the Conversion of Land Use and its Effects http://gissrv.iend.wau.nl/~clue/ (Veldkamp & Fresco 1996;Verburg et al. 1999;Verburg et al. 2001)). The "CLUE" modelling approach has the following characteristics:

- All simulations are made in a spatially explicit way so that the geographical pattern of land use change is resulting. The spatial resolution of the simulations is dependent on the extent of the study

area and the resolution of data available for that study area. Applications include the country of China (spatial resolution 32x32 km) and the Central American continent (15x15 km), but also the suburban area around Kuala Lumpur, Malaysia (750x750 m) and Sibuyan Island, the Philippines (100x100 m).

- Allocation of land use change is based on the dynamic simulation of competition between different land use types. Competitive advantage is based on the 'local' and 'regional' suitability of the location and the national or regional level demand for land use type related products (e.g., food demand or demand for residential area).
- The 'local' and 'regional' suitability for the different land use types is determined by quantified relations between land use and a large number of location factors based on an empirical analysis that incorporates the wealth of knowledge available on the driving factors and constraints of land use change.
- Different scenarios of developments in land-use can be simulated. At the national or regional level scenarios include different developments of agricultural demands that can be determined on the basis of developments of consumption patterns, demographic characteristics, land use policies and export volumes. At the sub-national level different restrictions towards the allocation of land use change can be implemented, e.g., the protection of nature reserves or land allocation restrictions in areas susceptible to land degradation.

The results of the simulations are maps representing plausible patterns of land use change under the assumptions made in the scenarios. These results can be used to evaluate the consequences of land use change for environmental and socio-economic determinants of the livelihood of the inhabitants of the study area. In the example below the effects of land use change for fragmentation of forest is assessed.

EXAMPLE OF MODEL APPLICATIONS: THE PHILIPPINES

In this paper we illustrate the land use modeling approach with an example taken from the different case-studies where CLUE has been applied. For an overview of all case-studies and references to the relevant publications the reader is referred to our internet site: http://www.gis.wau.nl/~clue. In this example the results of two case-studies at different scales are presented. The first case-study is focused on the country of the Philippines as a whole. Based on land use data derived from remote sensing 7 land use classes are identified and a number of variables are selected that are assumed to determine the allocation of land use change. In Figure 1 the results for one of the scenarios is shown for the change in forest cover. From this type of

simulations it is easy to identify areas where large amounts of deforestation are to be expected, so-called 'hot-spots' of land use change. To better understand the dynamics within such hot-spots a more detailed analysis must be made. An example of such a more detailed analysis is the land use change simulation for Sibuyan Island, Romblon Province, the Philippines. This small island was studies at a high spatial resolution (100x100 m); 9 different land use types and a multitude of biogeophysical and socio-economic factors were taken into account for the simulations. In this paper we only show the change in forest cover resulting for 3 different scenarios (Figure 2). At this level of detail it is possible to assess the effects of land use change on forest fragmentation. Although forest cover decreases in all three scenarios, the spatial pattern is clearly different, due to the different scenario conditions, which lead to different pathways of land use change. Based on the generated land use patterns assessment of the impacts of the studied land use change processes for, e.g., biodiversity can be made.

FIGURE 1.
THE PHILIPPINES: DEFORESTATION (BLACK) AND REMAINING FOREST FOR A LAND USE CHANGE SCENARIO (1990-2010)

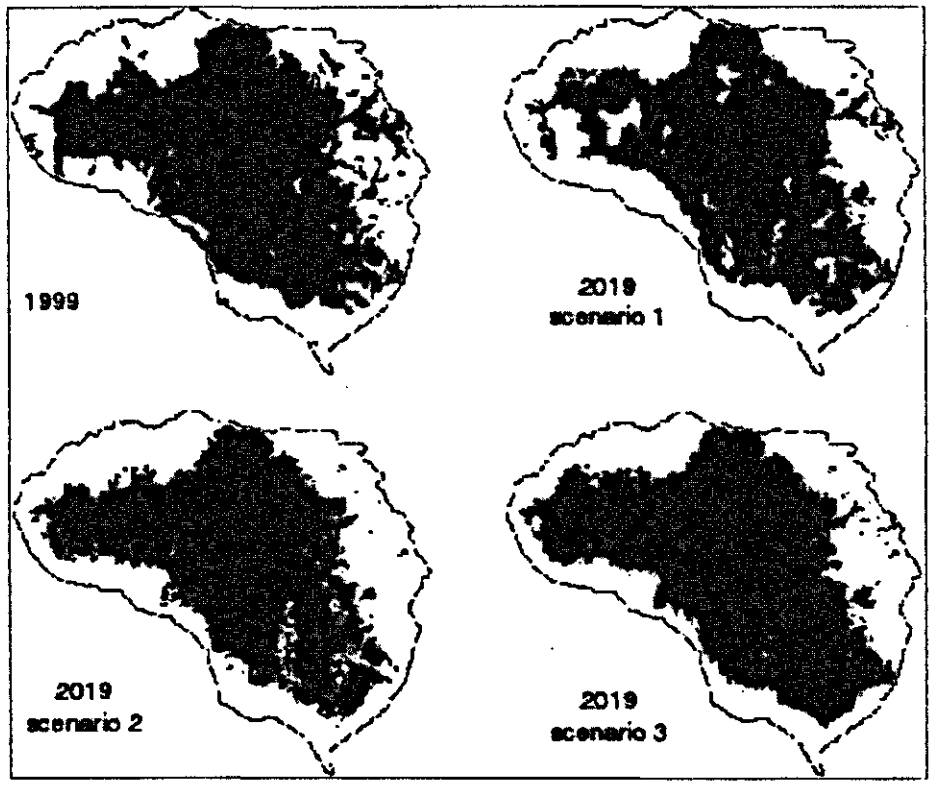

FIGURE 2
SIBUYAN ISLAND: FOREST AREA (BLACK) AT THE START OF SIMULATION (1999) AND AT THE END OF THE SIMULATION FOR THREE DIFFERENT SCENARIOS.

The example above is only one of the possible applications of spatially explicit simulations of land use change.. The simulations must be seen as a tool to summarize knowledge about land use change with specific attention for the spatial variability in this process. It can help researchers as well as policy makers to visualize the consequences of aggregate changes for different locations.

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Verburg, P. H., Veldkamp, A., de Koning, G. H. J., Kok, K., & Bouma, J. 1999, "A spatial explicit allocation procedure for modelling the pattern of land use change based upon actual land use", *Ecological Modelling*, vol. 116, pp. 45-61.