A global-to-local model approach to assess future land use dynamics: An application to Vietnam

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ABSTRACT

Future Land use in Vietnam is expected to change considerably as a result of global trade, economic growth and structural change and national land use policies. This study describes a methodology in which a global economic simulation model and a land use allocation model have been linked to capture the impact of global drivers and spatial policies on future land use dynamics. A Business As Usual scenario for the period 2010-2030 is implemented and results for Vietnam are presented. The findings indicate that structural change in the Vietnamese economy will continue resulting result in a more demand for commercial forestry land and less for paddy rice land. Finally, a Vietnamese land use map for 2030 is presented. The results for the Business as Usual scenario will be used as a reference to examine the impact of alternative futures (e.g. climate change, global regulation and integration) and national plans and policies (e.g. Green Growth Strategy) on land use in Vietnam.

INTRODUCTION

Land plays a crucial role in the development process of Vietnam. With a GDP share of 21 percent and a rural population share of 41 percent, most of which are poor small scale farmers involved in the production of paddy rice, the agricultural sector is key to poverty reduction and food security. Land use, land use change and forestry (LULUCF) also plays a crucial role in climate change mitigation and adaptation. At the moment the Vietnamese government is in the process of drafting a Green Growth strategy and a special plan to reduce emissions from agriculture (20/20/20). Vietnam also recently completed the final approval of the REDD program document and is now in the inception and implementation phase.

LULUCF patterns in Vietnam are expected to change dramatically as a consequence of several global and local processes that interact at various scales and domains. Key global drivers that will affect land use change in Vietnam are technological change, climate change, population growth and international trade. The latter is in particular important since after accession to the WTO in 2007, Vietnam's economy has become increasingly integrated with the world economy. Global integration has contributed to rapid economic growth (estimated at 6.7% in 2010), in turn, resulting in accelerated demand for food, feed, fibre and fuel and competing demands for land and water resources. Furthermore, Vietnam is considered to be a high-risk country in the context of climate change because of its delta structure and the long coast line that is sensitive to flooding and extreme weather events. The country has a large portion of population whose life depends on agriculture and aquaculture. It is expected that these people, their life and their production, will face serious problems under climate changes. At the national and local level, spatial policies that ensure the safeguarding of areas with rich biodiversity but also climate adaptation and mitigation strategies (i.e. REDD), expansion of urban and industrial zones and the food security policies such as a mandatory allocation of land for the production of paddy rice will have important consequences for land use.

The interplay between global and local drivers is complex and uncertain which makes it difficult to predict their impact on landscapes, rural livelihoods and the environment are complex and uncertain. To formulate pro-active policies and identify challenges and opportunities, decision makers need information about potential land use outcomes in different situations as well as insights about the underlying dynamics that lead to these outcomes and the potential impact of policies. A popular approach to assess the future of complex systems and identify policy alternatives is the use of scenarios in combination with models. The study of global-to-local land use impacts possess certain challenges as an integrative assessment is needed at different scales: (1) the global-to-national scale examining the interplay between macro-economic factors, population growth and climate change, and (2) the national-to-local scale which demands a spatial analysis at low levels of resolution.

In this paper we will apply an innovative assessment method which integrates a global macro-economic model with a spatial land use allocation model to analyze future land use patterns in Vietnam under various scenarios. It builds upon the work of Van Meijl *et al.* (2006) and Verburg *et al.* (2006; 2007) to model land use dynamics in for Europe that was part of the EURURALIS project. This study is the first application of this approach in the context of a developing country. The results of this exercise can be used as input for policies concerning climate change, REDD, land use and climate smart agriculture.

METHOD

Overview

The methodology used in this study is designed to quantify the impact of both global and national drivers and policies on land use

in Vietnam up to 2030 using a number of scenarios. Figure 1 presents an overview of this approach. The first step is the development of scenarios. Scenario analysis is commonly used in environmental impact assessment studies which need to take into account the complex and uncertain interplay between climatic, economic, technological and political factors. In such a setting simple projections based on historical trends are of limited use. Scenarios are not equal to projections or forecasts. Instead they are storylines with a coherent set of assumptions that together describe potential but plausible futures. They are a tool to help thinking about the future and guide the formulation of policies that are contingent on future expectations. The second step in the approach is the application of models to quantify the scenarios. Not one model is able to capture the impact of global and local drivers of land use changes. For this reason, two models, a global economic model (MAGNET) and a spatially explicit land use allocation model (CLUE) are combined. Finally, the outcome of the model simulations is a number of indicators for each of the scenarios that summarizes the findings and assess the possible impacts. Indicators include macro-economic figures that reflect changes in socio-economic drivers such as food price changes, trade and sectoral development in Vietnam and the rest of the world, as well as output that reflect physical land change itself, such land use maps.

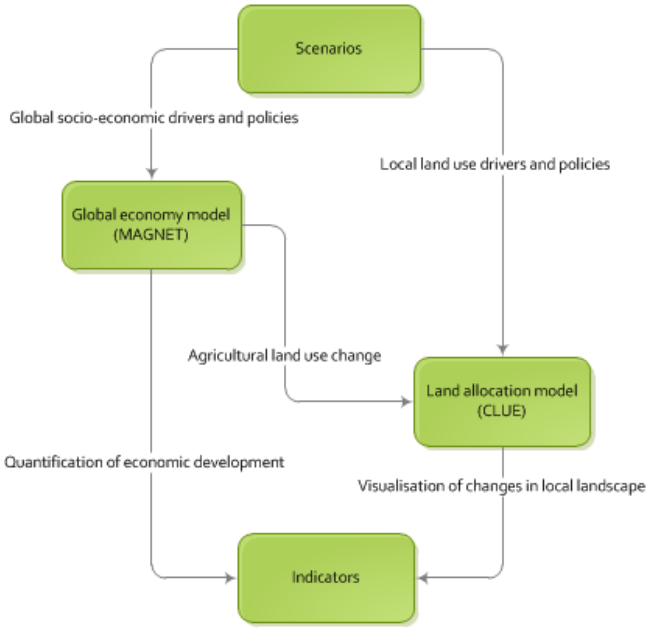

Figure 1: Overall representation of the methodology

Scenarios

The start of the analysis is the formulation of a 'business as usual' (BAU) scenario that reflects common expectations on how the (global) economy will develop. The BAU scenario is used as a reference to investigate the impact of certain policies or alternative assumptions on global drivers. The simulation results will reveal what the BaU scenario implies for the economy of Vietnam in terms of production, consumption and food security, structural change, factor markets, trade, and land use at the national and local level. All scenarios are run over the period 2007-2030. At the global level three drivers that are specified per country or region determine socio-economic change: population growth, economic growth and technological change (yields). Table 1 summarizes these drivers for the BAU scenario.

Table 1: Drivers for the Business as Usual scenario

	Vietnam	Rest of the world
GDP growth	6.59	3.93
Population growth	0.82	0.67
Yield growth (paddy rice)	1.23	0.81

Source: USDA and FAO(2009).
Note: yields for other crops not presented.

To analyze future land use change in Vietnam, a number of other scenarios will be considered. Following the approach taken in the EURURALIS project, (a sample of) the concept storylines of the IPCC Special Report on Emission Scenarios (SRES; Nakicenovic et al., 2000) will be taken as a starting point. The SRES scenarios are structured around four marker scenarios distinguished by different degrees of global (market) integration and different levels of (policy) regulation. Alternatively, building on Hertel *et al.* (2010) an optimistic climate scenario and a pessimistic climate scenario are defined to assess the impact of climate change on land use dynamics in Vietnam. The optimistic scenario depicts a world with relatively slow warming, low sensitivity of crops to climate change, and high CO2 fertilization. The pessimistic scenario reflects a future with rapid temperature change, high sensitivity of crops to warming, and a CO2 fertilization effect at the lower end of published estimates. On the basis of a literature review Hertel *et al.* (2010) present a table with productivity (yield) shocks – negative in case of the pessimistic scenario and positive in case of the optimistic scenario – for six agricultural commodities (rice, wheat, coarse grains, oilseeds, cotton, and other crops) per region.

Apart from assumptions on global drivers of socio-economic change, the scenarios can be extended to investigate the impact of (spatial) policies in Vietnam, such as the Green Growth Strategy and environmental policies such as the protection of areas with a rich biodiversity. In the remainder of this paper only the results for the BAU scenario are presented, without considering the effect of national policies.

Global-to-national modelling

The global economy is modeled with the Modular Applied GeNeral Equilibrium Tool (MAGNET), a global economic simulation model that that has been used to analyze the medium and long run effects of global and EU agricultural, trade and biofuels policies (Francois et al., 2005; van Meijl et al., 2006; Banse et al., 2008). It is based on the GTAP (Global Trade Analysis Project) model, a widely used tool for global trade analysis which is extended in various directions in a modular fashion. In this context, MAGNET will be used to isolate the effects of global economic growth, trade policies and technological change on the Vietnamese economy and the associated demand for land by agricultural sectors towards 2030. The model also takes into account the relation and interaction between the manufacturing, services and agricultural sectors that indirectly affect the demand for land in an economy. At the same time it also captures the impact of Vietnamese economic development on other countries, for instance, by means of changes

in imports and exports. The model has been estimated (calibrated) using the most recent GTAP database version 8, final release, which contains data for 2007. Vietnam is specified separately, as are its most important neighboring and trading partners. The sectoral division distinguishes 12 agricultural (land using) sectors available in GTAP at the highest level of detail, including paddy rice, various other crops and livestock and animal produce sectors as well as a (commercial) forestry sector, a fishing sector, manufacturing and services. Land use data for the 2007 (base year) are refined for Vietnam using data from the Vietnamese Ministry of Agriculture and Rural Development, consistent with the land use maps that are used by CLUE.

National-to-local modeling

MAGNET is not able to make an assessment beyond the individual country level. At the spatially disaggregated level, land change is also dependent on biophysical conditions (e.g. soil, slope and infrastructure) as well as specific spatial policies such as the location of protected areas and restrictions on land conversion. CLUE or the Conversion of Land Use change and its Effects model (Verburg et al., 2002) is used to downscale the aggregate land use information from MAGNET to the 1x1 km2 spatial resolution. It has been applied to study land use dynamics in a number of countries including Vietnam (Verburg, Overmars, et al., 2006; Castella et al., 2007). CLUE quantifies future land use by identifying the biophysical and human drivers of agricultural land use, on the basis of current land use information. Data for drivers has been incorporated in the analysis: elevation, slope, rainfall, distance to community centers, distance to major water bodies, distance to roads, distance to coast, population density, soil and temperature. Subsequently, information on the demand for the different agricultural sectors at the national level from the MAGNET model as well as other land use scenario information is allocated over the land area according to location suitability, spatial policies and rules for natural succession. The land use map for 2007 and policy documents from the Vietnamese National Institute for Agricultural Planning and Projection (NIAPP) are as input in the analysis.

RESULTS

Structural change of the Vietnamese economy

The output of MAGNET includes a wide range of indicators to measure economic change. Here only the decomposition of GDP into major sectors (agriculture, manufacturing and services) is presented in Table 2 to demonstrate the expected structural change of the Vietnamese economy in the baseline scenario. The Table also shows the shares for large agricultural sectors. The model predicts a continuation of the current growth path of Vietnam which is characterized structural change from an agricultural-based economy towards a modern economy where services play a key role. Agriculture, and in particular the crop sector, is expected to decrease from 19 to 11 percent of GDP, while services increases from 46 to 54 percent. There is no growth in the manufacturing sector.

Table 2: Structure (%) of the Vietnamese economy in BAU scenario, 2010-2030.

Sector	2010	2030
Agriculture,incl.	19	11
Crops	11	5
Livestock	2	2
Forestry	2	1
Fishing	4	3
Manufacturing	35	36
Services	46	54
Total	100	100

Land use change in Vietnam

Structural change in the Vietnamese economy will results in a change in the demand for land, which is also presented by MAGNET. Table 3 shows the decomposition of land use in 2010 and 2030 for the baseline scenario. The land used by the commercial forestry sector increases from 19 to 28 percent of total land cover. The extra demanded land is taken from protected and special use forest (non-production forest) areas which decreases substantially. Modernization of the economy is accompanied by a change in diets towards more meat and less rice, resulting in lower demand for rice and an associated decrease in the land area for paddy rice. There are no substantial changes in the other land use classes between 2010 and 2030. Figure 1 depicts the spatial allocation of land use by class in Vietnam for the year 2030.

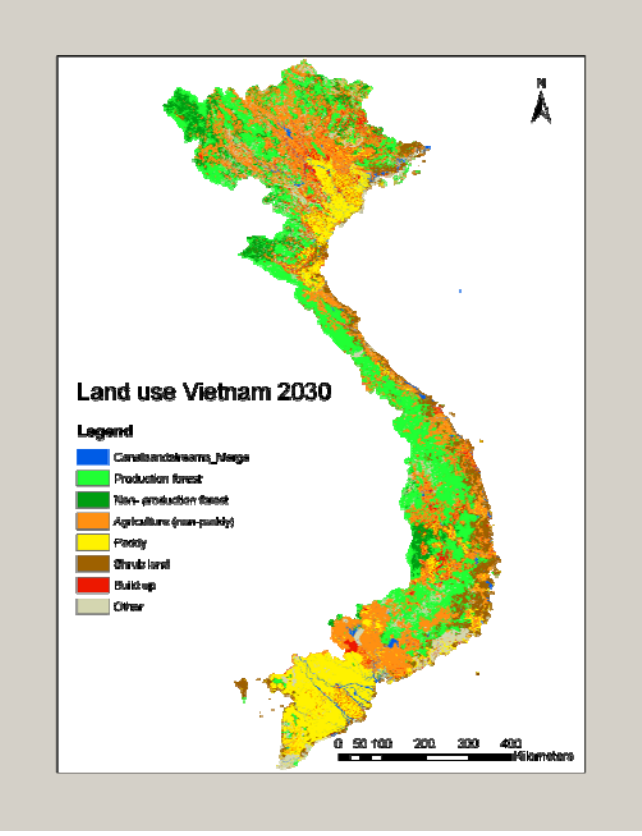

Figure 1: Land use in Vietnam in the BAU Scenario, 2030

Table 3: Land use (%) in Vietnam in the BAU scenario, 2010-2030

	2010	2030
Production forest	19	28
Non-production forest	16	6
Agriculture (non paddy rice)	26	26
Paddy rice	21	17
Shrub land	7	10
Build up areas	3	4
Other (water, natural bare, rock, swamp)	9	9
Total	100	100

DISCUSSION AND CONCLUSIONS

This paper has described an innovative global-to-local modeling framework to assess the impact of global socio-economic drivers and national spatial policies on land use, with an application to Vietnam. Results are presented for a Business as Usual scenario (2010-2030) incorporating assumptions on global economic growth, population growth and technological change. A selection of indicators is presented including structural change of the economy, land use change and a land use map for the year 2030.

These results will be the key point of reference to examine the impact of alternative futures (e.g. climate change, global regulation and integration) and national plans and policies (e.g. Green Growth Strategy) on land use in Vietnam. The output of the scenario analysis will be useful input for the Vietnamese government to evaluate alternative policies (e.g. economic, climate change and environmental) and their trade-offs at the national and local level.

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