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<http://dx.doi.org/10.1016/j.worlddev.2014.01.020>

# Land Use Dynamics, Climate Change, and Food Security in Vietnam: A Global-to-local Modeling Approach

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**Summary.** — We present an innovative global-to-local modeling approach to analyze impacts of uncertain and complex futures on Vietnam's economy via changes in land use patterns. Socio-economic changes are shown to have major implications for the Vietnamese landscape, including natural forest losses with negative consequences for biodiversity and greenhouse gas emissions, and losses of paddy rice and other agricultural lands in the Red River Delta and the Mekong River delta. Climate-related flood risks in these areas further threaten the population, economic assets, and food security. The scenarios reveal the importance of investments in agriculture, land markets, and climate change mitigation and adaptation.

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**Key words** — Food security, land use change, climate change, Asia, Vietnam, global-to-local modeling

## 1. INTRODUCTION

Land plays a crucial role in the development process of Vietnam. Agriculture still accounts for around 20% of GDP and close to 70% of the Vietnamese population resides in rural areas. The rural population mostly consists of poor and small-scale paddy rice farmers, the most important staple food in Vietnam and its most important export product, which makes the agricultural sector key to poverty reduction and food security (FAO, 2012). Food security is a concern since, even though Vietnam is the second largest exporter of rice in the world, many rural households are net buyers of food. Vietnam experienced one of the fastest increases in food prices in early 2008, and, consequently, has been identified as a hunger hotspot in Asia and the Pacific.

Changes in land use patterns over time also play a crucial role in climate change mitigation and adaptation. Vietnam's delta structure and the long coast line are sensitive to flooding and extreme weather events. As a result, Vietnam is a high-risk country in the context of climate change, which makes the population increasingly vulnerable in terms of poverty and food security. Climate change concerns have risen as a result of Vietnam's rapid GDP growth, averaging 6–8% over the last decade, which has led to an exponential increase in greenhouse gas (GHG) emissions. In 2010, total emissions in Vietnam were 151 million tons of GHG in carbon dioxide equivalent (CO<sub>2</sub>e), of which 53% was attributable to agriculture and land use change and over half in turn was accounted for by rice farming (MONRE, 2010).<sup>1</sup>

Land use patterns in Vietnam may change dramatically over time as a consequence of several global and local interacting processes. Key global drivers that may affect land use in Vietnam are climate change, international trade, population

growth, and technological change. At the national and local level, spatial policies that safeguard areas with rich biodiversity, climate adaptation, and mitigation strategies (i.e., REDD), the growth of urban and industrial zones and food security policies, such as a mandatory allocation of land for the production of paddy rice, will have important consequences for land use.

A common approach to assess the complexity and uncertainty that is associated with issues such as food security, biodiversity, and climate change is to carry out a scenario analysis, often combined with quantitative modeling (Nakicenovic *et al.*, 2000; McIntyre, Herren, Wakhungu, & Watson, 2009; Parry, Rosenzweig, Iglesias, Livermore, & Fischer, 2004; Nelson *et al.*, 2010). However, a major limitation of most of

\* The authors are grateful to Geert Woltjer, Hans van Meijl, Jeff Powell, and Andrej Tabeau for advice on economic modeling, to Arno Bouwman for calculation of flood risks, to Tran Kim Long (MARD) for guidance and policy support, to Vuong Thuc Tran (NIAPP/MARD) for logistical assistance, to Tran Trung Kien for help with the GIS data, to Kiki Kartikasari for research on climate change and to Ralph Ashton for overall project guidance. We are indebted to Timothy Tomas, Alex de Pinto and other participants at the workshops held in Hanoi and the Hague for their useful comments and advice. The paper also benefitted greatly from participation in the 15th Annual GTAP Conference on Global Economic Analysis, the Agro Environ 2012 Conference, and the 2nd Global Conference on Agriculture, Food Security, and Climate Change. The usual disclaimer applies. We acknowledge financial support from the Climate Development Knowledge Network (CDKN) and the Dutch Ministry for Economic Affairs, Agriculture and Innovation of the Netherlands (BO-10-2012-01), which had no involvement in the research. Final revision accepted: January 16, 2014.

these studies is their modeling of land use change, which is often done at the country, agro-ecological zones or coarse grid level. Such an aggregated approach fails to capture the local level determinants of land use change, such as infrastructure, population density, elevation, and soil quality (Turner *et al.*, 1995) and is not able to present spatially explicit outcomes (i.e., maps) to measure and depict land use change. This information is essential to estimate emissions from land use change and forestry (IPCC, 2006), analyze biodiversity change (Reidsma, Tekelenburg, van den Berg, & Alkemade, 2006) and investigate the impact of sea-level rise (Dasgupta, Laplante, Meisner, Wheeler, & Yan, 2009), which are highly spatial and landscape-specific phenomena.

This study provides an innovative assessment method which integrates global and local (landscape) approaches to assess future land use in Vietnam. It combines a global macro-economic Computable General Equilibrium (CGE) model (MAGNET) with a spatial land use allocation model (CLUE), to analyze future land use patterns in Vietnam under various scenarios for the period 2007–2030. The use of a global economic model (as compared to a single-country CGE model) makes it possible to explicitly take into account global-to-local (trade) linkages, which are expected to be important in an export-oriented country such as Vietnam.<sup>2</sup> The outcomes of the model exercise provide relevant information on the impact of climate change on economic growth, the development of food prices under different futures and, when combined with flood maps, areas that have the highest risk of being flooded as a consequence of climate change, which provides a richer analysis than a pure CGE modeling exercise. The approach builds upon van Meijl, van Rheenen, Tabeau, and Eickhout (2006), Verburg, Schulp, Witte, and Veldkamp (2006), and Verburg, Eickhout, and van Meijl (2008), which model land use dynamics in Europe. Our paper is the first application of this approach in the context of a developing country. The study contributes to existing modeling studies for Vietnam (Coxhead & Van Chan, 2011; World Bank, 2011) in terms of its global coverage, especially addressing interactions of Vietnam with the global economy, improved country data for Vietnam, most notably data and projections for land use, forestry sectors, and yields, and improved modeling of the land market. Our final contribution lies in the participatory, bottom-up approach through which the scenarios carried out in this study have been formulated and implemented.

The global-to-local model framework is used to implement two scenarios: (1) a High Climate Impact (HCI) scenario that reveals impacts of climate change on Vietnam's economy and land use and (2) a High Economic Growth (HEG) scenario which addresses the consequences of high economic growth for Vietnam's economic structure and national and local land use. The scenarios are implemented compared with a baseline scenario, or the "Business as Usual" (BAU), i.e., a growth path for Vietnam and the rest of the world assuming no implementation of new policies. This paper is organized as follows. The next section presents the methodological approach of the study, including a description of the modeling framework, data used, and scenarios that have been implemented. Section 4 presents the results of the scenarios. Section 5 discusses the results. The final section concludes.

## 2. METHODOLOGY

Scenario analysis is an important tool to help policy makers, researchers, and other stakeholders to envision what the future may look like and guide the formulation of policies that are contingent on future expectations. There exist several ap-

proaches to formulate, prepare, and assess scenarios (Börjesson, Höjer, Dreborg, Ekvall, & Finnveden, 2006; Westhoek, van den Berg, & Bakkes, 2006).

Our scenario methodology resembles the Story and Simulation (SAS) approach (Alcamo, 2008), which combines participatory and analytical methods of scenario building via (1) the development of qualitative storylines and (2) the quantification of storylines with the use of models and numerical data, including feedback loops and re-iterations to revise the storylines and model quantification and to enhance their coupling.<sup>3</sup> This study has taken similar steps, albeit bounded by limited resources. While this approach has greatly enhanced the accuracy and relevance of our scenarios to policy, science, and the agricultural land using sectors, it does remain problematic to translate qualitative knowledge into quantitative knowledge and back again. This should be taken into account when interpreting the results of the scenario analysis.

The scenarios have been used to quantify the impacts of global and national drivers and policies on land use and the wider economy of Vietnam up to 2030, using a global-to-local modeling framework with improved data. The methodology is summarized in Figure 1.

The most important building blocks of the methodology, i.e., the modeling framework, data used, and scenarios that have been analyzed, are discussed below.

### (a) Modeling framework

To capture the impacts of global and local drivers of land use change, this study combines two models: the global economic simulation model MAGNET and the spatially explicit land allocation model CLUE.

#### (i) MAGNET

MAGNET (Modular Applied GeNeral Equilibrium Tool) is a multi-sector, multi-region Computable General Equilibrium (CGE) model that has been widely used to simulate the impacts of agricultural, trade, land, and biofuel policies on global economic development (Banse, van Meijl, Tabeau, & Woltjer, 2008; Banse *et al.*, 2011; Francois, van Meijl, & van Tongeren, 2005; Rutten, Shutes, & Meijerink, 2013). MAGNET is based on the Global Trade Analysis Project (GTAP) model and can be extended in various directions in a modular fashion, depending on the policy questions at hand.

The GTAP core model accounts for the behavior of households, firms, and the government in the global economy and how they interact in markets (Hertel, 1997). For the purpose of this Vietnam study, MAGNET, compared to GTAP, employs a more sophisticated production structure, accounting for the inherent difference in the ease of substitution between land and non-land factors of production, a more sophisticated consumption structure, allowing for a better depiction of changes in diets observed over time, segmented labor and capital markets, allowing for differences in factor remunerations between agricultural and non-agricultural sectors, and an improved modeling of the land market.<sup>4</sup> These extensions, and particularly those regarding the land market, were the outcome of discussions with Vietnamese land use planners and stakeholders, backed up by recent findings in the literature (HLPE, 2011; Kirk & Tuan, 2009; Markussen, Tarp, & van den Broeck, 2010). Specifically, with regard to the land market, under the economic reform process *Doi Moi*, Vietnam's land tenure system has been reformed. However, important challenges remain which ensure that the actual land allocation over different land using sectors in Vietnam is still far from smooth and market driven. First, land allocation still seems

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