Global-to-local modelling of land use dynamics in Vietnam

Potential effects of high climate impact and high economic growth scenarios

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Abstract

This paper presents the preliminary results of two hypothetical futures for Vietnam, a High Climate Impact and a High Economic Growth Scenario using a modified version of GTAP. The land use component has been improved and more detailed data for Vietnam has been added. However, the most notable feature is the implantation of a global-to-local modelling approach, which combines the macroeconomic MAGNET model and CLUE land use model. Results show that the structure of the Vietnamese economy, land distribution, and the composition of the food consumption basket are little affected by the scenarios. Impacts are, however, visible across sectors, with important inter-sectoral linkages between primary and processing industrial sectors. Climate change, primarily modelled via yields, is shown to slow down the economy. An increased demand for land by crops at the cost of livestock and commercial (production) forestry pushes up land prices with knock-on effects for the rest of the economy. Food security deteriorates across the globe and in Vietnam, with substitution towards cheaper imports. Pursuing higher economic growth by increasing yields and technological progress in manufacturing and agriculture sectors can turn these developments around and minimise land price increases. Food security improves in Vietnam (and globally), with substitution towards cheaper domestic goods and a slight shift away from processed rice towards other food products. Future land use maps reveal that the largest changes will take place in the conversion of non-production forests and bare and shrub land to production forest. The increase of built up land is partly the result of a decrease in paddy land. The increase in urban area is mainly located in the Red River Delta region, the northern part of the North Central Coast and in the Central Highlands. While land use patterns across scenarios are relatively similar, climate change is shown to lead to a slightly lower increase of the production forest areas, while a higher economic growth path for Vietnam is shown to result in a higher growth of production forest, mainly in the west, and urban areas. An overlay of future paddy and urban area with potential flood maps show that a significant area of these land uses are threatened by floods, which are likely to result in reduced crop productivity and economic losses, posing a threat to food security.

Keywords: CGE modelling, scenario studies, local land use change, food security, climate change, technological change

1. Introduction

Land plays a crucial role in the development process of Vietnam. Not only does the agricultural land using sector in Vietnam account for a substantial share of GDP (approximately twenty per cent including forestry and fisheries), a large part of the Vietnamese population (over sixty per cent) resides in rural areas, mostly consisting of poor and small-scale farmers involved in the production of paddy rice, making the agricultural sector key to poverty reduction and food security.[1] Food security is a concern since, even though Vietnam is the second largest exporter of rice, 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 classified as one of the hunger hot spots in Asia and the Pacific.[2]

Land use by agriculture and forestry sectors and changes in land use patterns over time also play a crucial role in climate change mitigation and adaptation. Climate change concerns have risen as a result of Vietnam's rapid GDP growth, averaging six to eight per cent over the last decade, which has led to an exponential increase in greenhouse gas (GHG) emissions. In 2010, total emissions in Vietnam were reported to equal 151 million tons of GHG in carbon dioxide equivalent (CO_2), of which fifty-three per cent was attributable to agriculture and land use change and over half in turn was accounted for by rice (Salas et al., 2012). Whilst Vietnam's GHG emissions are relatively low in the global context, they are expected to continue to grow rapidly and will likely triple by 2030 unless significant mitigation options are undertaken. 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. This makes the rural population increasingly vulnerable in terms of poverty and food security.[3] The Vietnamese government has demonstrated its commitment to combat climate change by signing Decision 3119/QD-BNN-KHCH in December of 2011, which confirms the country's commitment to increase agricultural production by twenty per cent and reduce emissions and poverty by twenty per cent by 2020, the 20-20-20 target. The Vietnamese government is currently also in the process of drafting a Green Growth strategy and completed the final approval of the REDD (Reducing Emissions from Deforestation and Forest Degradation) program document, which is now in the inception and implementation phase.[4] Vietnam has signed up for the Clean Development Mechanism (CDM) and allows for voluntary carbon projects in agriculture but implementation so far is slow (only few projects seek CDM finance and there are currently no voluntary carbon projects) due to limited capacity (policies, institutions) at the local level.

Land use patterns in Vietnam are expected to change dramatically over time as a consequence of several global and local processes that interact at various scales and domains. Next to climate change, key global drivers that will affect land use in Vietnam are technological change, population growth, and international trade. 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 food security policies such as a mandatory allocation of land for the production of paddy rice will have important consequences for land use. Some of these policies may conflict. For example, reducing land use for rice and increasing forest area to reduce GHG emissions will affect food security negatively unless rice yields rise or rice imports increase.

[1] See http://www.fao.org/countries/55528/en/vnm) for more key facts on Vietnam's agricultural sector and food security situation.
[2] See http://www.foodsecurityportal.org/Vietnam for more key facts on food security in Vietnam.
[3] For more information on climate change and food security in Vietnam see http://www.unescap.org/LDCCU/Meetings/HighLevel-RPD-food-fuel-crisis/Paper-Presentations/C2-FoodSecurity/VietNam-FoodSecurity.pdf.
[4] For more information on the UN-REDD programme in Vietnam see http://www.un-redd.org/UNREDDProgramme/CountryActions/VietNam/tabid/1025/language/en-US/Default.aspx.

The interplay between global and local drivers is complex and uncertain which makes it difficult to predict their impact on the economy, on landscapes, rural livelihoods and the environment. To formulate pro-active policies and identify challenges and opportunities, decision-makers need information about potential land use and other, economic, outcomes in different situations as well as insights about the underlying dynamics, potential trade-offs and the potential impacts of policies. A popular approach to assess the future of complex systems and identify policy alternatives is to implement scenarios using a combination of models. Studying global-to-local land use impacts poses 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 high levels of resolution.

We apply an innovative assessment method which integrates a global macro-economic Computable General Equilibrium (CGE) model with a spatial land use allocation model to analyse future land use patterns in Vietnam under various scenarios. It builds upon the work of van Meijl et al. (2006) and Verburg et al. (2008a) to model land use dynamics in Europe.[5]

This study is the first application of this approach in the context of a developing country. It adds to the existing CGE studies on Vietnam that have generally focused on the economic impacts of trade liberalisation, with a few focussing on the environment and natural resources (Coxhead and Van Chan, 2010; World Bank, 2011). These studies, however, use a single economic modelling approach and are thereby unable to derive impacts on local land use changes and missing out potentially important feedback effects (e.g. areas that become more vulnerable to climate change are likely to become less food secure). Similarly, the national scope of these studies misses out important global effects (e.g. via the channel of trade). Our study also contributes to existing modelling studies in terms of improving country data for Vietnam, most notably data and projections for land use, forestry sectors and yields, and improved modelling 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. Specifically, two workshops were held[6], which informed the model set up, data used and construction of the scenarios to be analysed. The results of this exercise are therefore particularly useful to inform policies concerning economic growth, food security, climate change, REDD, land use, green growth and climate smart agriculture in Vietnam.

The global-to-local model combination is used to implement three scenarios: (1) a baseline scenario reflecting the 'Business as Usual' (BaU) and simulates a growth path for Vietnam and the rest of the world assuming no implementation of new policies, (2) a High Climate Impact (HCI) scenario that reveals the consequences of climate change on Vietnam's economy and land use (modelled primarily through yields) and (3) a High Economic Growth (HEG) scenario which implements the growth target incorporated in the Socio-Economic Development Strategy (SEDS, 2010) of Vietnam and yield targets of Vietnam's Master Plan on Agriculture (NIAPP, 2011) and demonstrates the consequences for Vietnam's economic structure and national and local land use. The outcomes can be compared with economic targets, and targets for land use and the agricultural and forestry sectors envisioned by aforementioned plans.

This paper is organised as follows. The next section presents the methodological approach of the study, including a description of the models and data used. Section 3 discusses the formulated

[5] This research was part of the EURURALIS project, see http://www.eururalis.eu/.
[6] The first 'scoping' workshop was held in Hanoi, October 12-13 2011, and focussed on the formulation of scenarios to be analysed, the modelling assumptions and improving the land use data. The second 'scenario' workshop was held in Hanoi, March 22 2012, and focussed on discussion of preliminary results and further refinement of the scenarios.

scenarios. Section 4 presents the results of the scenarios. Finally, section 5 presents conclusions and policy implications.

This paper presents the results of the global-to-local modelling exercise carried out in this study, i.e. in terms of a variety of national macro-economic and sectoral indicators, as well as local land use outcomes (indicators, maps), but with a focus on macro-economic impacts and policy implications. A second paper (van Dijk et al., 2012) presents more detailed local land use outcomes and policy implications.

2. Methodology

For this study, a global economic simulation model is linked to a spatially explicit local land use model for Vietnam. The global economic simulation model used is the Modular Applied GeNeral Equilibrium Toolbox (MAGNET), a CGE model developed by LEI-Wageningen UR. MAGNET is a global economic simulation model that can be used to study the impact of changes in trade and agricultural policies on international trade, production, consumption, prices and use of production factors around the world. It is based on the GTAP (Global Trade Analysis Project) model[7], a widely used tool for global trade analysis, but can be extended in various directions in a modular fashion. The model has been used to analyse, for example, the medium and long run effects of global and EU-agricultural, trade and biofuels policies.

To downscale the aggregate information on land use from MAGNET to a map, the Conversion of Land Use change and its Effects (CLUE) model is used.[8] It quantifies land use changes by combining spatial data on the bio-geophysical and human drivers of agricultural land use with current land use patterns and information on land use conversion and spatial policies. It has been applied to study land use dynamics in a number of countries, including Vietnam (Castella et al., 2007).

2.1 MAGNET model description

For the purposes of this project, MAGNET is set up around the standard GTAP core model but with a more sophisticated production and consumption structure, segmented factor markets and a more sophisticated land market so as to make it suitable to carrying out analyses applied to agri-forestry sectors and questions pertaining to land use. These model specifications were the outcome of the first scoping workshop held in Hanoi. The data, GTAP core and adjustments made to the GTAP core of MAGNET are discussed below.

2.1.1 Data

The model has been estimated (calibrated) using the most recent GTAP database version 8, final release, which contains data for 2007. The 129 countries and/or regions and 57 sectors of the GTAP database have been aggregated in more manageable categories, namely fifteen regions and twenty-three sectors (Table 2.1). Vietnam is specified separately, as are its most important neighbouring and trading partners. The sectoral division distinguishes twelve 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 -, a commercial forestry sector[9] and a fishing sector. Furthermore, we distinguish six processed food categories, which have strong links with aforementioned primary sectors, and aggregate the remaining sectors into lumber industry (destination of most of the

[7] See https://www.gtap.agecon.purdue.edu/
[8] See http://www.ivm.vu.nl/en/Organisation/departments/spatial-analysis-decision-support/Clue/index.asp for more information on the CLUE model.
[9] Commercial forestry or production forestry, as opposed to natural forests, produces an economic output, timber, using scarce resources, most notably land, for which it competes with the agricultural sector.

commercial forestry sector's output), other manufacturing and services categories. The model retains the standard GTAP specification of five factors of production, including skilled and unskilled labour, capital, land and natural resources.

Table 2.1: MAGNET aggregation and CLUE land classes

MAGNET						CLUE	
Countries/regions			**Sectors**			**Land use classes**	
1	eu27	EU27	1	pdr	Paddy rice	1	Paddy rice
2	fsu	Former Soviet Union excl. Baltics	2	wht	Wheat	2	Other agriculture
3	roe	Rest of Europe	3	gro	Cereal grains nec	3	Production forest
4	nam	North America	4	v_f	Vegetables, fruit, nuts	4	Non-production forest
5	csa	Central and South America	5	osd	Oil seeds	5	Shrub and grass land
6	mena	Middle East and North Africa	6	c_b	Sugar cane, sugar beet	6	Built up land
7	ssa	Sub-Saharan Africa	7	pfb	Plant-based fibres	7	Other land
8	vnm	Vietnam	8	ocr	Other crops		
9	asean	rest of ASEAN	9	ctl	Cattle: sheep, goats, horses		
10	chn	China (+ Hong Kong, Taiwan and rest of East Asia)	10	oap	Animal products nec		
11	kor	South Korea	11	rmk	Raw milk		
12	jpn	Japan	12	wol	Wool, silk-worm cocoons		
13	ind	India	13	frs	Commercial forestry		
14	rsa	Rest of South Asia	14	fsh	Fishing		
15	oce	Oceania	15	pcr	Processed rice		
			16	cmt	Cattle & meat products		
			17	vof	Vegetable oils & fats		
			18	mil	Dairy products		
			19	sgr	Sugar		
			20	fbt	Food, bev & tobac prod nec		
			21	lum	Wood products		
			22	mnf	Other manufacturing		
			23	svc	Services		

The economic data for Vietnam that are contained in the GTAP 2007 database are derived from a Social Accounting Matrix (SAM) for 2005, constructed to be consistent with 2005 macroeconomic structure and with the sectoring scheme of the GTAP data base.[10] Key economic indicators for Vietnam that can be derived from the SAM are included in the Appendix (A1). Below we describe the most important characteristics of the Vietnamese economy (in 2007) according to these indicators.

GDP in 2007 is estimated at roughly 68 billion US$, of which 67 per cent represents consumption and 41 per cent investments (Table A1.1). The exports (value) to GDP ratio in 2007 is estimated at a relatively high 78 per cent and imports at 93 per cent, which combined gives a gross trade-to-GDP ratio of 171 per cent. On net, however, Vietnam is an importing country, with a net trade-to-GDP ratio of -15 per cent. Vietnam's economy is very much a service-oriented economy (Figure A1.1). In 2007, most value added was generated by the services sector (46 per cent), followed by manufacturing (29 per cent; including 1.5 per cent for the lumber industry, but excluding 5 per cent for processed foods), and crops (13 per cent). Considering crops only (Figure A1.2), paddy rice is the biggest contributor in terms of value added (38 per cent), followed by vegetables, fruits and nuts (33 per cent) and other crops (24 per cent). The latter category includes the for Vietnam important commodities of coffee and rubber. In terms of trade, the EU and North America are Vietnam's biggest export partners, accounting for 24 per cent and 22 per cent of Vietnam's value of exports, followed by ASEAN and Japan (Figure A1.3). Manufacturing represents the majority of Vietnamese exports (67 per cent, excluding 6 per cent for lumber and 11 per cent for processed food categories), as shown in Figure A1.4. On the import side, Vietnam's most important trading partners are China and ASEAN (capturing 32 per cent and 20

[10] See https://www.gtap.agecon.purdue.edu/databases/regions.asp?Version=8.211 for more information on Vietnam data in GTAP.

per cent respectively of Vietnam's value of imports), followed by the EU, South Korea and Japan (12 per cent, 10 per cent and 10 per cent respectively). Most of these imports are in manufacturing as well (81 per cent, excluding 1 per cent for lumber and 5 per cent for processed food categories). Considering trade in rice, still by far the most important Vietnamese crop, which here includes both paddy and processed rice, major consumers of Vietnamese rice are the ASEAN countries (66 per cent), followed by Sub Saharan Africa (13 per cent) and Central and South America (13 per cent), whereas Vietnam imports most of its rice from China (83 per cent) and ASEAN (14 per cent). Imports of rice are only a fraction (less than 1 per cent) of Vietnamese rice production.

For all countries/regions in the world, the land use data in MAGNET were obtained from data compiled by GTAP in two steps. First SAGE (Centre for Sustainability and the Global Environment)/FAO land cover data for 2004 are corrected for the percentage change over 2004-2007 reported by FAO. In a second step, the data was distributed over crops in proportion to harvested area using data from SAGE/FAO, and over livestock sectors using data on value add of land in these sectors.[11] Land for commercial forestry was obtained from the DGTM (Dynamic Global Timber market Model) database. Land rents in commercial forestry are obtained from natural resources. Lee et al. (2009) provides more information on the land cover database that is used by GTAP. [12]

The land cover and land use data that result are displayed in the Appendix (A2). Of the total amount of land available, 21 per cent is non-production forest, 35 per cent is in commercial forestry (production forest) and 28 per cent in agriculture (Table A2.1, left-hand side). One per cent is used for built up areas (e.g. residential areas, industrial zones and ports). The remaining 14 per cent, mostly degraded savannah grassland, is assumed not to be in use for economic activities, i.e. is unproductive land. Taking a closer look at the various agricultural land using sectors, most is used in the production of paddy rice and represents 24 per cent of total land in use by economic activities (Table A2.2, left-hand side).

The Vietnamese Ministry of Agriculture and Rural Development (MARD) provided a 2007 land cover map, produced by the Forest Inventory and Planning Institute (FIPI), a research institute under MARD. This map, combined with land use survey data from MARD, was used to improve the land use data for Vietnam in MAGNET. In contrast to the GTAP database, it presents information on the location of paddy rice areas and other agriculture (including livestock). To distribute the land cover over the agricultural subsectors, the same distribution is used as in the SAGE/FAO database which uses data on harvested area and value added for crops and livestock, respectively. Apart from agriculture and forestry, the land use map also provides information on the location of four other land classes: non-production forestry (e.g. natural forest areas and protected areas), shrub land, build up land (residential areas, industrial zones and land for national security) and 'other' land (land with rivers, canals and streams, swamps, and rock land). The resulting land cover and land use data for Vietnam are displayed in Table A2.1 (right-hand side). The main difference with the GTAP data is the area allocated to production forest, which is much lower in the FIPI data. On the other hand, agriculture land (including paddy rice) and built up land are larger in the FIPI map. The distribution over the land using sectors is very similar, with only the share of commercial forestry land use being significantly smaller (Table A2.2, right-hand side; 42 per cent compared to 55 per cent before). As before, most land in agriculture is used for the production of paddy rice and vegetables, fruit and nuts

[11] As shown, savannah grassland, next to shrub land and built-up land, is not allocated to agricultural sectors as no significant economic production comes from it.

[12] A problem with the GTAP land database is that it does not present information on land used to grow paddy rice. The rice sector is key to national food security, economic development and poverty reduction. Moreover, it is an important source of greenhouse gasses in Vietnam. Hence, leaving it out would considerably weaken our analysis. Another problem with the GTAP data is that is does not provide information on non-production forest and natural parks, which is essential to give insights in future perspectives on REDD and biodiversity.

(resp. 29 per cent and 14 per cent of total land in use by economic activities, compared to 24 per cent and 9 per cent before).

2.1.2 GTAP core model

The GTAP model, documented in Hertel (1997), captures the behaviour of three types of agents: households, firms and government, in each country or region of the world. Household behaviour is captured via a 'representative regional household', which aims to maximise its utility, collects all income that is generated in the economy and allocates it over private households and government expenditures on commodities, and savings for investment goods. Income comes from payments by firms to the regional household for the use of endowments of skilled and unskilled labour, land, capital and natural resources. The regional household also receives income from (net) taxes paid by the private household (on private consumption and income), firms (taxes on intermediate inputs and production) and the government (on its expenditures). Firms, profit maximisers, produce commodities by employing the aforementioned endowments and intermediate inputs from other firms using a constant returns to scale production technology[13] so as to sell them to private households, the government and other producers. Domestically produced goods can either be sold on the domestic market or to other regions in the world. Similarly, domestic intermediate, private household and government demand for goods can be satisfied by domestic production or by imports from other regions in the world (Armington assumption). These come with their own import and export taxes. Sourcing of imports happens at the border, after which – on the basis of the resulting composite import price – the optimal mix of import and domestic goods is derived.

Demand for and supply of commodities and endowments meet markets, which are perfectly competitive and clear via price adjustments. Natural resources and land are assumed to adjust sluggishly between sectors, whereas capital and labour are fully mobile. The assumptions regarding labour, land and capital markets are discussed below as they are different from standard GTAP. With all markets in equilibrium, firms earning zero profits and households on their budget constraint, global savings must equal global investments. Investments are computed on a global basis, via a 'global bank' which assembles savings and disburses investments, so that all savers in the model face a common price for this savings commodity. In GTAP, global savings determine global investments, i.e. the macro closure is savings driven and essentially neoclassical in nature. Since the CGE model can only determine relative prices, the GDP deflator is set as the numéraire of the model, against which all other prices are benchmarked. Changes in prices resulting from the model simulations thus constitute real price changes.

Since GTAP is essentially a comparative static model, investments only influence the pattern of production (via investments as a demand category) and are not installed so as to add to the productive capacity of industries over time. For the purpose of this study we are using the model to carry out dynamic analysis over time, specifically for 2007 (the base year) up to 2030. The projections into the future are obtained by allowing the exogenous endowments of capital, land, natural resources and labour, and the productivity of these factors, most notably yields, to grow according to a specific growth path. This is discussed below when treating the assumptions of the baseline.

2.1.3 MAGNET: extending the GTAP core

In this section we discuss the features that have been added and/or improved upon in MAGNET relative to the GTAP core model. These include, for all countries and/or regions, a more sophisticated

[13] This means that as firms grow, they do not become more or less efficient.

production structure and consumption structure, segmented capital and labour markets and a more sophisticated specification of the land market.

Production structure

The MAGNET model has a more flexible Constant Elasticity of Substitution (CES) production structure which allows inputs into the production of final goods, as measured by the substitution elasticities, to vary across nests. Whereas different sectors may have different production structures, for this study a simple three-level structure has been chosen for all sectors and in all countries/regions of the world. Specifically, in the top nest value added and intermediate inputs are combined into production. In the second nest, land and non-land value added are combined into value added. In the third nest, capital, skilled and unskilled labour and natural resources are combined into non-land value added. The distinction between land and non-land value added, to account for inherent differences in the degree of substitutability between land and non-land factors is new relative to standard GTAP. The value of the elasticity of substitution increases as we go down in the tree structure as inputs used in production become more similar (and so can more easily be substituted). In the top nest the substitution elasticity is assumed zero (as in standard GTAP), so that inputs cannot be substituted and are used in production according to fixed input-output coefficients. In the value added nest, the substitution elasticity equals 0.1 and in the non-land value added nest in between 0.25 and 1.36 depending on the commodity in question.[14]

Consumption structure

In GTAP, private (household) consumption behaviour is modelled via a Constant Difference of Elasticity (CDE) function, which is a more flexible, non-homothetic function allowing for non-constant marginal budget shares, and is calibrated using data on income and price elasticities of demand. Since the use of the CDE function in practice results in constant income elasticities over time – leading to unrealistically high consumption of food items in fast growing economies – in MAGNET income elasticities are dynamically adjusted using real GDP per capita (in the form of a decreasing function). The services sector is used as a residual to guarantee that the sum of the income elasticities is one. The updating of income elasticities takes place in each step of the Euler optimisation routine used in solving the model, and preserves the welfare calculations as present in the GTAP model. This approach has been documented in Verburg et al. (2008b).

Segmented labour and capital markets

In standard GTAP, capital and labour are assumed to be fully mobile across sectors. In reality however, there's limited movement of capital and labour between agricultural and non-agricultural sectors, in contrast to relatively free movement within these sectors. This is evident from, for example, differences in wage levels for unskilled labour in agriculture compared to industry and services sectors. MAGNET allows for the modelling of such segmented factor markets, by introducing a nested Constant Elasticity of Transformation (CET) function for capital and labour, which includes a nest for agriculture and non-agriculture. Within these nests, capital and labour are assumed to be perfectly mobile, but between these nests it is more difficult to move. A consequence of this approach is that unskilled and skilled) labour and capital receive different remunerations (i.e. wage and rental rate respectively) in agricultural and non-agricultural sectors. The elasticity of transformation, which governs the sluggishness of movement of these factors across sectors, is set at a level of minus one.[15] This approach has been documented in Tabeau and Woltjer (2010) and originally derives from Hertel and Keeney (2005).

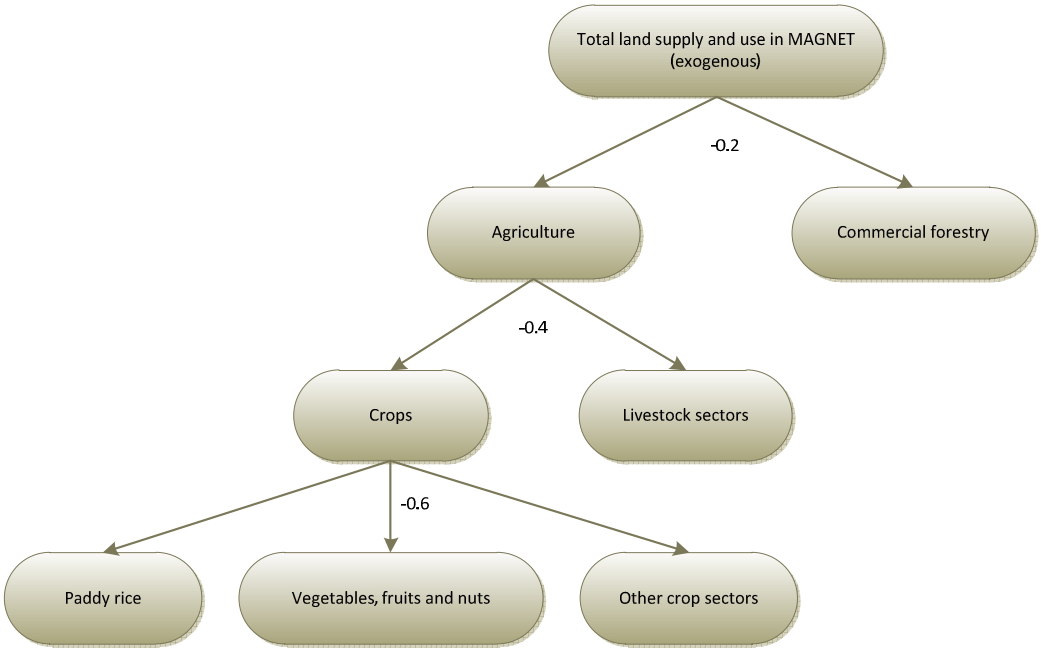
[14] An elasticity of substitution of x, implies that as the relative price of an input rises by 1%, its relative demand falls by x%.
[15] An elasticity of transformation of –x implies that as the relative price of a factor rises by 1% its relative supply rises by x%.

Land market

In standard GTAP, total land supply is fixed and is assumed to adjust sluggishly between sectors (with an elasticity of transformation equal to -0.5, as for natural resources). MAGNET can refine this approach by allowing for the incorporation of different degrees of sluggishness between different types of land, again using a nested CET function. Generally, the ease with which land is allocated from and to agricultural sectors differs for different types of land. We adopt a relatively simple three-level nested-CET approach, which in the top nest allocates land to commercial forestry and agricultural sectors, in the second nest allocates agricultural land to crops and livestock, and in the third nest allocates cropland to paddy rice, vegetables, fruit and nuts and other crops (Figure 2.1). As we move down the tree, the elasticities of transformation increase in absolute value, signifying it becomes more easy to transfer land between sectors. This approach creates different land prices in each level of the tree. This approach has been documented in van Meijl et al. (2006). The elasticities are obtained from GTAP.

A novel feature of the land allocation specification is that it includes commercial forestry in the top level as an economic land using sector. Whilst commercial forestry harvests are flexible in that extra harvests are possible, we assume that it is difficult to reallocate land from agriculture to commercial forestry (by means of the relatively low elasticity of transformation), thereby doing justice to the long term nature of the decisions in the forestry sector.

Figure 2.1: MAGNET land allocation



The extent to which land can be reallocated between agriculture and forestry and between different agricultural sectors depends very much on the country's land property regime. Vietnam's land tenure system has been reformed under the economic reform process known as *Doi Moi*. In this process, land has been re-assigned from collectives to small-scale farmers, establishing their land rights in a Land Law and enhancing tenure security via inheritable land rights that also asserted women's rights (HLPE, 2011; Kirk and Tuan, 2009). As a consequence of the reforms and parallel agricultural liberalisation process, a lot of gains have been made in terms of increased agricultural production and trade, intensification of rice production and diversification into crops other than rice, which enhanced food security and reduced hunger and rural poverty. 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 very much planned and regulated by national, regional, provincial, district and commune level authorities, each with their own, often inconsistent, land use plans, which do not match socio-economic plans and construction plans (scoping workshop, Hanoi). Also, whilst legal systems are in place, they are not always operational in practice for a variety of reasons (Kirk and Tuan, 2009; scoping workshop Hanoi). As a result, it is unclear whether one can speak of a real market for land in Vietnam, with (sectoral) demand responding to a price and with price adjustments assuring equilibrium between demand and supply.

Two main points of importance to the global-to-local land use modelling emerged from the discussions with Vietnamese land use planners and stakeholders (scoping workshop, Hanoi). Firstly, land reallocation in agriculture is often not instantaneous and easier between some sectors relative to other sectors. We secure this in MAGNET via low levels of substitution, which increase for more similar commodities (Figure 2.1). And secondly, once a year the central government establishes the (official) price for land. It was suggested that two systems operate in parallel, the market with a 'market' price and an official system with an official price. The market price is not monitored on a regular basis and so the valuation of land by the government in terms of an official price is generally not in line with market developments. Given that it is impossible to model these two systems at the same time, given the lack of information on land prices, and given that the focus of this study is on implications of global, national and local drivers on land use patterns, we decided to keep the land market in the model (i.e. land use across sectors, albeit sluggish, is an endogenous outcome of the model and responds to changes in prices, and land prices adjust so as to ensure equilibrium). The land prices or land rental rates and changes therein that emerge from MAGNET are thus best interpreted as (changes in) shadow prices for land, signifying (changes in) relative scarcity and pressures for land.

2.2 CLUE model description

At the spatially disaggregated level, land change is also dependent on biophysical conditions (e.g. soil, slope, rainfall, infrastructure) as well as specific spatial policies such as the location of protected areas and other restrictions on land conversion. These issues cannot be taken into account by MAGNET as it only provides results at the aggregate country level. For this reason the CLUE model is used to project land use data from MAGNET on a map with a spatial resolution of 1x1 km2. The model quantifies future land use by identifying the biophysical and human drivers of agricultural land use, on the basis of current land use information and incorporating information on land use policies. To ensure consistency between the global and national analysis with MAGNET, the FIPI 2007 land use map classes have been aggregated to similar classes for the analysis in CLUE (Table A2.3).

By linking GIS based information on land use drivers (e.g. location characteristics) with a land use map, a suitability map is generated that identifies the most probable allocation for the seven land classes for which information is available: paddy rice, other agriculture, production forest, non-production forest, shrub land, build up land and other land (Table 2.1). Additional GIS information on the following location characteristics was collected to create the suitability map: elevation, slope, rainfall, distance to community centres, distance to major water bodies, distance to roads, distance to coast, population density, soil and temperature.

In the next step, land use scenarios are simulated. For all seven land classes assumptions are made about the expansion or contraction over time with the help of a so called land use conversion matrix and setting of conversion elasticities. These instruments determine which classes can be converted into one or more of the other land use classes and the time it takes to convert one land class into another. For some classes this is relative easy (e.g. from natural forest to crop land), for others more time

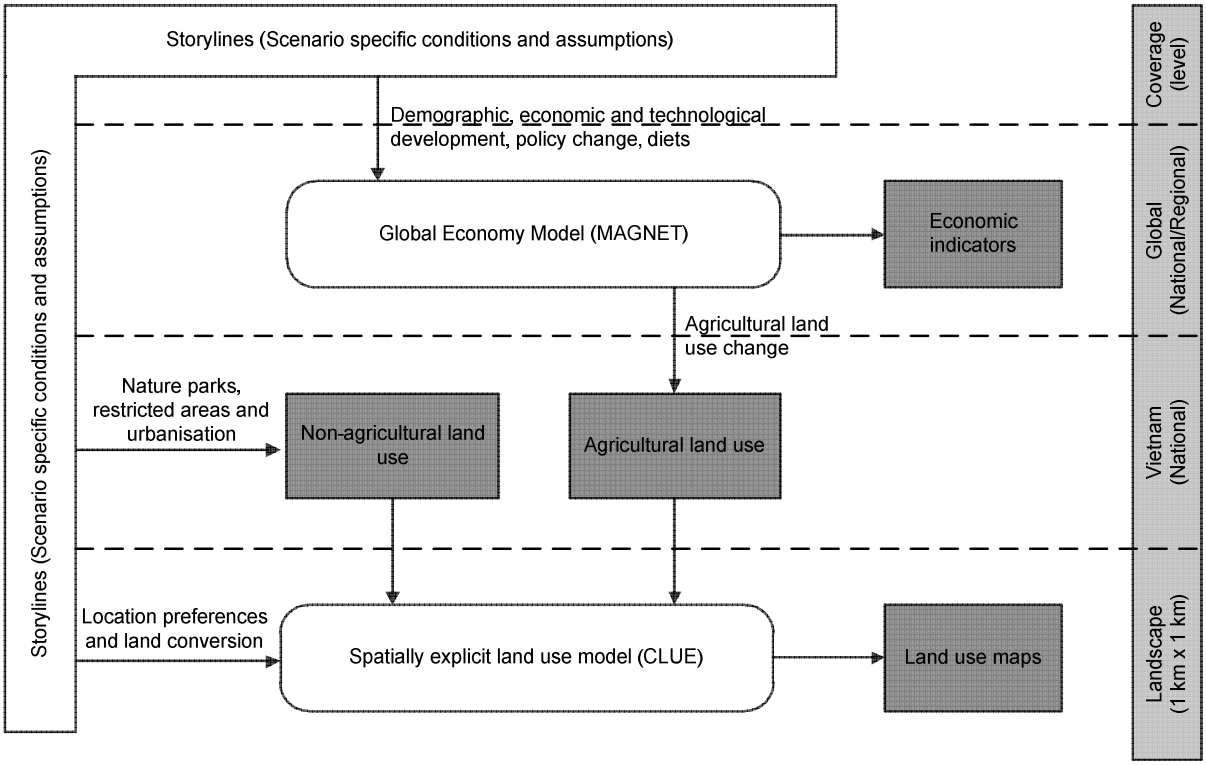
consuming (e.g. from pasture to commercial forest) and for yet others it might be impossible (e.g. from rock land to paddy rice). Information on growth of paddy rice, other agriculture and production forest land is taken from MAGNET, while change in land use for the other classes is set exogenously depending on the scenario and available information. CLUE also makes it possible to 'block' the conversion of certain areas (grid cells), which is useful to simulate land use policies that do not allow land use change in protected parks. Finally, the land conversion matrix, the suitability map and the future trajectories of the seven land use classes are all combined in CLUE in order to create land use maps for the period 2007-2030 for each scenario.

3. Scenarios

The MAGNET-CLUE model combination is put to use in a scenario analysis. The scenario analysis aims to quantify the impact of both global and national drivers and policies on land use in Vietnam up to 2030. Scenario analysis is commonly used in economic and environmental impact assessment studies which need to take into account the complex and uncertain interplay between economic, climatic, technological and political factors. In such a setting simple projections based on historic trends are of limited use. Scenarios are not equal to forecasts. Instead they are the product of storylines with a coherent set of assumptions that together describe potential but plausible futures. They are 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. The outcome of the model simulations are captured by changes in a number of indicators for each of the scenarios that summarises the findings and assesses the possible impacts. Indicators include macro-economic indicators of socio-economic drivers such as production, consumption, income, prices and trade for Vietnam and the rest of the world, as well as land use indicators that are able to capture physical land changes, visualised by land use maps. Figure 3.1 summarises the overall approach and the links between the models.

From the scenario workshop held in Hanoi two scenarios emerged. The first scenario to be implemented is, a High Climate Impact (HCI) scenario that reveals the consequences of climate change on Vietnam's economy and land use. The second scenario to be implemented is a High Economic Growth (HEG) scenario which implements the growth target incorporated in the Socio-Economic Development Strategy (SEDS) of Vietnam and yield targets from the Master Plan on Agriculture (MPA) that is linked to the SEDS. For both scenarios, the consequences for Vietnam's economy and national and local land use will be shown. Results will be presented relative to the baseline, 'Business as Usual' (BaU), scenario which reflects common expectations on how the (global) economy will develop with no new policies being implemented. Since the base year of MAGNET is 2007, the BaU scenario will be run for the period 2007-10 to project the model towards 2010, and then up to 2030 divided up into two periods of equal length, 2010-2020 and 2020-30. The outcomes of the alternative HCI and HEG scenarios can be compared with economic targets, and targets for land use and the agricultural and forestry sectors envisioned by Vietnamese official plans. Below follows a discussion of the assumptions underlying each of the scenarios.

Figure 3.1: Schematic representation of scenario setup and outcomes



3.1 Business as Usual (BaU) scenario assumptions

The BaU scenario reflects a future in which major socio-economic drivers follow current trends. It assumes that there are no major policy changes (e.g. WTO agreement, REDD, biofuels, etc.). Furthermore, yields will keep on increasing at the same pace as in the past. Climate change over the simulation period is assumed not have any significant impact on agricultural productivity and economic growth, and extreme weather events are not an issue.

3.1.1 Drivers of socio-economic change: MAGNET

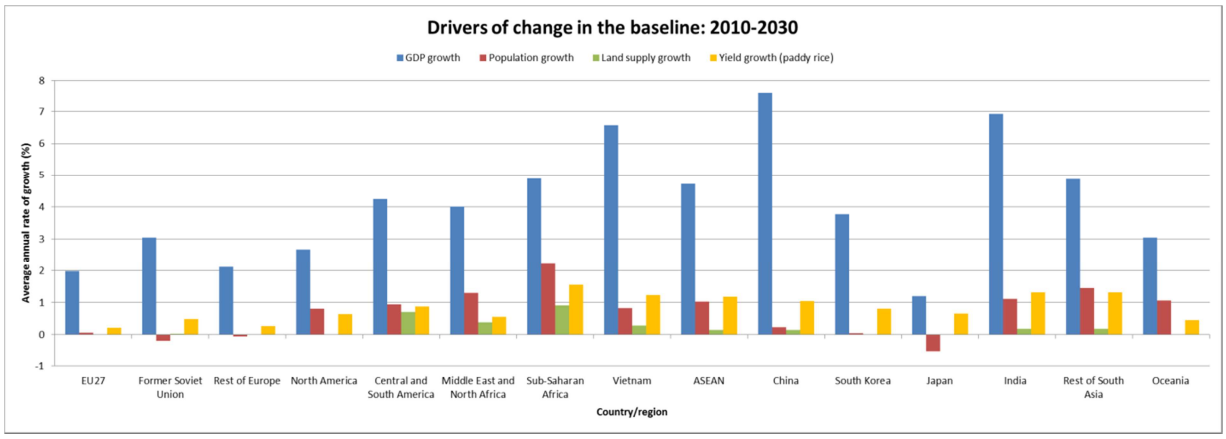
The BaU scenario in MAGNET is generated using information on the expected growth path of the economy (GDP) and endowments (capital, labour, land and natural resources) over time for all countries and/or regions in the world, and the productivity of these endowments, most notably that of land, i.e. yields. This information is then used to derive the implied technological change by region, which is subsequently fixed so as to endogenously generate the targeted GDP. The resulting BaU scenario forms the starting point of all further analyses. In generating the baseline in MAGNET, it is assumed that productivity in primary agriculture will grow twice as fast as in services and productivity in manufacturing will grow 2.65 as fast. This is consistent with more pessimistic views about the future of agricultural productivity as represented by predictions of stable or even rising real agricultural prices in the future. Technological progress is assumed to be labour saving.

MAGNET uses USDA's Economic Research Service projections for GDP and population for its BaU scenario.[16] Specifically, MAGNET assumes that labour supply follows the growth path for population and that capital growth equals growth in GDP. The latter assumption is consistent with the stylised fact of economic growth that the capital-output ratio is roughly constant over time. Growth of natural resources is linked to growth of capital with a factor of 0.25, i.e. natural resources grow at a quarter of the rate of capital. Land supply (to agriculture and commercial forestry combined) growth rates are

[16] Available from http://www.ers.usda.gov/data/macroeconomics/#BaselineMacroTables

obtained from the National Institute of Agricultural Planning and Projection (NIAPP) for Vietnam and from Willenbockel (2011) for the rest of the world. Land productivity (i.e. yield) projections are included from the Dutch Environmental Assessment Agency (PBL), drawn from its IMAGE (Integrated Model to Assess the Global Environment) model and based upon FAO projections up to 2030 (Bruinsma, 2003). The baseline assumptions are displayed in Figure 3.2, for the period 2010-2030.

Figure 3.2: Assumptions underlying the Business as Usual (BaU) scenario



Source: USDA (ERS): GDP and population; NIAPP (Vietnam) and Willenbockel (2011): land supply; Bruinsma (2003): yield growth. Note: changes in yields other than for paddy rice not shown but available from authors upon request

As shown, Vietnam is expected to realise high economic growth, averaging 6.6 per cent per year over the coming two decades, which is the third highest growth rate in the world after China (7.6 per cent) and India (6.9 per cent). Population numbers generally stabilise across the world, with the exception of Sub-Saharan Africa which realises a population growth of 2.2 per cent per year over the period 2010-2030. Over this period, Vietnam's population is growing at a rate of 0.8 per cent per year, lower than the rest of ASEAN, India and Rest of South Asia, but higher than in China (one child policy), Japan (which experiences negative population growth due to low birth rates and an ageing population) and South Korea (which experiences declining fertility rates, also due to encouragement by government in the past to only have only one child). Land available for use in agriculture and commercial forestry in Vietnam is growing at a rate of 0.3 per cent per year over the coming two decades. This is higher than the growth rate of land recorded elsewhere in the Southeast Asia region, and only lower than the Africa region (0.4 to 0.9 per cent) and Central and South America (0.7 per cent). The expected growth in agricultural land is based on historic trends which show a considerable expansion of plantation forest over the last two decades as well as an increase in perennial crop area. Growth in paddy rice yields for Vietnam is projected to be high, at a level of 1.2 per cent per year over the period 2010-2030, and in the same range of those of other countries in the region. Only Sub-Saharan Africa is expected to realise a higher growth rate in paddy rice yields (1.5 per cent per year over the period 2010-2030).

3.1.2 Assumptions on land use drivers: CLUE

For the spatial analysis with CLUE in the BaU scenario, land use projections for paddy rice, other agriculture and commercial forestry are taken from MAGNET. It is assumed that the expansion of agricultural and commercial/production forestry land will take place at the expense of shrub lands and non-production forest. According to expert information (NIAPP), the shrub land category includes fertile but unused grass land that is suitable for agricultural production. The growth of built up land change is derived from two types of urban population projections. Projections for urban population in

Vietnam are taken from the World Urbanisation Prospects (UNDESA, 2011) and is based on the proportion of the population living in urban areas. This is combined with projections on urban density (persons per m2). It is assumed that the land required for industrial areas, ports and military purposes grows proportionally to urban land.

3.2 High Climate Impact (HCI) scenario assumptions

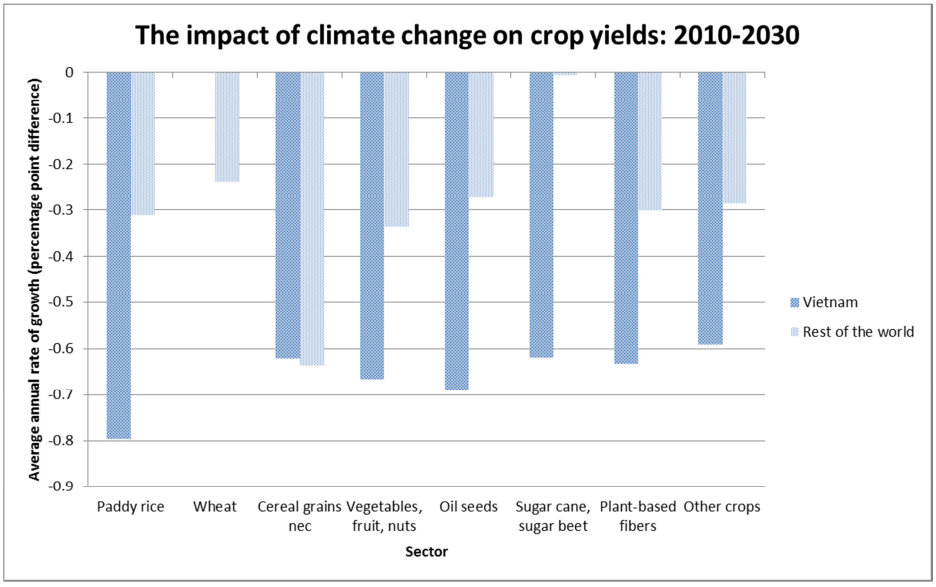
The HCI scenario reflects a future with rapid temperature change, high sensitivity of crops to global warming, and a CO2 fertilization effect at the lower end of published estimates. In Vietnam, extreme weather events will be more frequent resulting in flooding in the coastal areas and the Mekong Delta. Lower yields and flood risks pose a threat to agricultural production and food security, and are expected to have a negative impact on GDP growth.

3.2.1 Drivers of socio-economic change: MAGNET

Relative to the baseline, the yield growth assumptions will be scaled downwards, generating an new growth path for the Vietnamese economy, with a different land use pattern.

The impact of climate change on crop yield growth under the HCI scenario is shown in Figure 3.3. It shows that Vietnam is particularly negatively affected by climate change; with the exception of wheat (not grown) and other grains, yield growth is at least 0.3 percentage points (pp)[17] per year lower in Vietnam compared to the rest of the world.

Figure 3.3: HCI scenario - change in yields (in difference from BaU)



Source: Zhu (2010) for Vietnam, Hertel et al. (2010) for the rest of the world

3.2.2 Assumptions on land use drivers: CLUE

Assumptions on land use drivers for the HCI scenario are the same as in the BaU scenario.

3.3 High Economic Growth (HEG) scenario assumptions

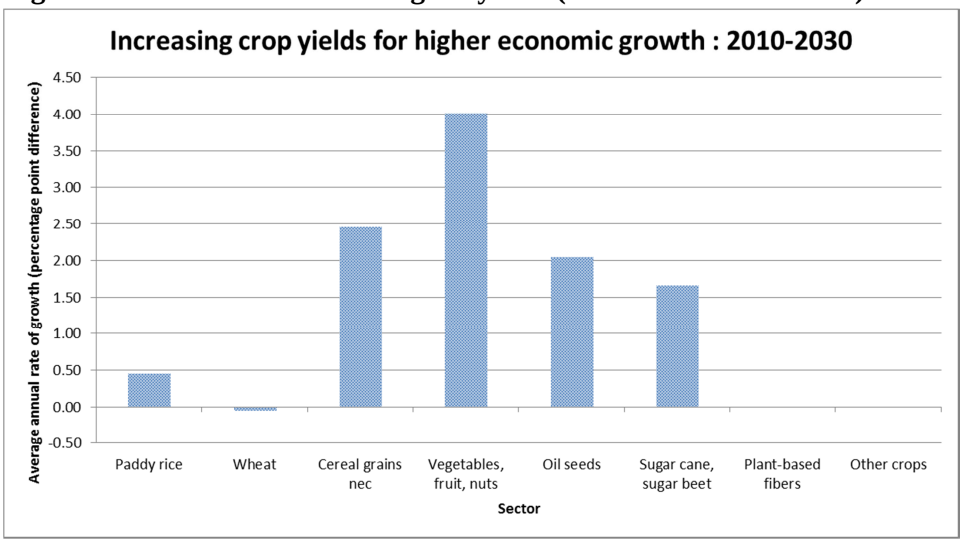
In the HEG scenario the Vietnamese economy is projected to grow at a higher pace, in line with Vietnamese official growth targets. A main driver of this growth is assumed to be growth in agricultural yields for which the projections also follow Vietnamese official targets, and technological change geared towards manufacturing, and to a lesser extent agriculture and services sectors. Climate change is assumed to be absent. The rest of the world is assumed to grow at the same pace.

[17] Defined as the arithmetic difference between two percentages.

3.2.1 Drivers of socio-economic change: MAGNET

Under this scenario the Vietnamese economy is assumed to obtain a higher growth path, of 8 per cent per year over the period 2010 to 2030. This is in line with the high end of the growth target of 7 to 8 per cent formulated in the Socio-Economic Development Strategy 2011-2020 (SEDS, 2010). With this high economic growth, the Vietnamese government aims to achieve a GDP per capita of 3000 US$ in 2020. Combining GDP figures under this scenario with population estimates from USDA's ERS reveals that this target will not be met in 2020 (GDP per capita is then expected to be around 1800 US$) but somewhere around 2028 assuming 8 per cent GDP growth. A main driver of the high economic growth is assumed to be growth in yields (Figure 3.4). Yield figures are taken from the Master Plan on Agriculture, prepared by NIAPP in 2011, that presents detailed land use planning for the period 2010-2020 in line with the SEDS. As shown, yields particularly grow faster in vegetables, fruit and nuts (4pp) additional growth per year relative to the baseline) and other grains (2.5pp extra growth per year), followed by oil seeds (2pp additional growth per year). The remainder of the higher growth is generated by technological change geared towards manufacturing and to a lesser extent agriculture and services sectors (in line with the distribution of total productivity growth over sectors in the baseline).

Figure 3.4: HEG scenario - change in yields (in difference from BaU): 2010-2030



Source: NIAPP (2011).

3.2.2 Assumptions on land use drivers: CLUE

As before, land use change for paddy rice, other agriculture and production forest is calculated by MAGNET. Similar to the BaU and the HCI scenario, built up land is a function of the number of people living in urban areas and urban density measured by the number of persons per km2. In line with the SEDS and related national land use plans (Van Chinh, 2011), it is assumed that 45 per cent of the total population is living in urban areas in 2020 and this reaches 55 per cent in 2030. In addition, as a consequence of a rise in welfare and the demand for larger houses and more space, urban density will be lower in the HEG than in the BaU. To fulfil the demand for agricultural and built up land, non-production forest, and shrub and grass land will be converted. To capture the higher pressure on land, it is assumed that nature reserves and protected zones are no longer shielded off from land conversion and can be used for productive purposes or settlements.

4. Results

We start each sub-section with a story line describing the main outcomes of each of the scenarios, followed by an analysis of socio-economic impacts (resulting from MAGNET) and land use impacts (resulting from CLUE).

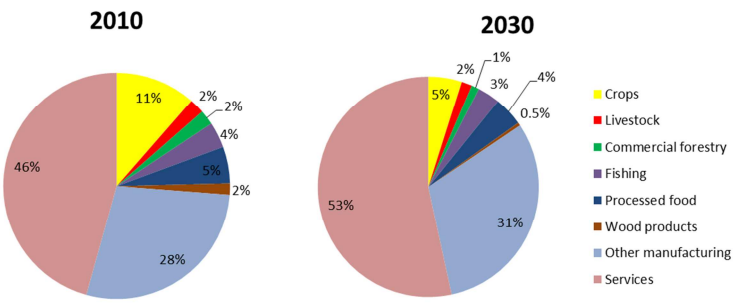
4.1 Baseline (BaU) scenario results

Vietnam increasingly becomes a service and manufacturing-orientated economy, at the cost of agriculture and commercial forestry. Especially the paddy rice sector is slowing down, growing only marginally over the coming two decades. The lumber industry that produces wood products mostly for exports is the only sector in Vietnam that contracts. It suffers mostly from increased prices for forestry inputs and, to a lesser extent, rising industrial wages, due to which it becomes less competitive compared to the rest of the world. The price rise for commercial forestry can largely be explained by increasing land prices in Vietnam, which are occurring even more so globally and signify increased pressures for land. Land use by commercial forestry and livestock sectors increases and declines for crop sectors, with land moving out of paddy rice and vegetables and fruit sectors. The land price rises more so for commercial forestry than for crops and also livestock, not only because the commercial forestry (and livestock) sectors are growing faster than crops, but also since it is more difficult to transfer land from agriculture to commercial forestry than it is from crops to livestock. Overall food security in Vietnam improves, both from domestic and imported sources. The Vietnamese consumption pattern changes, however, with a rising importance of fish, vegetable oils and fats and other food, beverage and tobacco products, at a cost of processed rice and vegetables, fruit and nuts. Trade in manufacturing and services continues to rise in prominence and display increasing trends over time. Despite the declining importance of the paddy rice sector in Vietnam's economy, Vietnam continues to be one of the main exporters of rice in the world, with exports of processed rice increasing substantially over the coming two decades, thereby contributing to global food security and notably that of Sub Saharan Africa.

4.1.1 Socio-economic impacts

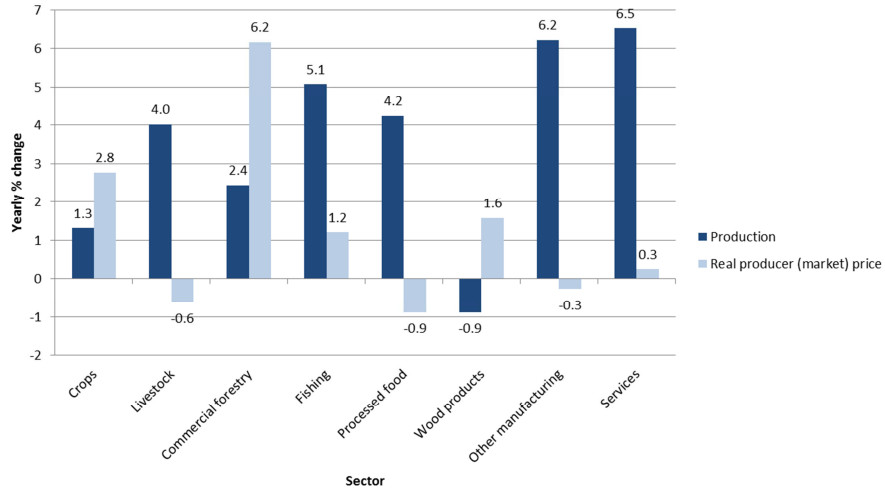
In the BaU scenario, the structure of the Vietnamese economy changes into one more dominated by services (value added share of over 50 per cent in 2030) and manufacturing, away from agriculture, and most notably crops (Figure 4.1). Within crops (not shown), most of the fall of the value added share can be attributed to the paddy rice sector (falls from 4.3 per cent to 1.6 per cent) and vegetables, fruit and nuts (falls from 3.7 per cent to 1.7 per cent). Commercial forestry sector becomes less important (value added share falls from 2.1 per cent to 1.1 per cent) as does its most important client, the lumber industry producing wood products (value added share falls from 1.6 per cent to 0.5 per cent).

Figure 4.1: Value added generated in Vietnam by broad economic sector (BaU)



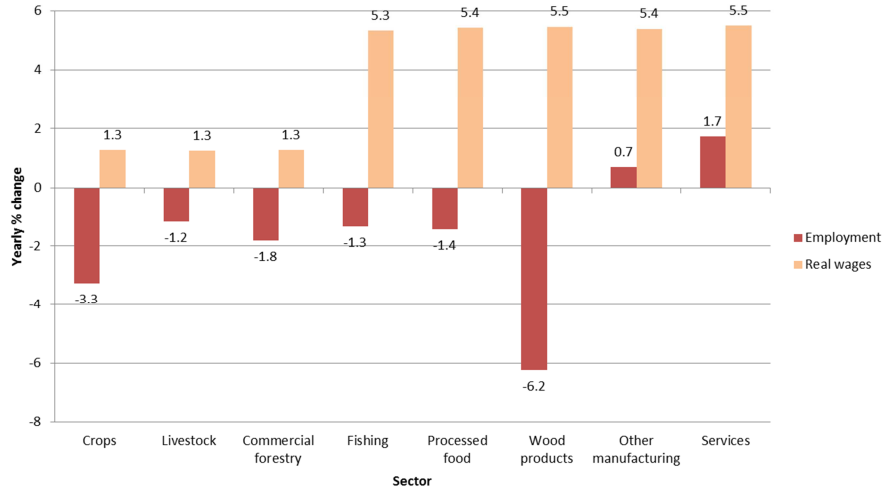
Underlying the changes in the economy are differential growth rates across economic sectors. Notably, the economic growth that Vietnam records over the period 2010-2030 primarily takes place in services and other manufacturing, experiencing annual growth rates of over 6 per cent (Figure 4.2). Other sectors also expand but with lower growth rates. Considering the land using sectors, crop sectors still grow by 1.3 per cent per year, livestock sectors by 4 per cent per year and commercial forestry by 2.4 per cent per year. Within crops (not shown), especially the paddy rice sector is slowing down, recording a growth of only 0.5 per cent over the period 2010-2030. The only contracting sector is the lumber industry producing wood products, which also experiences a (real) producer price increase of 1.6 per cent per year.

Figure 4.2: Changes in production and prices in Vietnam: 2010-2030 (BaU)



The lumber industry is different from other sectors in that most of its output (93 per cent in the base year) is destined for the export market, and most of consumer demand for its wood products (82 per cent in the base year) is satisfied by imports. Compared to the rest of the world this sector becomes less competitive (globally, the real producer price for wood products even falls slightly) and so produces and exports less, whilst the increased consumer demand is satisfied by imports. The lumber industry is also different from other manufacturing sectors in that it has strong linkages with the commercial forestry sector; using base year data approximately 91 per cent of commercial forestry output is destined for the domestic market, and most of this (99 per cent) for producers, of which 75 per cent goes to the lumber industry as intermediate input. These forestry inputs account for approximately 40 per cent of the cost of one unit of output of the lumber industry. As shown, the commercial forestry sector expands and also records the highest price increase (growth rate of around 6 per cent per year over 2010-2030), followed by crops (around 3 per cent increase per year in the producer price). This provides the most important part of the explanation for the producer price increase for wood products. Given that, as a consequence, intermediate demand by the lumber industry is falling, the rise in commercial forestry output is destined primarily for exports (albeit small) and domestic producers other than the lumber industry. Compared to the rest of the world, the commercial forestry producer price increase in Vietnam is below average (the global average being a 6.7 per cent increase per year) so that Vietnam's forestry sector is becoming more competitive relative to the rest of the world. The observed changes in Vietnamese producer prices, including that of the commercial forestry sector, are likely to have their origin in factor markets. Two markets that are of importance are the labour market and the market for land.

Figure 4.3: Changes in employment and wages in Vietnam: 2010-2030 (BaU)



The increased service and industry orientation of Vietnam generates employment in services and to a lesser extent manufacturing at a cost of other sectors, most notably wood products and crops, with employment falling by 6.2 per cent and 3.3 per cent per year (Figure 4.3). Segmentation between agricultural and non-agricultural labour markets causes (real) wages in crops, livestock and forestry sectors to lag behind (increase of 1.3 per cent per year, compared to 5.5 per cent per year in non-agriculture). The real wage rises explain part of the rise in the (real) producer prices. For commercial forestry (and crops), the explanation is also likely to be found in the land market.

Figure 4.4: Changes in land use and land prices Vietnam: 2010-2030 (BaU)

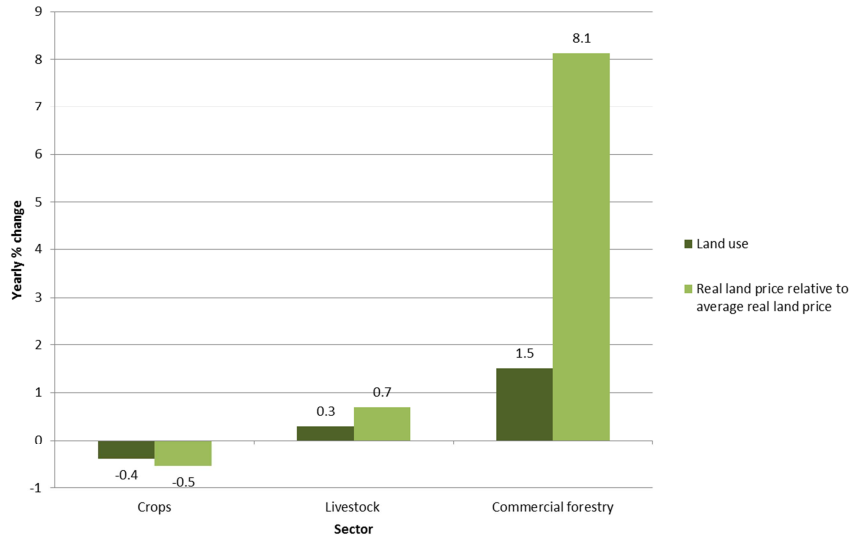
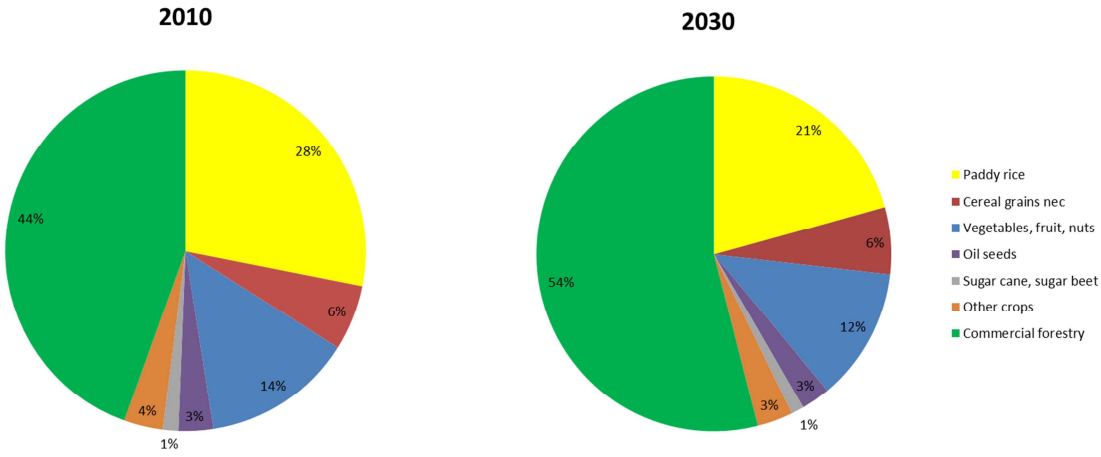


Figure 4.4 displays the change in land use and the (real) relative land price over 2010-2030 for the baseline. Real land prices, which represent the real value of one extra unit of land, are very small in the base year, so we've scaled the prices with the average real land price (the average real price of all land in Vietnam used in agriculture and commercial forestry, which goes up by 8.3 per cent over the period 2010-2030). The graph shows that the relative land price in commercial forestry goes up by a lot (8.1 per cent per year over the period 2010-2030) in response to its increased demand for land (1.5 per cent per year), followed by a small increase in the relative land price for livestock following its small increase in demand for land (0.3 per cent per year), whereas the relative land price in crops actually falls as does its demand for land (though in absolute terms the real land price in crops will still be increasing). The overall increased demand for land from the agricultural and commercial forestry

sectors in Vietnam (0.5 per cent per year on average) leads to upward pressure on the land price and more so for commercial forestry compared to livestock and crops, not only because the commercial forestry and livestock sectors are growing faster, but also since it is more difficult to transfer land from agriculture to commercial forestry then it is from crops to livestock.

Figure 4.5: Land use in Vietnam by agricultural and commercial forestry sectors (BaU)



Note: small data points (with a share < 1%) have been removed

The observed changes in land use lead to a different allocation of land across sectors. Notably, the share of land used by the commercial forestry sector increases at a cost of land used by paddy rice and vegetables, fruit and nuts (Figure 4.5).

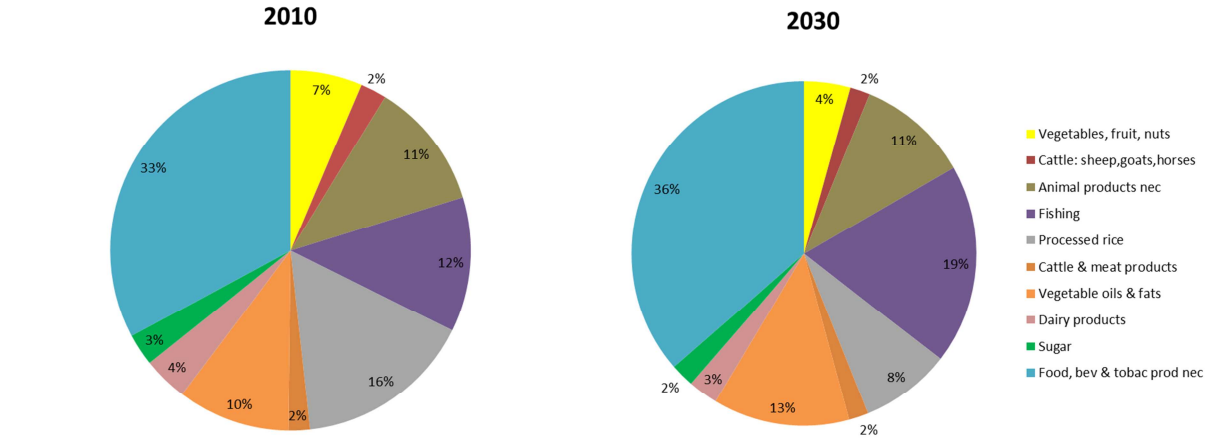
Overall food security, measured in terms of the change in the Vietnamese consumption of food items (weighted by their expenditure shares in the base year), improves by approximately 4 per cent per year, both from domestic and imported sources. The average food price, the composite of the consumer (market) prices of all food items consumed (again weighted by their shares in the base year), in Vietnam falls slightly by 0.8 per cent per year over the period 2010-2030. As shown in Figure 4.6, The Vietnamese consumption pattern does however change, with a rising importance of fish (from 12 per cent of the consumption basket in 2010 to 19 per cent in 2030), vegetable oils and fats (from 10 to 13 per cent) and other food, beverage and tobacco products (from 33 per cent to 36 per cent), at a cost of processed rice (share falls from 16 per cent to 8 per cent) and vegetables, fruit and nuts (from 7 per cent to 4 per cent).

Figure 4.7 displays the changes occurring in Vietnamese trade in terms of exports, imports and the value of the trade balance. As shown, most trade continues to take place in other manufacturing (accounting for 75 to 80 per cent of trade in 2030) and services (7-10 per cent of trade in 2030), with trade in both rising over time. With respect to the other traded commodities, trade is generally improving, with the exception of vegetables, fruit and nuts (decline in exports of close to 2 per cent per year) and wood products from the lumber industry experiencing a fall in exports of 1.5 per cent per year and a rise in imports of around 5 per cent per year due to decreased competitiveness relative to cheaper foreign wood products. Most of the increase in imports of wood products is coming from China, which doubles its share in Vietnamese lumber imports from 25 per cent in 2010 to 50 per cent in 2030, partly substituting for imports from the second most popular source of imports, rest of ASEAN (declining share in Vietnamese lumber imports from 42 per cent in 2010 to 14 per cent in 2030). The fall in exports of wood products is especially borne by the two most important export

destinations, EU27 and North America, accounting for 30 per cent and 40 per cent of Vietnamese exports in 2010, and with both shares falling by 5 percentage points up to 2030. China's share in Vietnamese lumber exports as with imports almost doubles (from 6 to 11 per cent).

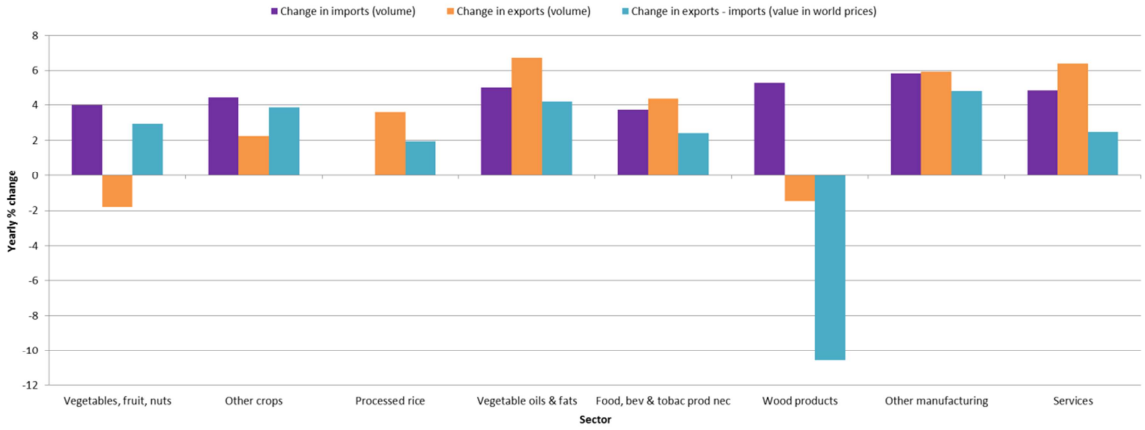
Finally, despite the declining importance of the paddy rice sector in Vietnam's economy, Vietnam continues to be one of the main exporters of rice in the world, with exports of processed rice increasing by close to 4 per cent per year over the coming two decades (Figure 4.7). Vietnam thereby contributes to global food security and notably that of Sub Saharan Africa, which sees its imports of processed rice from Vietnam increase by around 6 per cent per year over the period 2010-2030. Global food security, or the consumption of food, improves by 1.5 per cent per year over the period 2010-2030, with global food consumption prices slightly falling (by 0.1 per cent per year over the period 2010-2030).

Figure 4.6: Vietnamese food consumption pattern (BaU)



Note: small data points (with a share < 1%) have been removed

Figure 4.7: Changes in the Vietnamese trade pattern: 2010-2030 (BaU)



Note: categories with trade shares < 1% have been removed

4.1.2 Local land use impacts

In the BaU scenario, as well as in the other scenarios, the production forest area shows the biggest absolute increase of all land uses, from 22 per cent of the total land area in 2007 to 31 per cent in 2030 (Appendix A3; Figures A3.1 to A3.3) equivalent to a growth rate of 37%. This goes mostly at a cost of non-production forest (share falls from 12 to 10 per cent), paddy rice area (share falls from 16 to 12 per cent) and bare and shrub land areas (share falls from 17 to 14 per cent).

Figure 4.8b, left- and right-hand side panel, shows respectively the aggregated FIPI land use map for 2007 and 2030 according the BAU. By comparing the two maps, a good impression can be obtained of the spatial distribution change over time. Again, the increase of the light green production forest area is mostly at the cost of non-production forest and bare and shrub land areas.

In order to produce the BaU map of 2030, the protected areas were not excluded from land use change. According to the land use conversion matrix, new production forest can only be created in non-production forest areas, extensive agriculture and from bare and shrub land. Paddy land, urban and other land cannot be converted into production forest. The areas with the highest probability for production forest, paddy rice and other areas are shown in the Appendix A3 (Figure A3.4). Finally the elasticity for production forest was set at a value of 0.5 which means that production forests are considered to have a moderate conversion cost and have a slight preference to be located adjacent to areas where it already grows.

The increase of built up or urban area in the BaU scenario (Figure 4.8b) is 2 per cent for the whole of Vietnam and is the highest in the Red River Delta region (Figure 4.8a), followed by the northern part of the North Central Coast and in the Central Highlands. Built up areas are set with a high elasticity (value of one), implying a high conversion cost. This means that in CLUE new built up areas are only allocated adjacent to areas that are already under built up in 2007. The upper right probability map of Figure A3.4 in Appendix A3 shows a high probability for built up in the Red River Delta area.

Figure 4.8a: Land use pattern in the Red River Delta in the BaU Scenario

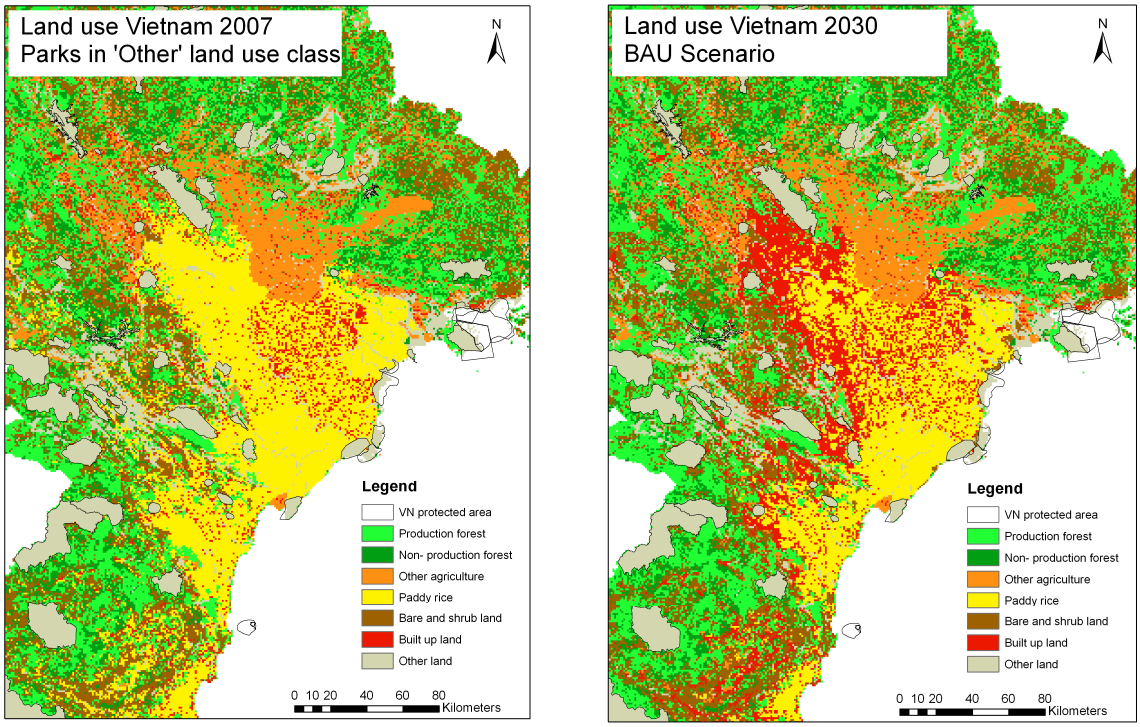
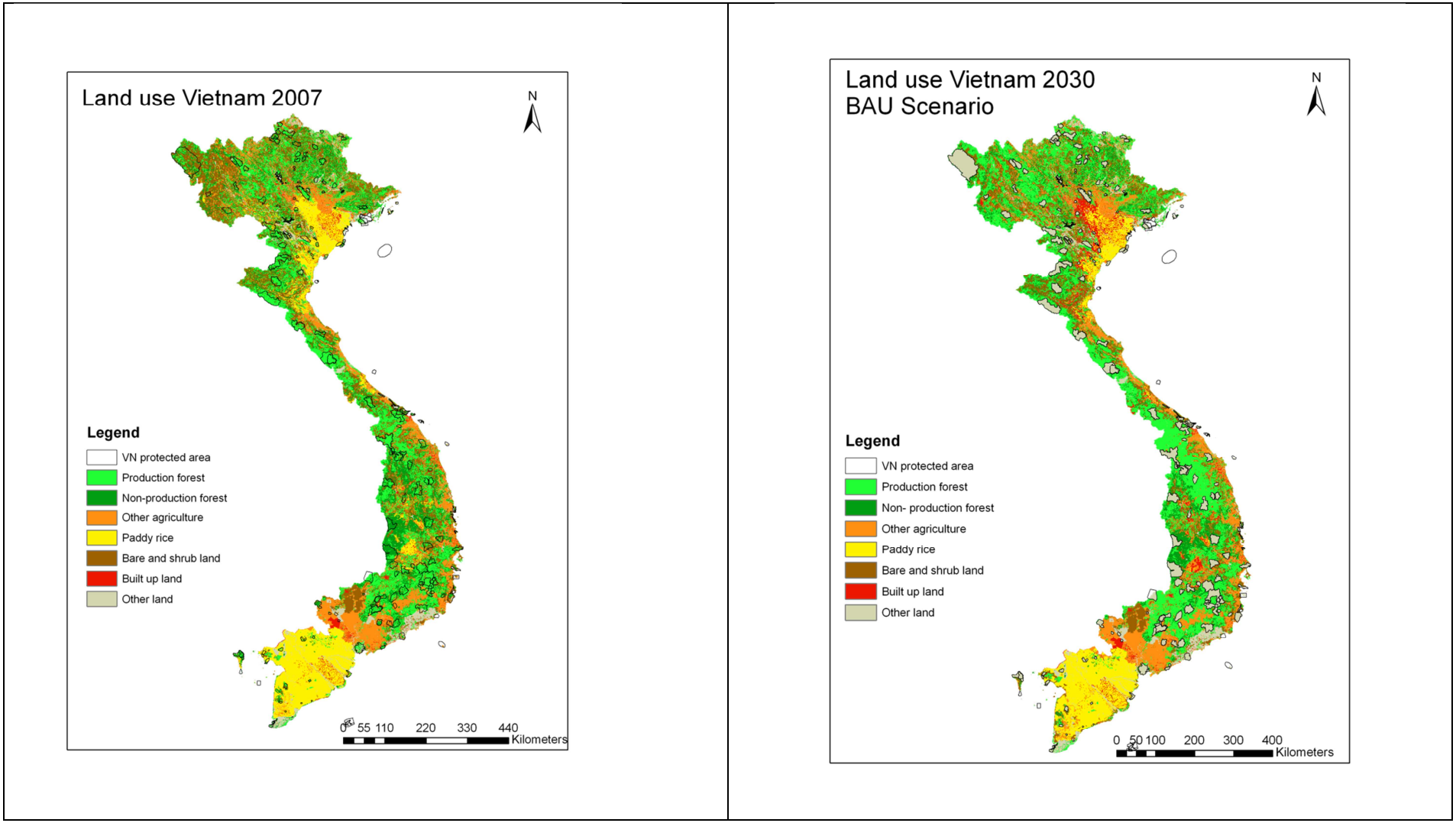


Figure 4.8b: Land use pattern in Vietnam in the BaU Scenario



4.2 High Climate Impact (HCI) scenario results

Climate change slows down the Vietnamese economy. Whereas the structure of the economy roughly remains the same, impacts are felt at the sectoral level, where the fall in crop yields lowers production of crop sectors (notably paddy rice and vegetables, fruit and nuts) and increases their unit costs. The latter is primarily due to increased demand for land by crops, at a cost of livestock and forestry, which puts upward pressure on the price of land. This causes livestock and commercial forestry also to contract and has negative knock-on effects on industries of processed food and wood products. Employment falls in all sectors, apart from services and commercial forestry, which lowers wages, but this is generally not sufficient to counteract the rise in costs from rising land prices. Overall food security falls in Vietnam, but generally with substitution towards imported commodities away from domestic commodities as it is cheaper to consume certain products from abroad. Exceptions are fish and vegetable oils and fats that actually become cheaper in Vietnam, with consumption of fish rising. In terms of trade, the lumber industry becomes less competitive and less is exported of Vietnamese processed rice, including to Sub-Saharan Africa. Across the globe, climate change is worsening food security.

4.2.1 Socio-economic impacts

Due to climate change the Vietnamese economy is slowing down by 0.2pp (percentage points) per year over the period 2010-2030, from a growth rate of 6.6 per cent per year in the BaU scenario to a growth rate of 6.4 per cent per year on average in the HCI scenario. This is equivalent to a fall in growth of 11 pp in total over the period 2010-2030.

Climate change has little impact on the structure of the economy (Figure 4.9), with value added shares of the broad economic sectors staying roughly constant. The share of crops falls slightly (by 0.6pp), mostly accounted for by paddy rice (0.2pp) and vegetables, fruit and nuts (0.2pp), whereas that of other manufacturing and notably services increases (by 0.1pp and 1.2pp respectively).

Changes are however visible at the sub-sectoral level, with production of all primary sectors, fishing, processed food and wood products sectors falling and their prices mostly rising (Figure 4.10). Within crops, paddy rice and vegetables and fruit sectors contract by 0.7pp with (real) producer prices rising by about 2.7pp in addition to the baseline. The lumber industry producing wood products is most affected by climate change in terms of production and experiences a fall in production of 2.6pp per year in addition to the 0.9 per cent per year contraction in the BaU scenario. This highly traded sector becomes less competitive compared to the rest of the world and so produces and exports less. Part of the explanation comes from the commercial forestry sector which sees its (real) producer price increase by 1.3pp per year in addition to the BaU scenario. The crops sector records the biggest (real) price increase of 2.7pp per year in addition to the BaU increase of 2.8pp per year. This is due to the fall in yields caused by climate change.

The observed changes in Vietnamese producer prices have their origin in factor markets. In line with sectoral developments, employment in primary sectors, fishing, processed food and especially wood products falls (by 2.5pp per year in addition to the BaU), whereas employment in services (and commercial forestry) rises slightly (Figure 4.11). This leads to downward pressure on (real) wages, in the range of 0.6pp to 0.7pp per year compared to the BaU scenario.

Considering the land market (Figure 4.12), land use is increasing in crops relative to the BaU scenario, as crop yields have dropped due to climate change, at a cost of livestock and commercial forestry. The average (real) land price of all land used in Vietnam is going up by 10.5 per cent per year in the HCI scenario, 2.2pp higher than in the BaU scenario, and this is especially due to the rise in the price for

crop land (which increases by 10.1 per cent per year, 2.4pp higher than in the BaU scenario). Land prices in livestock and commercial forestry also grow faster than in the BaU scenario (1.6pp and 1.5pp per year respectively), but less so compared to crops so that, relative to the average land price, land prices in these sectors fall compared to the BaU scenario (Figure 4.12). The absolute real land price increases recorded in all land using sectors are to a large extent responsible for the producer price increases in the primary sectors, with knock-on effects on processing industries (processed food, lumber industry).

The observed changes in land use, however, have little impact on the allocation of land across sectors (Figure 4.13). As a share of total land available in 2030, only slightly more is allocated to crops (most notably 0.5pp to paddy rice, 0.3pp to other grains and 0.2pp to vegetables, fruit and nuts), at a cost of commercial forestry.

Overall food security in Vietnam falls by approximately 0.2pp per year compared to the BaU scenario due to an increasing food (market) price of on average 1pp per year, but with a bigger fall in domestic consumption compared to consumption from imports. Due to domestic price rises it actually becomes cheaper to consume certain food products from abroad. Exceptions are fish and vegetable oils and fats, which actually become cheaper in Vietnam relative to the rest of the world. Fish consumption improves, whereas in total vegetable oils and fats consumption still falls. These changes in the Vietnamese consumption pattern have little impact on the composition of the consumption basket (Figure 4.14). As a share of total food consumption in 2030, only slightly more (1pp) is consumed of the fish sector.

In terms of trade (Figure 4.15), exports of wood products decline, whereas imports rise due to its decreased competitiveness. The Vietnamese commercial forestry's trade (albeit small) improves despite the fact that this sector is contracting and experiences a price increase, as the price increase on the world market is slightly higher (0.8pp per year over the period 2010-2030) compared to the BaU and so it is becoming more competitive viz-a-viz the rest of the world. The processed rice sector, following the paddy rice sector, contracts and experiences higher unit costs and prices, and so exports less and imports more. Within imports of processed rice there is substitution away from China and India towards other rice exporting countries. Exports of processed rice to Sub Saharan Africa fall by almost 2pp per year over the period 2010-2030 compared to the BaU scenario. Generally, climate change is detrimental for global food security, which deteriorates by close to 0.25pp per year over the period 2010-2030 compared to the BaU, with global food consumption prices rising by 1.4pp.

Figure 4.9: The structure of Vietnam's economy in 2030 under different scenarios

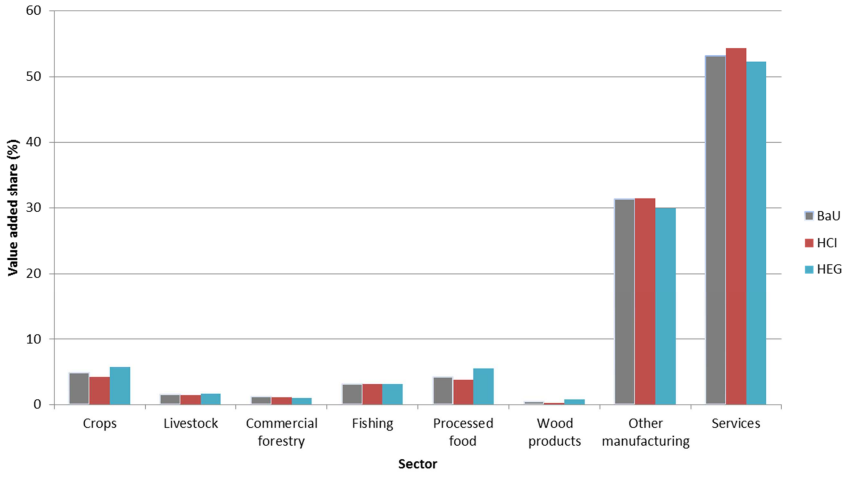


Figure 4.10: Changes in production and prices in Vietnam under different scenarios, relative to the BaU: 2010-2030

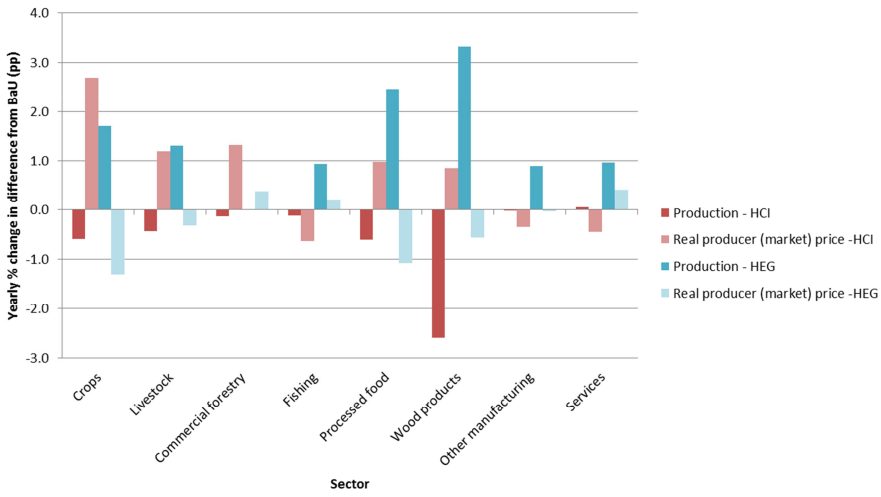


Figure 4.11: Changes in employment and wages in Vietnam under different scenarios, relative to the BaU: 2010-2030

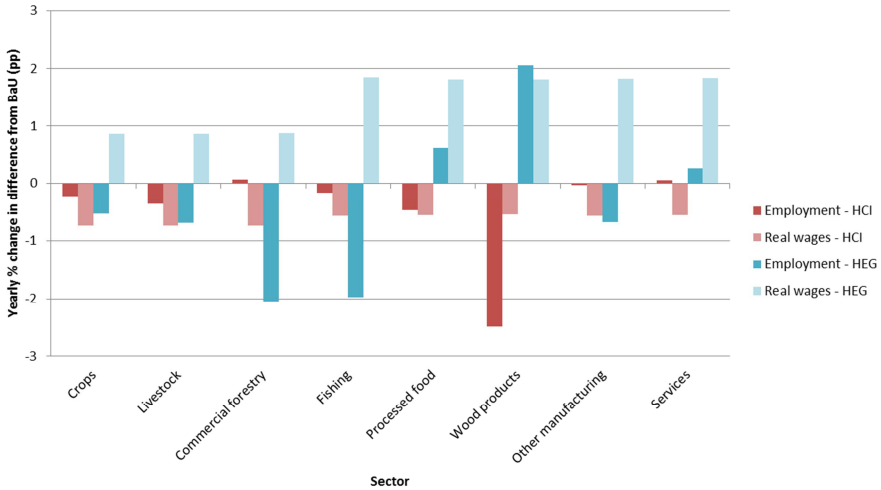


Figure 4.12: Changes in land use and prices in Vietnam under different scenarios, relative to the BaU: 2010-2030

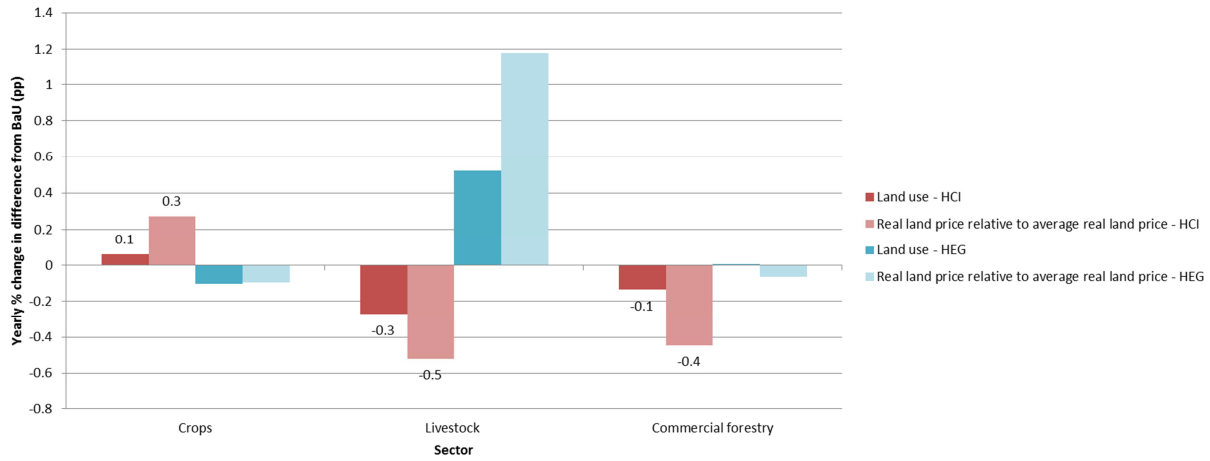
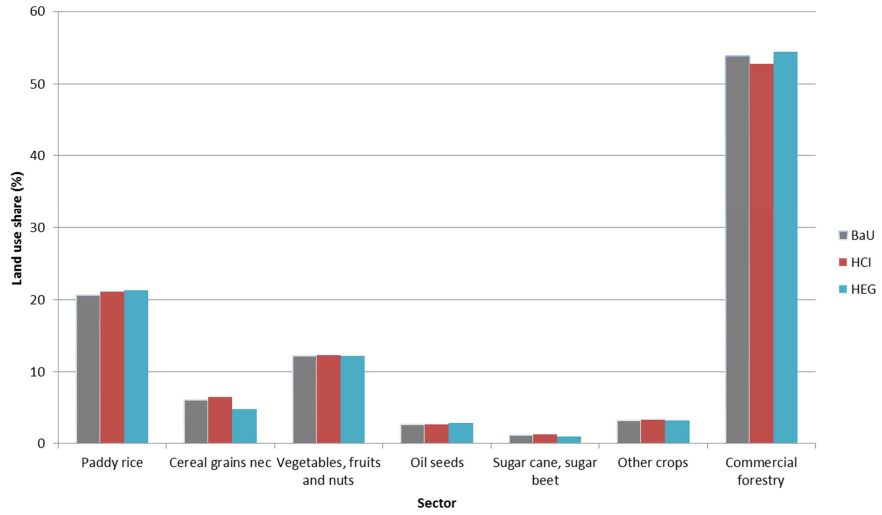
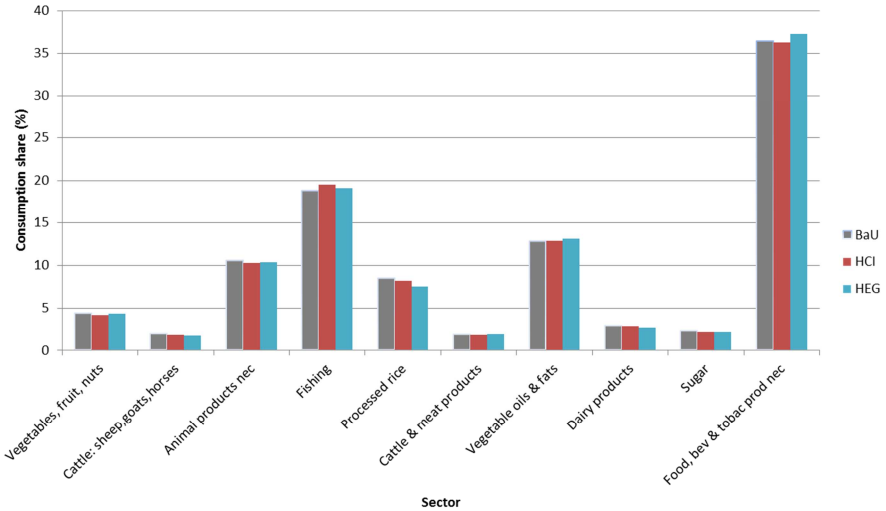


Figure 4.13 Land use pattern in Vietnam in 2030 under different scenarios



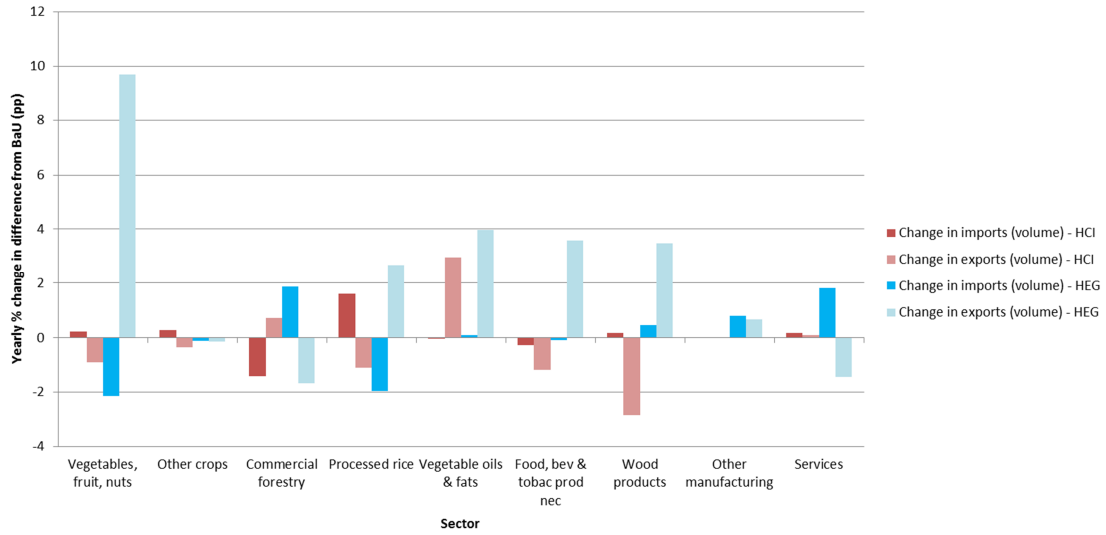
Note: small data points (with a share < 1%) have been removed

Figure 4.14 Vietnamese food consumption pattern in 2030 under different scenarios



Note: small data points (with a share < 1%) have been removed

Figure 4.15: Changes in imports and exports of Vietnam under different scenarios, relative to the BaU: 2010-2030



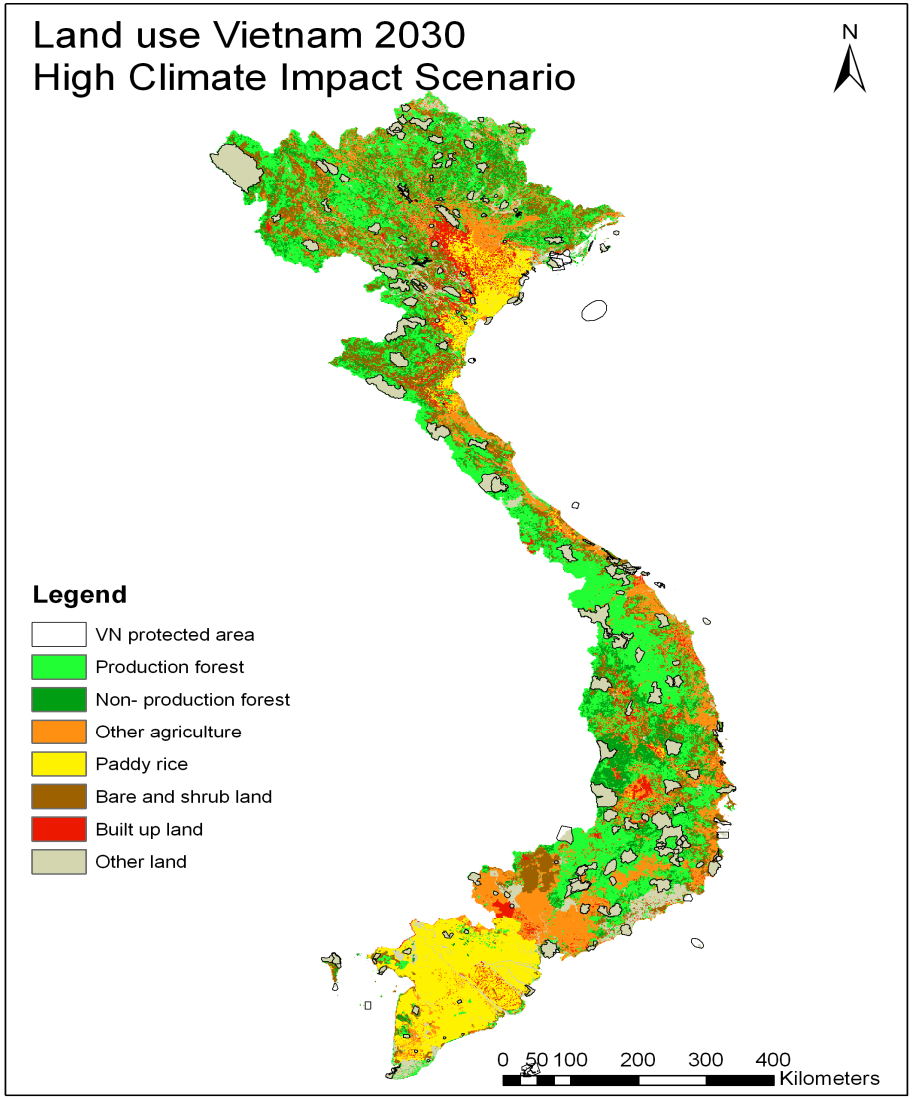
Note: categories with trade shares < 1% have been removed

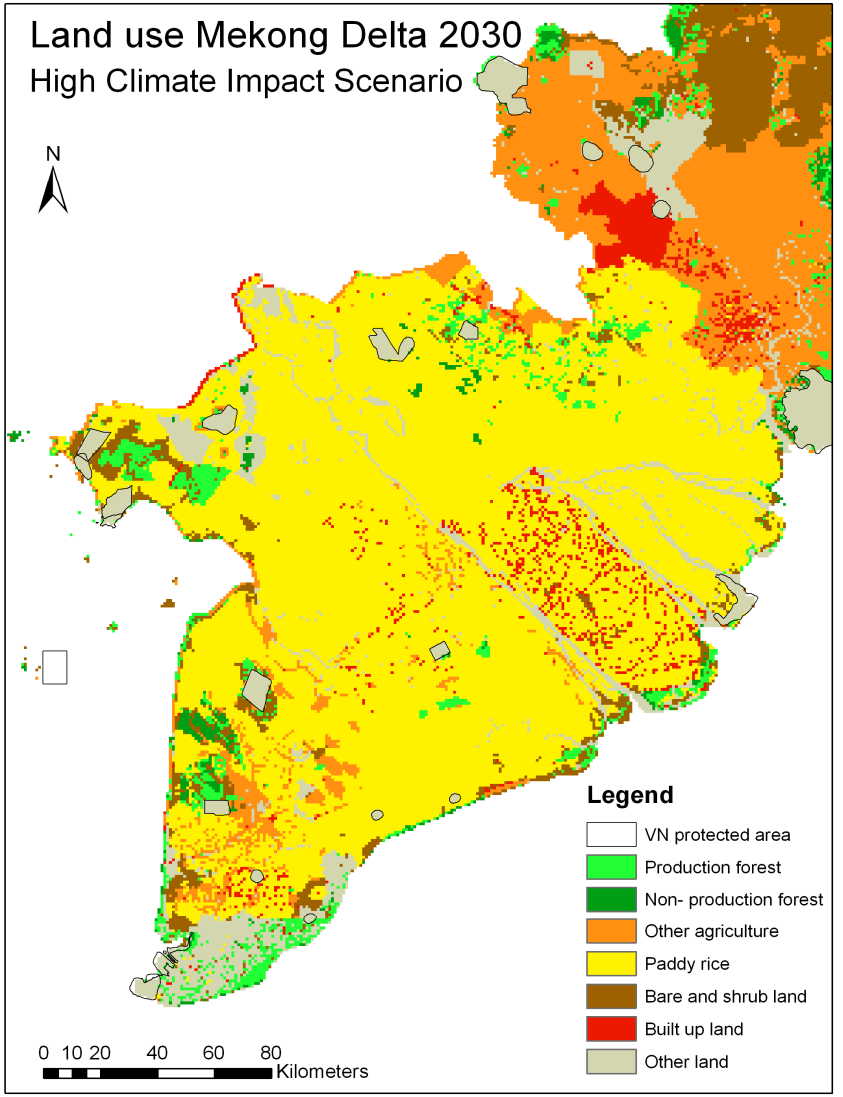
4.2.2 Local land use impacts

In the HCI scenario, the production forest area, as in the BaU scenario, shows the biggest absolute increase of all land uses, equivalent to a growth rate of 34 per cent, lower than in the BaU and so resulting in a slightly lower share in total land of 30 per cent in 2030 compared to 31 per cent in the BaU scenario (Appendix A3; Figures A3.1 to A3.3).

The land use map for 2030 in the HCI scenario is shown in Figure 4.16, which is roughly similar to the land use map for 2030 in the BaU scenario. In the more detailed map of the Mekong Delta area it can be seen that this area has changed remarkably little compared to the land use situation in 2007. Some of the extensive agriculture in this area is converted to paddy rice, but compared to the Red River Delta there is much less urban development. In the Red River area, part of the paddy is converted to urban land use, mainly in the western part of the paddy area.

Figure 4.16: Land use pattern in Vietnam and Mekong Delta in 2030 in the High Climate Impact Scenario





4.3 High Economic Growth (HEG) scenario results

Rising crop yields and higher technical progress bring Vietnam onto a higher growth path. As a result, the structure of the economy changes in favour of crops (vegetables, fruit and nuts), and the processing food and lumber industry, at a cost of manufacturing and services. All sectors expand in size nevertheless and producer prices fall, except for commercial forestry, fishing and services. The fast expanding lumber and food processing industries and services draw in labour at a cost of employment elsewhere. Market segmentation causes wages to rise faster in industry and services compared to agriculture. Land used by crop sectors (most notably vegetables, fruit and nuts) falls due to high yield growth to the benefit of mostly livestock sectors. Overall food security in Vietnam improves as domestic food has become cheaper. Especially more is consumed of cattle meat, fish, vegetable oils and fats, other food products and beverages, and vegetables, fruit and nuts. Consumption of processed rice becomes less important, whereas consumption of other food products and beverages becomes relatively more important. Almost all sectors become more competitive and export more and import less, notably vegetables, fruit and nuts. Processed rice exports rise to the benefit of Sub Saharan Africa and global food security, which slightly improves.

4.2.1 Socio-economic impacts

Due to higher growth in crop yields in the HEG scenario, the crop sector is becoming visibly larger, accounting for a share in the economy of 5.8 per cent in 2030 compared to a share of 4.9 per cent in 2030 in the BaU scenario (Figure 4.9). Within crops, the vegetables, fruit and nuts sector is especially growing with a 1.2pp higher share in 2030 compared to the BaU. This benefits processed food industry, which increases its value added share to 5.6 per cent in 2030 compared to 4.3 per cent in the BaU scenario), but goes at a cost of other manufacturing and services.

The production pattern that emerges from this scenario is quite different from the baseline and climate change scenario (Figure 4.10). All sectors expand in size, most notably wood products (by 3.3pp per year in addition to the BaU), and the processed food industry (by 2.5pp in addition to the BaU), with (real) producer prices falling everywhere compared to the BaU scenario, except for commercial forestry, fishing and services, which experience small producer price increases.

Employment is affected very differently across economic sectors (Figure 4.11). The expanding lumber industry, processed food and services sectors draw in labour, at a cost of other sectors, most notably commercial forestry and fishing sectors, but also crops, livestock and other manufacturing. Given that the latter sectors increase production there is substitution away from labour into other factors of production, including land for land using sectors (discussed below), but also capital and natural resources (not shown). Due to market segmentation the observed labour market developments drives up (real) wages by close to 2pp per year in industry and service sectors, and close to 1pp per year in agricultural sectors, in addition to the BaU scenario.

Land used by crop sectors falls and most of that in vegetables, fruit and nuts due to its high yield growth (Figure 4.12). This benefits livestock sectors which increase land use by 0.5pp per year in addition to the BaU scenario, with land use by commercial forestry also increasing slightly. This causes the average (real) land price in Vietnam to rise only slightly, by 0.5pp per year in addition to the BaU scenario. As a share of total land used, the land allocation across sectors remains fairly constant (Figure 4.13), with only the share of other grains falling and that of commercial forestry slightly rising (by 0.5pp in addition to the BaU scenario).

Overall food security in Vietnam improves by approximately 0.7pp per year compared to the BaU scenario due to a falling food (market) price by approximately the same amount, with substitution away from imported goods to domestic goods since domestic food products have become cheaper. Consumption increases especially for cattle meat, fish, vegetable oils and fats, other food products (all by about 0.8pp per year in addition to the BaU scenario), and vegetables, fruit and nuts (by 0.6pp per year in addition to the BaU scenario). This leads to small changes in the Vietnamese consumption pattern (Figure 4.14). Specifically, as a share of total food consumption in 2030, less is consumed of processed rice (1pp difference with BaU scenario), to the benefit of other food products, beverages and tobacco.

Finally, in the area of trade, almost all sectors become more competitive and export more and import less, most notably vegetables, fruit and nuts which exports almost 10pp per year more in addition to the BaU scenario over the period 2010-2030 due to its yield rise. Exceptions are the commercial forestry sector and the services sector that import more and export less. Processed rice exports rise by 2.6pp per year in addition to the BaU scenario, also due to higher yields (and lower costs), to the benefit of Sub Saharan Africa and global food security which slightly improves.

4.2.3 Local land use impacts

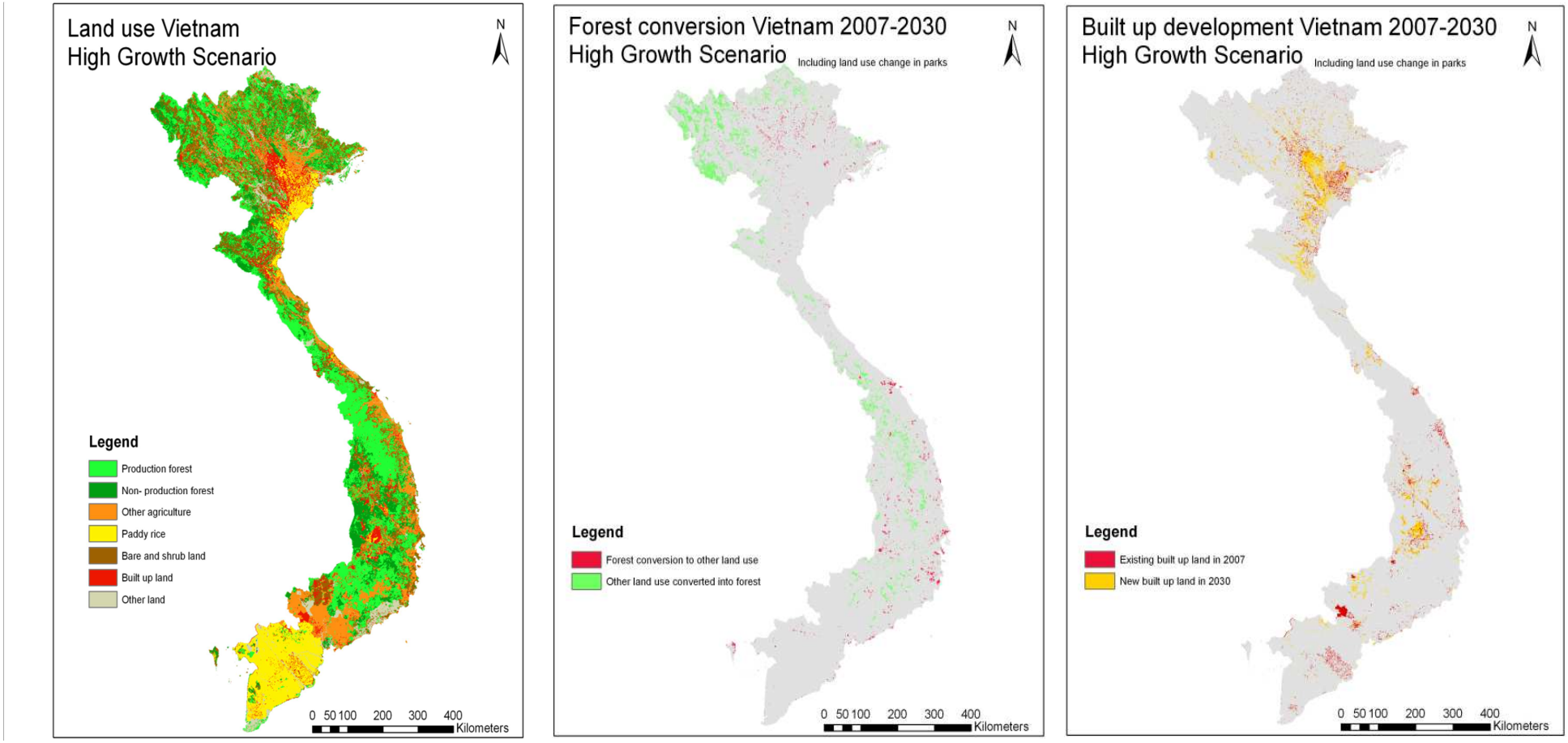
In the HEG scenario, changes in land areas by land class are roughly the same as in the BaU, with the main difference that built up land is assumed to grow much faster, leading to a higher share in total land in Vietnam in 2030 of 6 per cent compared to 5 per cent in the BaU (Appendix A3; Figures A3.1 to A3.3). This primarily goes at a cost of bare and shrub land in 2030 (share of 12 per cent compared to 14 per cent in the BaU).

Figure 4.17, left-hand side panel, shows the land use map for Vietnam in 2030 in the HEG scenario. Compared to the BaU, the pattern of land use change is relatively similar with the difference that now production forest and urban or built up areas display a stronger growth.

Figure 4.17, middle panel, shows the conversion of existing forest areas into other land use and vice versa for the period 2007 – 2030 for the HEG scenario. As shown, the largest forest area disappears in the eastern part of Vietnam, while the largest increase of forest land appears in the western part of the country. This is mostly production forest land; while the production forest increases from 22 per cent to 31 per cent of the country's surface, the non-production forest area decreases with 2 per cent, resulting in a net increase of the forest area of 8 per cent.

Figure 4.17, right-hand side panel, shows the change of the built up area between 2007 and 2030 for the HEG scenario. As in the other scenarios, the largest increase of built up areas can be found in the Red River Delta area, followed by the Northern Central region and the Central Highlands region.

Figure 4.17: Land use pattern in 2030 and forest conversion/built up development in Vietnam in the High Economic Growth Scenario



4.4 Discussion of results

The scenarios we've presented are themselves not set in stone, they are possible futures that are indicative of what may happen. Many more futures may be relevant which vary with the many uncertainties regarding climate change impacts and adaptation and mitigation policies, consumer preferences, trade policy, land use planning and so on.

The results current reveal little variation in land use allocation across sectors in the different scenarios compared to the baseline and as a result little variation in the general structure of the economy (e.g. value added or consumption shares). In contrast some of the price effects (e.g. land prices) are quite big. This seems to be due to the use of a three-level CET function with very low elasticities of transformation, which reflects the difficulty to switch land between forestry and agriculture (and to a lesser extent between crops and livestock). Forests are not grown instantaneously, nor is it costless to remove so, given the absence of forest dynamics in CGE models, it for now – given the lack of better alternatives - seems a plausible assumption. Moreover, it does some justice to the reality that in Vietnam decision making with regards to land use is still highly planned and not market-conform, and that planning capacity still needs to be improved.

Another caveat is that (real) land prices, i.e. the value of one unit of additional land, are very low in the base year. It is unclear what these prices should be, especially in Vietnam where there's no land market.

The future land use maps can be overlaid with other expected spatial developments in Vietnam so as to analyse the impacts of land use change on these developments and vice versa. Examples include overlaying the future land use maps with future potential conservation areas, hydro power catchment areas, tourism zones and poverty alleviation areas. Another interesting development is to analyse the impacts of climate change on specific land use types, such as paddy areas and urban areas. Useful spatial indicators of climate change are for instance the chance of floods, droughts and salinization.

Figure 4.18 Paddy areas in 2030-HEG under potential flood risk

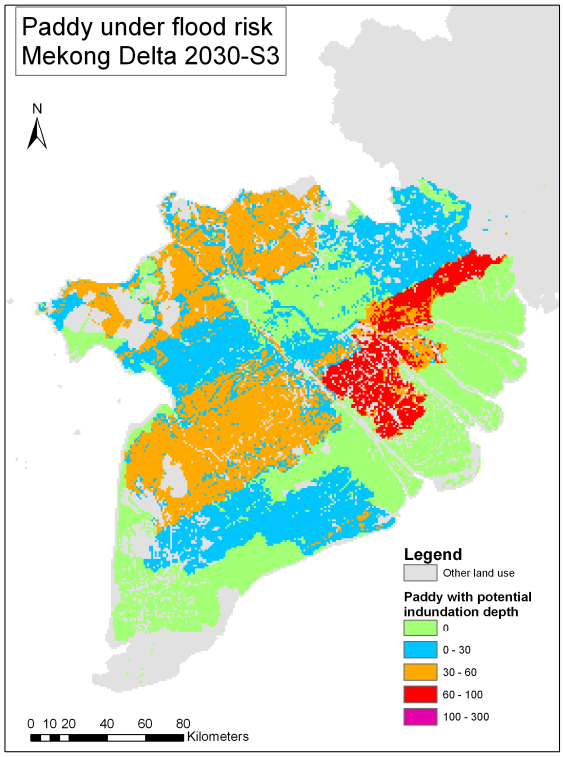
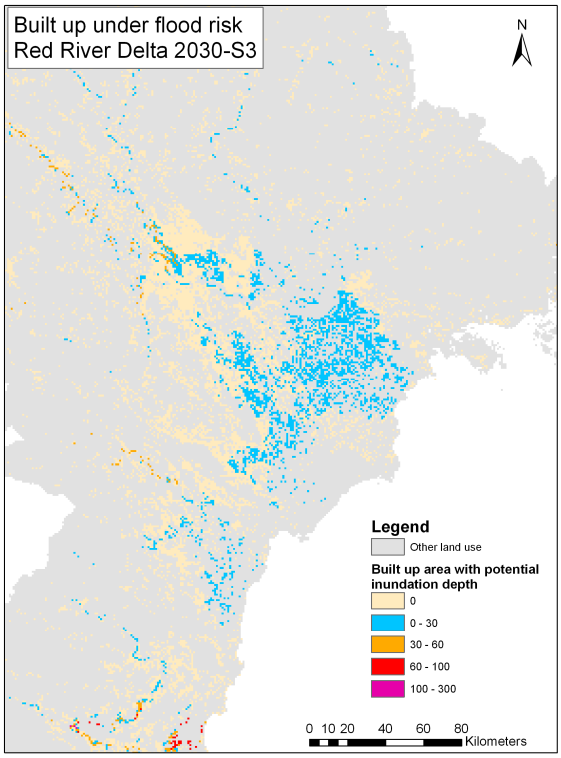


Figure 4.19 Built up areas in 2030-HEG under potential flood risk



In Figure 4.18, the projected paddy area in 2030 in the Mekong area for the High Economic Growth scenario is overlaid with the potential flood map for this region. The Mekong area has suffered several extreme floods over the last couple of years. The potential maximum inundation depth of these floods are also shown on the map. Once the frequency and average inundation depth of the floods are known, the severity of crop damage can be assessed. Together with an estimate of crop production loss per damage level, the total crop production loss and locality can be calculated. This information will add valuable information to food security assessments.

In Figure 4.19, the urban land in 2030 for the High Economic Growth scenario is overlaid with the potential flood map and shows the potential inundation depth in the urban areas. Again, when the frequency and average inundation depth of the floods are known, the severity of damage in these urban areas can be assessed.

5. Conclusions

We have presented the preliminary results of two hypothetical futures, a High Climate Impact and a High Economic Growth Scenario on the basis of an improved GTAP based model set up (notably land use) and improved data (notably for Vietnam) and using a global-to-local modelling approach (MAGNET-CLUE).

The macroeconomic (MAGNET) results show that the structure of the Vietnamese economy, land distribution and composition of food consumption basket are little affected by HCI and HEG scenarios. Impacts are however visible across sectors, with important inter-sectoral linkages such as linkages between primary and processed food sectors, and commercial forestry with wood products (produced by the lumber industry).

Climate change is shown to slow down the economy. The projected fall in yields causes agriculture (in particular crop sectors of paddy rice and vegetables, fruit and nuts) and associated processed food and wood product sectors to contract and increases their unit costs. The main cause is the increased demand for land by crops at a cost of livestock and commercial forestry. This pushes up land prices with knock on effects onto the rest of the economy. Food security deteriorates across the globe and in Vietnam, with substitution towards cheaper imports.

Pursuing higher economic growth by increasing yields and technological progress in especially manufacturing and agriculture can turn these developments around by creating relatively high growth in crops (notably vegetables, fruit and nuts) and processing food and wood product sectors. Expanding industry and services sectors draw in labour, which due to market segmentation drives up the real wage in industry and services, relative to agricultural sectors. The rise in yields leads to lower land use in crops (notably vegetables, fruit and nuts), benefiting mostly livestock sectors. As a result, land prices rise by very little. Almost all sectors become more competitive, most notably the vegetables, fruit and nuts sector. Food security improves (slightly across the globe and) in Vietnam, with substitution towards cheaper domestic goods and a slight shift away from processed rice towards other food products.

Future land use maps (from CLUE) reveal that the largest changes will take place in the conversion of non-production forests and bare and shrub land to production forest. The increase of built up land is partly the result of a decrease in paddy land. Land use changes are not distributed evenly over the country; most of the urban growth is concentrated in the Red River Delta region, followed by the northern part of the North Central Coast and in the Central Highlands. Spatial differences between the

distribution of future land use classes are relatively small across scenarios. The High Climate Impact scenario results in a slightly lower increase of the production forest area. The HEG scenario results in a higher growth of the production forest area and urban area, compared to the BaU scenario. The largest increase in forest land, mainly production forest land, appears in the western part of the country. An overlay of future paddy and urban area with potential flood maps show that a significant area of these land uses are threatened by floods, which are likely to result in reduced crop productivity and economic losses, posing a threat to food security.

Future work includes improving the modelling of the land allocation and land market in MAGNET (also relating to forestry). Secondly, food security impacts are better derived distinguishing different types of households rather than the one representative household as is currently present in GTAP. Thirdly, scenario assumptions regarding yields, technological change and changes in consumer preferences are likely to be crucial for the outcomes and need more attention. Finally, the future land use maps allow a spatial analysis of land use change in relation to other economic and climatic developments that are related to land use, for instance the assessment of future paddy and urban areas that are vulnerable to damage from extreme floods and other climate change impacts.

Acknowledgements

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Appendix

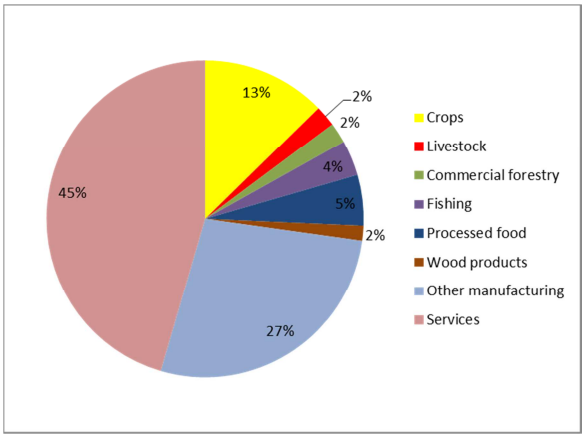
A1. Key economic indicators for Vietnam

Table A1.1: Decomposition of GDP of Vietnam, 2007

Source	Value (million US$)	Share (%)
Consumption	46007	67
Investments	28253	41
Government consumption	4302	6
Exports	53675	78
Imports	-63802	-93
Total	**68435**	**100**

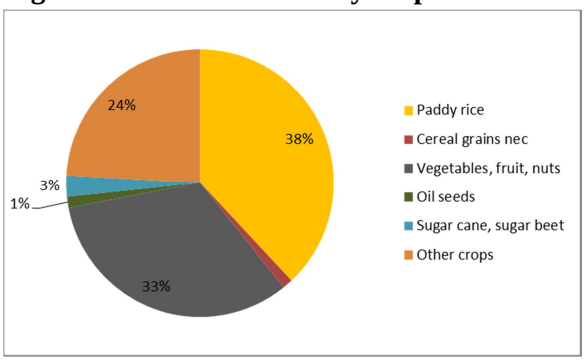
Source: MAGNET

Figure A1.1: Value added by broad economic activity in Vietnam (%), 2007



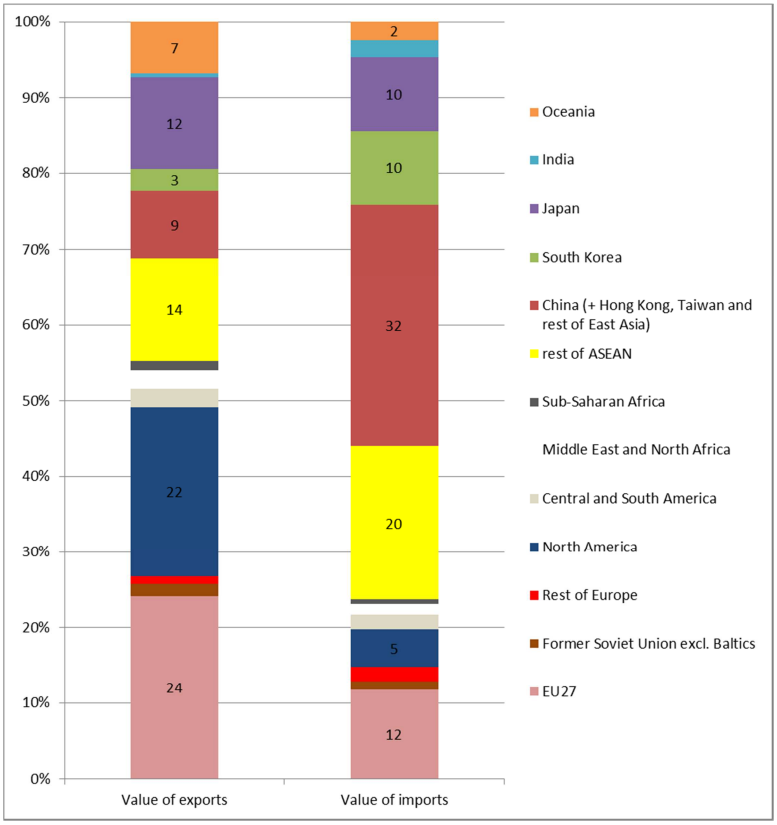
Source: MAGNET

Figure A1.2: Value added by crop sector in Vietnam (%), 2007



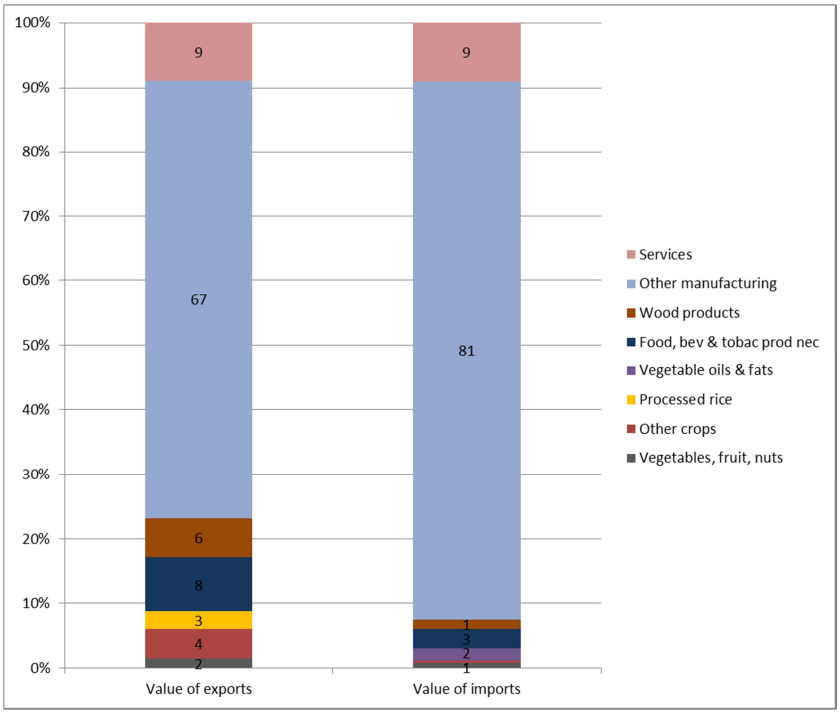
Source: MAGNET

Figure A1.3: Vietnamese trade by region (%), 2007



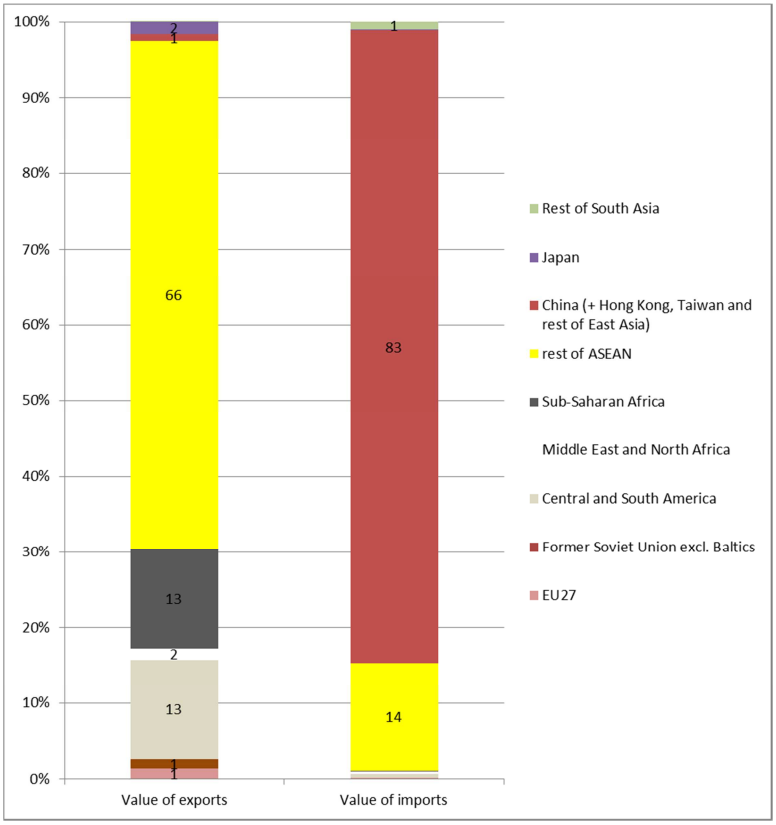
Source: MAGNET

Figure A1.4: Vietnamese trade by sector (%), 2007



Source: MAGNET. Note: sectors with trade values < 1% have been left out.

Figure A1.5: Vietnamese trade in paddy and processed rice (%), 2007



Source: MAGNET. Note: countries or regions with trade values < 1% have been left out.

A2. Land data for Vietnam

Table A2.1: Land cover in Vietnam, various sources

	GTAP (2007)		FIPI (2007)	
Category	**Land cover in km2**	**Share (%)**	**Land cover in km2**	**Share (%)**
Production forest	116900	35	74858	22
Non-production forest	70771	21[1]	61640	19
Shrub and Savannah grass land	47238	14	62986	19
Paddy rice	-[2]	-[2]	53462	16
Other agriculture	94676	28	52902	16
Built-up land	3281	1	8645	3
Other land	0	0	18517	6
Total	**332910**	**100**	**332910**	**100**

Notes: [1] Interpolated using total area from the FIPI map as GTAP only provides land use data for production forest; [2] Part of Other agriculture in the GTAP database.

Table A2.2 Land use in Vietnam, various sources

	GTAP (2007)		MAGNET using FIPI(2007)	
Sector	**Km2**	**Share (%)**	**Km2**	**Share (%)**
Paddy rice	50967	24	52296	29
Cereal grains nec	7762	4	10511	6
Vegetables, fruit, nuts	19106	9	24844	14
Oil seeds	4412	2	5779	3
Sugar cane, sugar beet	2075	1	2527	1
Plant-based fibres	266	0	195	0
Other crops	5390	3	6599	4
Cattle: sheep, goats, horses	4649	2	106	0
Wool, silk-worm cocoons	48	0	1	0
Commercial forestry	116900	55	74858	42
Total	**211575**	**100**	**177716**	**100**

A3. Local land use scenario data and probability maps

Figure A3.1: Land areas (km2) by land use class for different scenarios

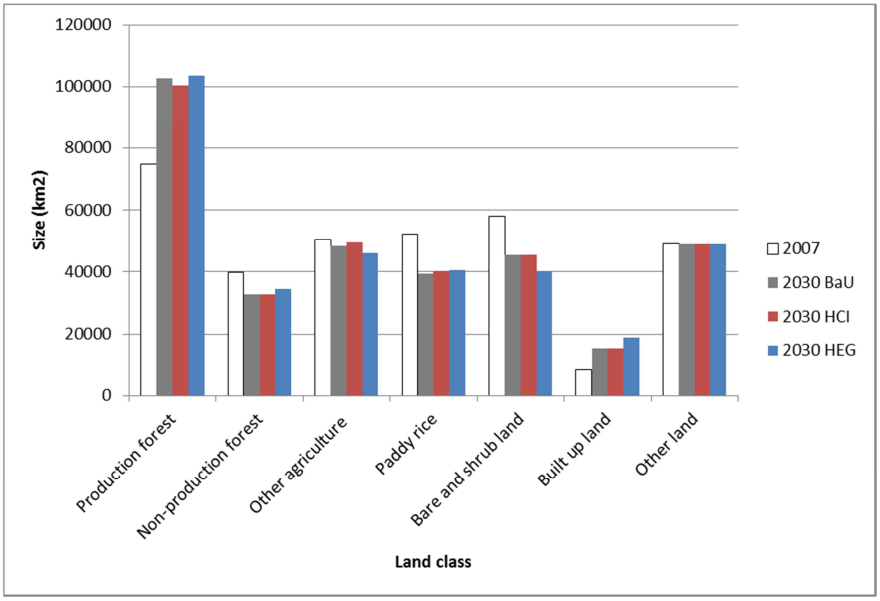


Figure A3.2: Land areas (% share) by land use class for different scenarios

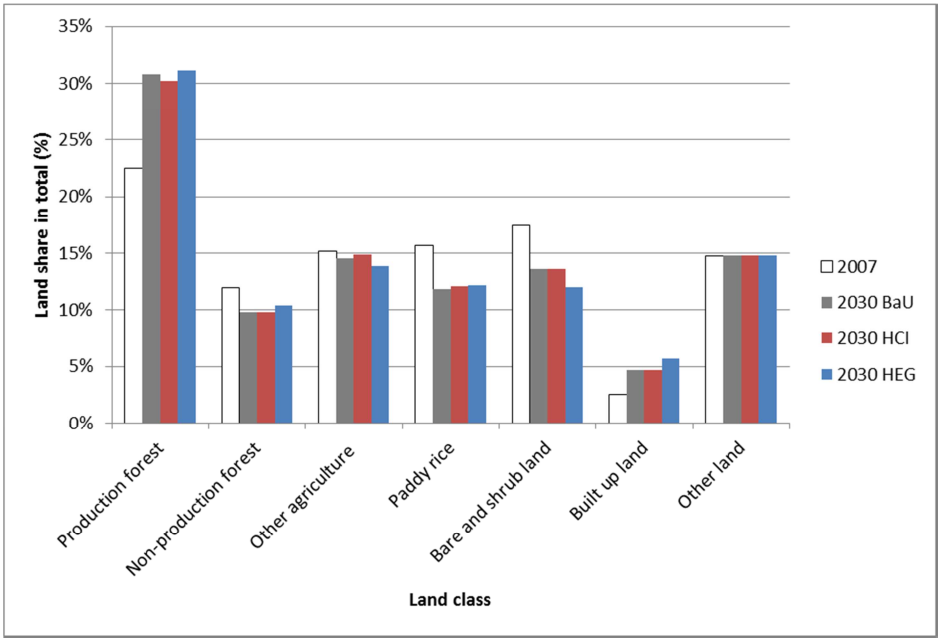


Figure A3.3: Growth in land areas (% change) by land use class for different scenarios

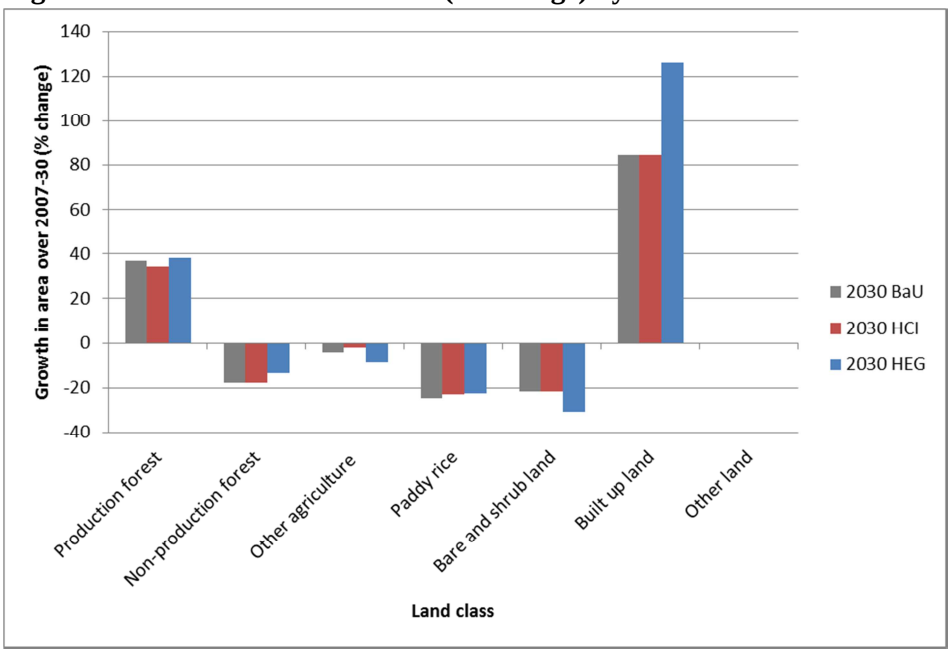
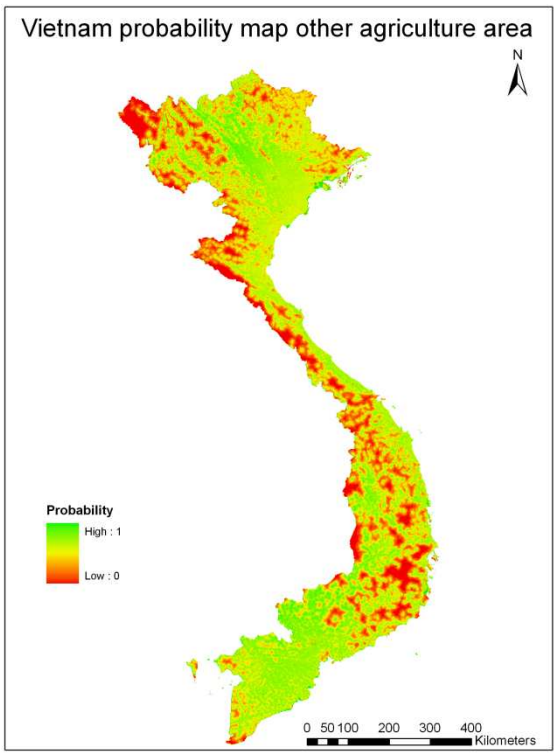
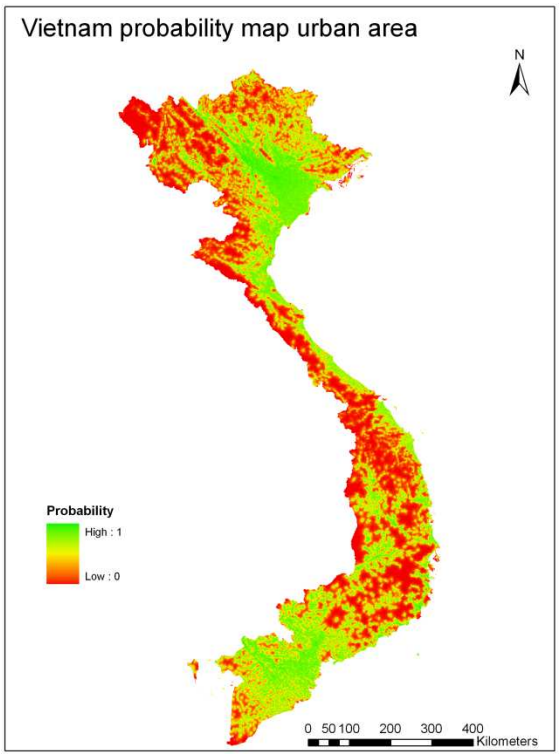


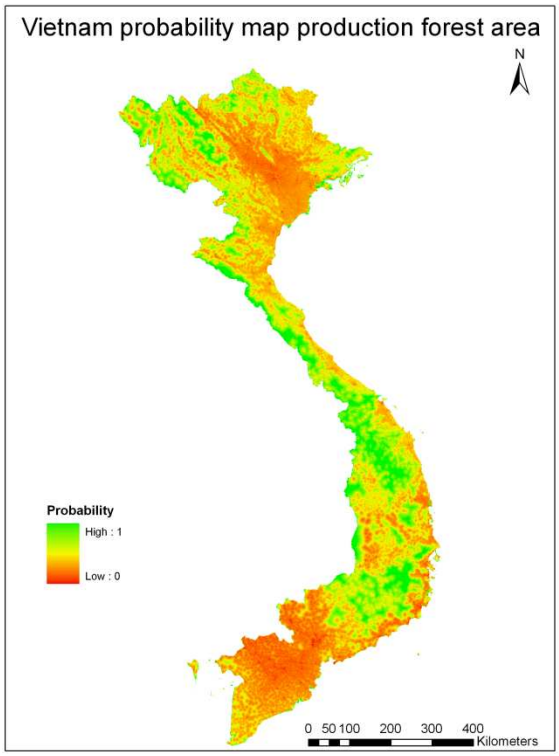
Figure A3.4: Probability maps



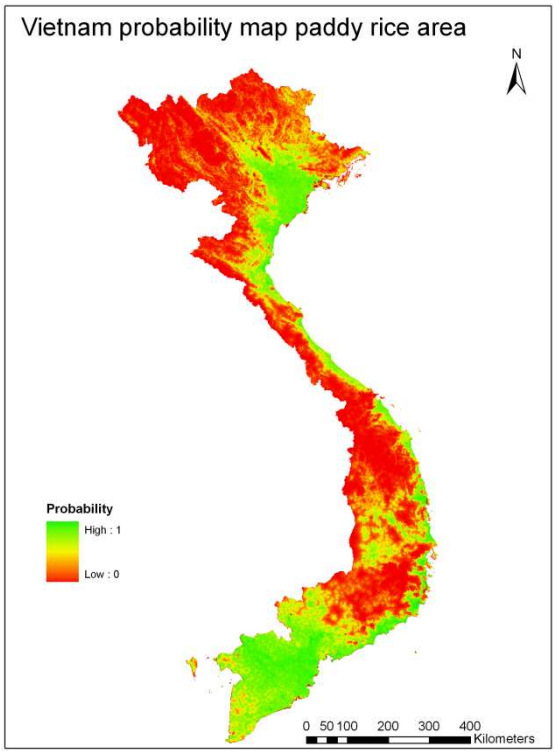
Note: Goodness of fit value ROC = 0.71



Note: Goodness of fit value ROC = 0.82



Note: Goodness of fit value ROC = 0.74



Note: Goodness of fit value ROC = 0.90