CHAPTER 5

Forest and crop-land intensification in the four agro-ecological regions of Viet Nam: impact assessment with the FALLOW model

Rachmat Mulia, Mai Phuong Nguyen, Hoan Trong Do

Summary

Climate change and food insecurity are two major global issues that are also of concern in Viet Nam. Developing high carbon-stock and low-emission land-use strategies that can reconcile the livelihoods and environmental functions of landscapes is essential. This chapter presents the results of 30-year simulations of land-use scenarios that promote forest and crop land intensification in the four agro-ecological regions of Viet Nam. We used the Forest, Agroforest, Low-value Land or Waste Land (FALLOW) model. The selected provinces have diverse biophysical and socio-economic conditions that contribute to high variation in the impact of land-use strategies on household incomes and provincial carbon stock.

Relative to the baseline, the scenario of agricultural and forest-plantation expansion, which included agricultural-intervention programs and expansion of plantations in degraded areas of protection forests, increased smallholders' annual incomes per capita by USD 21 (± USD 5.50) but at the same time decreased time-averaged carbon stock by 0.7 (± 0.5) x 10^6 ton CO_2 eq because naturally-regenerated forests accumulate higher carbon stock than if they were converted into short-rotation forest plantations. In the Reduced Emissions from All Land Uses scenario, replacement of upland annual crops with agroforestry and restoration of degraded forests conferred higher carbon stock by 15 (± 4.5) x 10^6 ton CO_2 eq compared to the baseline and increased incomes per capita by USD 28 (± USD 12).

We conclude that it is possible to escalate both income and carbon stock in the study provinces through agricultural and forestry interventions, including tree planting inside and outside forests. The additional income mainly would come from agricultural and production-forest land while agroforestry interventions on upland slopes coupled with enrichment of degraded protection and special-use forests with native forest-tree species accumulated higher carbon stock inside and outside forests.

1. Introduction

Climate change and food insecurity are two major global issues. Addressing the challenge of mitigating them requires a distinguished land-use strategy and implementation of a low-emission development strategy or high carbon-stock development pathway. With around 24% of the world's total greenhouse-gas emissions estimated to come from agriculture, forestry and other land uses (IPCC 2014), research is necessary to find ways of lowering this level. Given that rural peoples mostly rely for their livelihoods on both forestry and agricultural land, any emissions-mitigation strategy involving these sectors needs to address socio-economic factors.

Viet Nam has had rapid economic and population growth since the late 1990s and has been attempting to balance economic growth while reducing emissions of greenhouse gases. The country has carried out major policy reforms to improve the economy through agricultural expansion and innovation and also recover degraded forests through conservation and afforestation programs. To address economic and environmental trade-offs and to achieve multiple goals in both areas, the Government has been actively involved in international conventions, such as REDD+, Sustainable Development Goals and green growth, as well as formulating its own targets and work plans, such as the National Action Plan for Climate Change[1] and the National Green Growth Strategy[2]. The latter reads, 'Green growth, as a means to achieve a low carbon economy and to enrich natural capital, will become the principal direction in sustainable economic development. Reduction of greenhouse gas emissions and increased capability to absorb greenhouse gas are gradually becoming compulsory and important indicators in socio-economic development' (Government Viet Nam 2012).

The impact of land-use conversion on people's livelihoods and on environmental services, and its relation to climate change, have captivated the attention of the world's leaders and environmental advocates (Ellison et al 2012, West et al 2010). With a rapidly growing population, Viet Nam's need for high food production and economic returns has increased. Land-use conversion will likely accelerate with global market incentives for staple foods and key export products. There has already been large-scale conversion of forests to agriculture to address the increasing demand for food and other commodities (Gibbs et al 2010, Tilman et al 2011). In Viet Nam, besides the common forest-to-agriculture conversion that has mainly occurred in uplands, allocation of forest land to households or communities by the Government has been underway since the 1990s. The intention has been to engage local people in forest protection and plantation development to also help improve their livelihoods (Phuc at al 2013). The program is supported by policies on legal recipients and land-allocation procedures that have led to the creation of new regulations on land ownership; access to, and use of, forest land; and amendment of afforestation programs (Clement and Amezaga 2009).

Reducing land-use emission at landscape level cannot be achieved by merely attempting to avoid conversion from forest to agriculture (van Noordwijk and Minang 2009). A rural landscape can also consist of high biomass land uses, such as complex agroforestry or mixed-species' tree gardens. Conversion of these high biomass land uses into annual crops or monocultural plantations can significantly contribute to total emissions from a landscape. Only protecting forests can cause 'leakage' outside the protected forest land because people refused access to the forests turn to conversion of the high biomass land uses. The leakage rate can range from negligible to

[1] Available at: http://chinhphu.vn/portal/page/portal/English/strategies/strategiesdetails?categoryId=30&articleId=10051283
[2] Available at: https://www.giz.de/de/downloads/VietNam-GreenGrowth-Strategy.pdf

substantial (Murray et al 2004). The solution is to broaden the context into reducing emissions from all land uses not only those related to forest conversion (van Noordwijk et al 2009). Reducing emissions from non-forest land includes introducing trees into low biomass or annual crop land. Moreover, tree cover (whether in forests or on non-forest land) provides buffering and filtering functions that modify, and generally reduce, sensitivity to external shocks such as climate variability. Tree cover helps farmers adapt to longer-term trends (Nguyen et al 2013, van Noordwijk et al 2011, Simelton et al 2015).

As reported in Clement and Amezaga (2009), according to the Law on Forest Protection and Development (1991), forest land in Viet Nam is classified into three categories based on their intended uses: 1) production forests: designated mainly for commercial purposes through timber and non-timber production; 2) protection forests: protection of water and land resources for purposes such as climate and erosion control; and 3) special-use forests: national parks for conservation and landscape protection for research as well as eco-tourism. Forest land allocated to individual households is that from the production category whereas the other two types are usually managed by the state through forest management boards and state forest enterprises. The main forest-plantation type developed in production forests by farmers, and supported by local authorities, is 4-year cycle monocultural acacia for pulp and paper (Tran et al 2014, Trieu et al 2016). During more than two decades, the system, which is also part of the Government's afforestation program, has brought improvements to local livelihoods and rehabilitated degraded land in many regions in Viet Nam (Tran et al 2014, Pietrzak 2010). Across the country, a variety of tree species have been used in forest plantations, for example, *Litsea glutinosa* in the Central Highlands, rubber in the Northcentral Coast and *Acacia mangium* in the Northeast.

A land-use simulation model can be used to assess the impact of land-use changes on the livelihoods and environmental functions of a rural landscape. Among the available land-use-dynamics models (see, for example, those reviewed by Lee et al 2003, Messina and Walsh 2001, Soares-Filho et al 2008), the Forest, Agroforest, Low-value Land or Waste Land (FALLOW) model (van Noordwijk 2002, Mulia et al 2013a) offers a more detailed analysis of land-use-change processes by considering socio-economic and biophysical drivers. The model can be used as part of gaining more understanding about the process of land-use change at landscape level and help design more appropriate land-use strategies.

As part of contributing to the low-emission development pathway in Viet Nam, we used FALLOW to assess the impact of three different land-use strategies on carbon storage and people's incomes in the four agro-ecoregions. The strategies mainly involved tree planting inside and outside forests to generate higher levels of carbon stock as well as improving household incomes. We started from three main hypotheses.

1. To reconcile income and carbon stock, forest plantations can be expanded on production-forest land while degraded protection and special-use forests can be restored through planting native forest-tree species.
2. The traditional annual-crop practices in the uplands, which are exposed to environmental hazards, can be replaced by agroforestry practices. Intercropping can be conducted at least in the early years of newly-established agroforestry systems, allowing farmers to gain income from annual crops before the perennials reach their productive stage.
3. Compared to a baseline, integrating trees inside and outside forests can result in a positive impact on carbon stock and incomes and, thus, be in line with the targets of low-emission development strategies.

2. Materials and methods

Brief description of the study sites

The study was conducted in four provinces belonging to four agro-ecological regions of Viet Nam: the Northeast, Northcentral Coast, Central Highlands and Mekong Delta (Figure 24). The study sites were selected based on the diversity of biophysical and land-use conditions in the four regions, their geographical locations that are representative of the country's territory, available connections to local partners, and the availability of basic data, particularly, land-cover maps.

Ben Tre is a coastal province in the Mekong Delta, with high potential for agri-aqua products, such as rice, coconut, cacao and

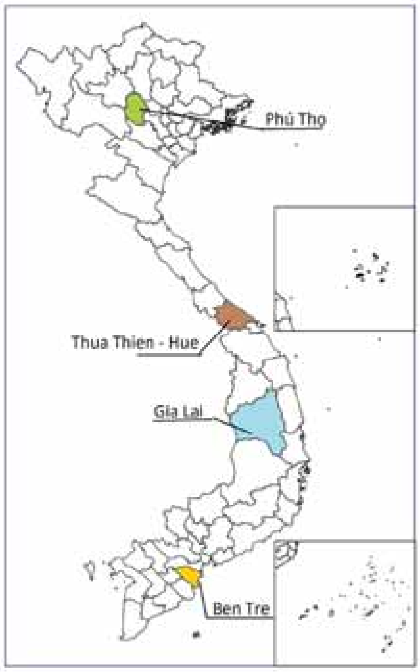


Figure 24. Geographic location of the study sites representing four agro-ecological regions

sugarcane (Table 18). In 2010, the area under coconut had reached about 40% of the total area of the province. In order to reduce risks from market fluctuations and increase economic returns, farmers mix coconut with other fruit trees, such as durian, longan or star apple (Catacutan et al 2013). Almost no natural forests remain in Ben Tre. Annual crop land constitutes 15.6% of the province's area. Large areas of mangrove forests have been degraded owing to conversion into shrimp farms and annual crop land, sea intrusion and extreme weather events (IUCN 2013). With a tendency toward stronger winds and waves, changes in rainfall patterns, and more frequent storm events, as indicated by climate-change scenarios, mangrove restoration in the province is crucial (IUCN 2013).

Gia Lai Province is located in the Central Highlands, a plateau with steep terrain. Farming is dominated by mono-cropping practices that carry myriad economic and environmental risks (Catacutan et al 2013). To increase plot productivity and resilience to climate-hazards, some farmers had developed agroforestry practices in which traditional crops—such as rice, maize and cassava—were intercropped with native tree species. The most popular, emerging agroforestry system was *Litsea glutinosa* intercropped with cassava (Catacutan et al 2013). Litsea is a multi-purpose indigenous tree found in evergreen broad-leaf and semi-evergreen forests in the Central Highlands. The tree's biomass (stems, leaves, bark and twigs) is processed into essential oil and and other aromatic products. In 2014, forest land occupied 38% of the total area of the province. Seventy percent (70%) of the forest land was categorised as production forest (Table 18). Annual crop land constituted 28.6% of the province's area.

Thua Thien Hue Province in the Northcentral Coast region has mountainous as well as coastal areas. Upland people have been practising swidden cultivation for a century or more (Catacutan et al 2013). The common agroforestry system is rubber with cash crops, such as banana, cassava or groundnut. Seeking higher economic return, farmers have been converting their hill gardens, shifting-cultivation fields and home gardens into rubber plantations (Catacutan et al 2013), although, there has been a growing tendency for acacia rather than rubber owing to its more stable market. In 2014, forest land occupied about 67% of the province's area. Forty-three percent (43%) of the forest land were categorised as production forest (Table 18).

Phu Tho is situated in the Northeast mountainous region. The dominant integrated agricultural system in this province is *Acacia mangium*-cassava, which is supported by local agricultural and forestry enterprises (Catacutan et al 2013). Farmers usually plant cassava in between rows of acacia trees during the first year, taking up about 25% of the total plantation area. Rice and acacia timber are the two main products of the province. In 2014, 48% of the province's area was occupied by forest land. Seventy-one percent (71%) of the forest land was designated as production forest. Of the four study sites, the Northeast was the poorest (Table 18).

Table 18. Description of the four provinces representative of the agro-ecological regions

Province	Region	Total area (km^2)	Population in 2014 (people)*	Poverty rate (2012) (%)+	% area forest land#1	% area production forest#2	% area annual crops#1	Main land-use systems
Ben Tre	Mekong Delta	2,321	1,260,000	16.2	3	0	15.6	Annual crops: rice, maize, mixed crops, sugarcane Perennial crops: coconut plantations, coconut-cacao agroforestry
Gia Lai	Central Highlands	15,495	1,370,000	29.7	38	70	28.6	Annual crops: rice, maize, cassava Perennial crops: litsea plantations, litsea-cassava agroforestry

Thua Thien Hue	North-central Coast	5,062	1,130,000	18.2	67	43	8.5	Annual crops: rice, maize, cassava Perennial crops: rubber plantations, rubber-cassava/banana/groundnut agroforestry
Phu Tho	North-east	3,528	1,360,000	41.9	48	71	17.8	Annual crops: rice, maize, cassava Perennial crops: acacia plantations, tea plantations, acacia-cassava agroforestry

[1]Relative to total province's area. [2]Relative to total forest land area
*Statistics Handbook Viet Nam 2014, General Statistics Office of Viet Nam
+Statistics Handbook Viet Nam 2012, General Statistics Office of Viet Nam
#Reports on Land Inventory Results 2014

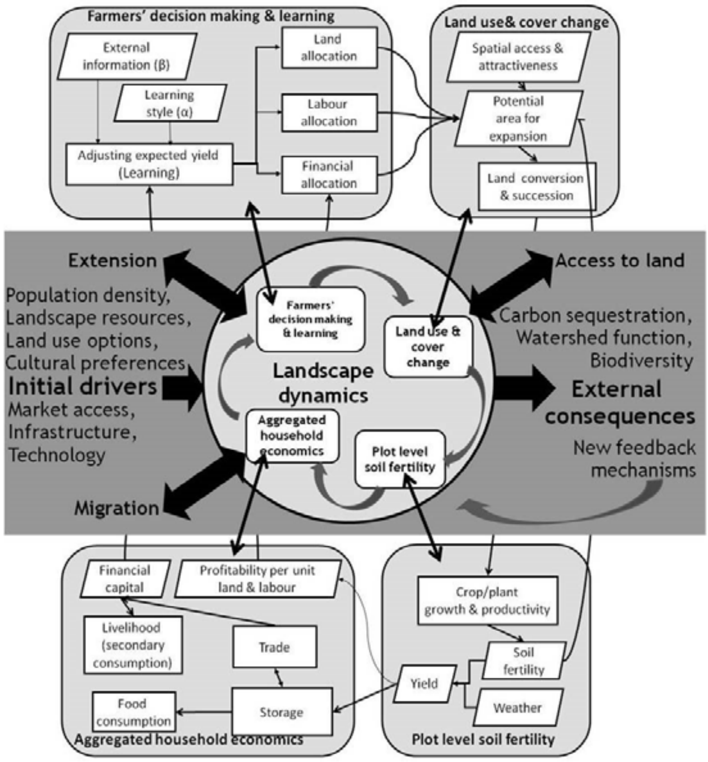
FALLOW

The FALLOW model can be used to simulate land-cover changes in a landscape that are driven by the decisions of farmers, local authorities and the private sector based on finance, labour and land allocation. The model is available in PC Raster language and can handle large-size input maps, for example, those produced for district and province levels. The default pixel size for the input maps is one hectare, with possible modification depending on the objective of the study and adjustment to parameter values.

Land-use and resource-allocation decisions are modelled as results of socio-economic and demographic drivers. Stakeholders in a landscape employ both spatial and temporal information about multiple drivers to make decisions on resource allocation that determines the final land-use distribution. Figure 25 describes the links between the four main modules in the model: 1) farmers' decision-making process; 2) land-use/-cover condition in the landscape as land capital; 3) aggregated household economics that determine financial and labour capital; and 4) dynamic soil fertility as a function of yield and recovery. The resultant land-use distribution was used to make projections of smallholders' annual income per capita and total carbon storage in the landscape.

The income per capita was calculated after the primary and secondary consumption demand and all related costs of farming activities. It is relative to total population in the landscape not to total labour force. The income calculation does not involve labour cost in self-sufficient labour households. Labour cost was taken into account only in the case of hiring external workers. All other costs related to farming activities were classified as non-labour costs. Related to farmers' decision making and learning, it was possible to simulate different types of farmers, for example, based on their degree of 'profit-orientedness'. Some farmers might be more reactive to information on product markets while others might prefer to keep land-use options that are linked to cultural values. In the model, the choices of land-use options by farmers were more influenced by socio-economic factors while actual locations for cultivation were influenced by biophysical factors for better plot management and productivity.

The model needed input maps, such as land-cover maps, and information on the biophysical and socio-economic conditions of the landscapes and local households. Annex 1 provides a list of input maps and the main parameters required to run the model. A detailed description of the modelling concept can be found in Mulia et al (2013a) and van Noordwijk (2002). Previous application of FALLOW includes studies of dynamic land use in different regions in Indonesia (Mulia et al 2013b, van Noordwijk et al 2008, Suyamto and van Noordwijk 2005). A version of FALLOW that can simulate fodder options is also available (Lusiana et al 2012).



Source: Adapted from Lusiana et al 2012

Figure 25. The four main modules in the FALLOW model

Input maps and parameter values

We obtained land-cover maps of 2010 for each province from the Institute of Geography. Other input maps, such as distance to roads or settlements, were produced by the Institute based on the administrative maps. Soil maps were obtained from the Soils and Fertilizers Research Institute. In the input land-cover maps, forests were classified into 1) natural timber forest; 2) bamboo forest; 3) mixed (bamboo and timber) forest; 4) forests on rocky mountains; and 5) mangrove forest. Annual crops were classified into 1) rice field; 2) mixed crops; or 3) shifting cultivation in uplands. Perennial crops were categorised as 1) forest plantation; 2) industrial crops; 3) mixed fruit garden; or 4) agroforestry. Mangrove forests only existed in Ben Tre and Thua Thien Hue provinces.

The biophysical, economic and demographic data were obtained from the statistics handbooks of the provinces for 2010. Owing to lack of data, no yields (timber or non-timber forest products) were simulated for all forest types, except for forest plantations. Tables 19 and 20 show the values of the main biophysical and economic parameters. The main outputs of the model's simulation were projected spatial and temporal (annual) land-cover distribution in the provinces with estimated net income per capita (USD) of smallholders and total carbon stock in the landscape (ton CO_2 eq).

Table 19. Average aboveground biomass and yield of each land-cover type in the four provinces used for the FALLOW simulations

	Ben Tre		Gia Lai		Thua Thien Hue		Phu Tho	
Land-cover type	**AGB++**	**Yield**	**AGB**	**Yield**	**AGB**	**Yield**	**AGB**	**Yield**
Forests+								
Natural timber forest	-	-	215	na*	149	na	130	na*
Bamboo forest	-	-	38	na	-	-	15	na
Mixed forest	-	-	124	na	-	-	124	na
Rocky mountain	-	-	-	-	-	-	121	na
Mangrove	66	na	-	-	66	na	-	-
Crop systems								
Rice	8	4.7	11	4	12	7	12	10
Mixed crops	8	3.6	9	4	9	7	19	8
Shifting cultivation	-	-	8	16	7	6	10	13
Perennial crops								
Forest plantation[1]	-	-	62	5.7	69	1.7	39	44
Industrial crops[2]	57	96	39	1.7	39	1.7	25	0.8
Mixed garden	19	9.2	19	36	25	3.2	25	3.2
Agroforestry[3]	52	41	35	4.7	23	3.7	38	28

*Note: yield (ton per hectare). +Types of forest by vegetation cover or biophysical feature, not by government-designated status (production, protection or special-use). Each forest type can be further classified into the designated status. ++Average aboveground biomass (AGB, ton per hectare) converted to carbon stock at the ratio of 0.46 and from carbon to CO_2 eq at 3.67. *na: data not available. 1 In Gia Lai: litsea plantations with 10-year rotation; Thua Thien Hue: rubber plantations with 25-year rotation; Phu Tho: acacia plantations with 7-year rotation. No forest plantations in Ben Tre. 2 In Ben Tre: coconut plantations; Gia Lai: rubber plantations; Thua Thien Hue: rubber plantations; Phu Tho: tea plantations. 3 In Ben Tre: coconut-cacao; Gia Lai: litsea-cassava, Thua Thien Hue: rubber-cassava, Phu Tho: acacia-cassava.*

Table 20. Returns to labour and land of each land-use type in the four provinces used for FALLOW simulations

	Ben Tre		Gia Lai		Thua Thien Hue		Phu Tho	
Land cover	**RTLa-bour**	**RT-Land**	**RTLa-bour**	**RT-Land**	**RTLa-bour**	**RTLand**	**RTLa-bour**	**RTLand**
Annual crops								
Rice	1.4	835	3	503	2.9	1,321	4	1,755
Mixed crops	3.8	8,154	2	324	4	1,300	4	1,127
Shifting cultiva-tion	-	-	2	275	4	1,440	20	494
Perennial crops								
Forest plantation	-	-	17	327	38	498	31	380
Industrial crops	6.8	159	8	946	28	1,960	30	3,314
Mixed garden	1.3	34	5.3	611	63	1,700	63	2,760
Agroforestry	4.2	511	10	301	16	1,700	26	437

Note: RTLabour: Return to labour = USD per person per day. RTLand: return to land = USD per hectare

Land-use scenarios

Table 21 describes the interventions covered in the three simulated land-use scenarios applied in all provinces, except for mangrove restoration, which applied only in Ben Tre. They include interventions into the forestry and agricultural sectors to increase timber output from production forests and agricultural products from annual crops, as well as restoration of degraded forest land, and an agroforestry program for sloping upland.

Compared to business as usual (BAU), in the Agricultural and Forest-Plantation Expansion (AFPE) scenario, farmers received a 20% subsidy for the establishment cost of annual-crop systems and were introduced to higher-quality seedlings that were expected to increase crop yield by 10%. These are examples of interventions that governments could implement as part of their agricultural support programs.

Regarding forestry, the Government plans to increase the area of forest plantations to boost timber production. We assumed that this will cover the entirety of production forests and include a possible expansion into degraded areas of protection forests.

In the Reducing Emissions from All Land Uses (REALU) scenario, the subsidy and higher-quality seedlings' intervention for annual crops were maintained but the expansion of forest plantations was restricted to within production forest boundaries. To increase the carbon stock inside and outside forests, the scenario also included restoration with native forest tree species of degraded land in protection and special-use forests, and the replacement of monocultural crop practices in uplands with agroforestry systems. ICRAF scientists formulated the latter two interventions. They were familiar to some farmers who had already deployed these practices, namely, coconut-cacao with intercrops in Ben Tre, litsea-cassava in Gia Lai, rubber-cassava in Thua Thien Hue, and acacia-cassava in Phu Tho.

Native forest-tree species' *Erythrophleum fordii* and *Dalbergia tonkinensis* were preferred for forest restoration in Viet Nam. Both have a wide habitat area. For the simulations, however, we did not parameterize the growth characteristics of these two species and their related carbon stock, instead, assuming that the enriched forests would have faster aboveground biomass growth than the naturally regenerated forests.

The model simulations run for 30 years to cover a complete cycle of some land-use types. For all scenarios, we assumed there would be no changes in roads, markets and settlement distribution during the simulation period. In relation to farmers' decision making, we assumed that the way farmers allocated resources to available land-use options was largely influenced by economic drivers, such as the land use's profit return and product markets, with more resources being allocated to more profitable land-use options.

Table 21. Three land-use scenarios for all provinces simulated with FALLOW

	Scenarios			
Land-use type	**Business as usual**	**Agricultural and Forest Plantation Expansion**	**Reducing Emission from All Land-Uses**	**Potential area for tree planting (ha)**
Annual crops	• No subsidy • To maintain food security, no conversion of rice fields into another land-use types	• 20% subsidy of production costs • 10% increase in crop yield owing to better plot management and higher-quality seedlings	• 20% subsidy and 10% increase in crop yield for rice and mixed crops only • Shifting cultivation practices replaced by agroforestry (except in Ben Tre where shifting cultivation does not exist) • Agroforestry will replace mixed crops	• Shifting cultivation area in Gia Lai: 281,000 ha • Thua Thien Hue: 8,100 ha • Phu Tho: 4,800 ha • Mixed crops area in Ben Tre: 9,600 ha
Production forests	Forest plantations	• Forest plantations	• Forest plantations	-
Protection forests	No intervention	• Expansion of forest plantations to degraded forest land under the assumption the Government allocates the land to households to be used for plantations	• Accelerate restoration by planting native forest-tree species	Total degraded forest land: • Gia Lai: 24,500 ha • Thua Thien Hue: 8,900 ha • Phu Tho: 5,200 ha
Special-use forests	No intervention	No intervention	• Accelerate restoration of degraded forest land by planting native tree species	Total degraded forest land: • Gia Lai: 4,300 ha • Thua Thien Hue: 4,600 ha • Phu Tho: 5,300 ha
Mangroves	No intervention	No intervention	• Mangrove restoration in Ben Tre	Degraded mangrove area in Ben Tre: 24,200 ha

3. Results

Impact of land-use strategies on land cover

Ben Tre

In Ben Tre, given there was no forest—either production, protection or special use—there would be no substantial impact of the AFPE scenario relative to land-use distribution under BAU. The agricultural subsidy and seedling innovation would have no substantial impact on the total area of annual crops because the land area for agriculture was limited and already occupied by existing annual-crop systems, such as rice or maize. The agricultural interventions, thus, would not lead to expansion of the area under annual crops but rather higher economic benefits.

REALU would result in 23,740 ha of restored mangroves in the southeast of the province and 12,370 ha of new coconut-cacao agroforestry (Table 22). Although the total area of mixed crops targeted by the agroforestry program was only about 9,600 ha, FALLOW projected that farmers would also develop coconut-cacao agroforestry on other land outside the targeted areas, for example, in some mixed-garden areas, because they would be attracted to replacing less-profitable land-use systems with the new system. Figure 26a shows the final land-use distribution under REALU with industrial coconut plantations, mixed gardens and rice fields dominating the landscape.

Table 22. Total area of the four land uses in the provinces under different scenarios

		Total area in the landscape											
		Forest plantation			Agroforestry			Mangrove			Restored forest land		
Province	Unit	BAU	AFPE	REALU	BAU	AFPE	REALU	BAU	AFPE	REALU	BAU	AFPE	REALU
Ben Tre	10^3 ha	-	-	-	1.6	1.6	14	0.5	0.5	24	-	-	-
	%	-	-	-	0.7	0.7	6.0	0.2	0.2	10	-	-	-
Gia Lai	10^3 ha	251	271	256	20	20	291	-	-	-	-	-	28
	%	16	17.5	17	1.3	1.3	19	-	-	-	-	-	1.9
Thua Thien Hue	10^3 ha	93	97	93	0.2	0.2	8.1	45	45	45	-	-	13
	%	18	19	18	0.0	0.0	1.6	9.0	9.0	9.0	-	-	2.7
Phu Tho	10^3 ha	80	84	81	6.4	6.2	18	-	-	-	-	-	11
	%	22	24	22	1.8	1.8	5.1	-	-	-	-	-	3.0

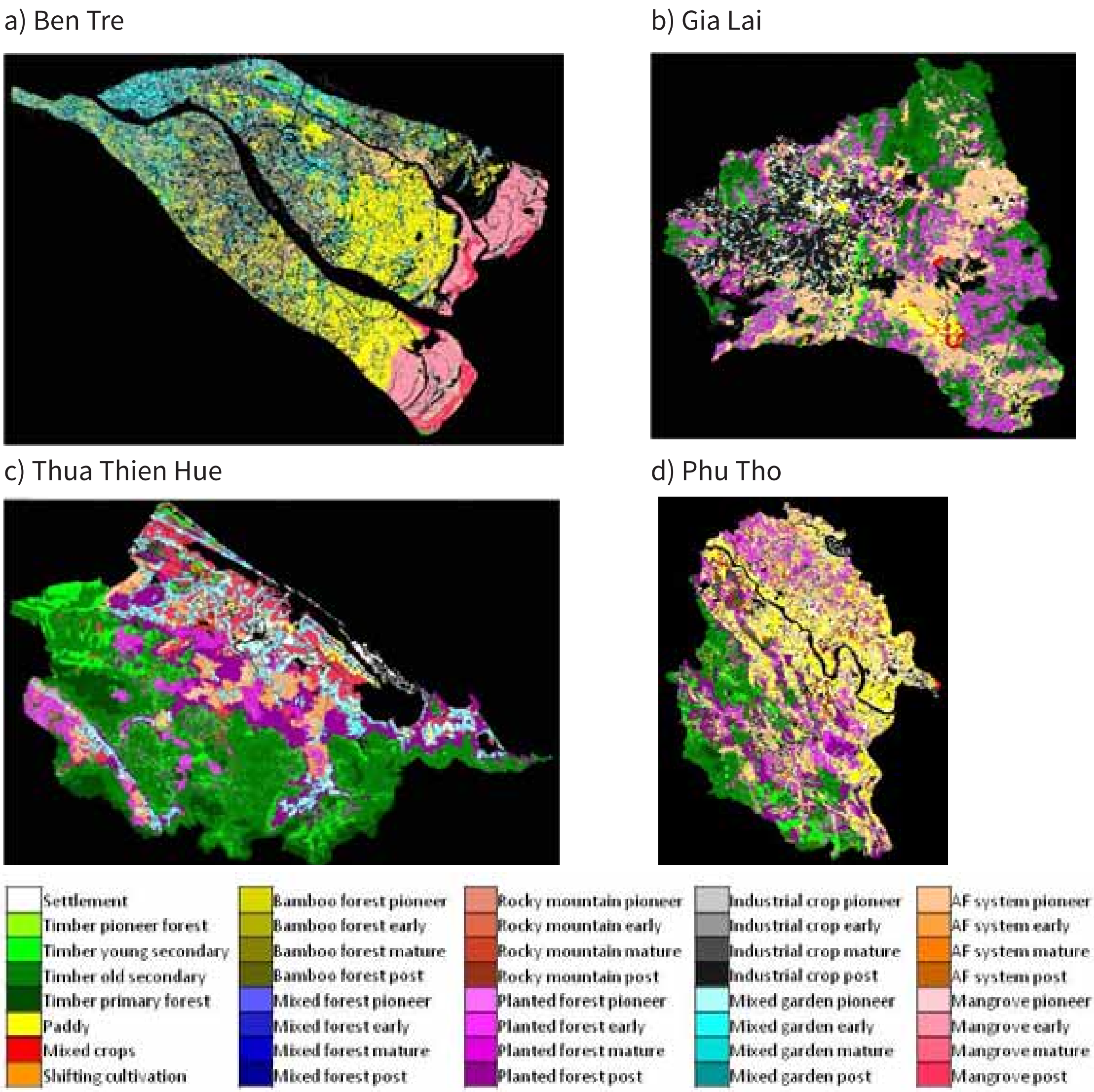
**Restored protection and special-use forest land*

Gia Lai

In Gia Lai, 20,000 ha of new litsea plantations would be developed under AFPE (Table 22). The actual converted area would be less than the total of degraded forest land because of limited resources for conversion, either a lack of finance or labour or both. The model indicates that farmers would need to allocate available resources to different profitable land-use options, restricting a thorough conversion of 24,500 ha of degraded forest land. The conversion of 270,000 ha of shifting-cultivation land under the REALU scenario would result in a large increase in the amount of litsea-cassava agroforestry compared to BAU (Table 22). The final land-use distribution under REALU (Figure 25b shows that natural timber forests, litsea forest plantations and litsea-cassava agroforestry systems would dominate the landscape.

Thua Thien Hue and Phu Tho

In Thua Thien Hue, the actual converted area of degraded land into rubber-forest plantations under the AFPE scenario would be around 4,000 ha (Table 22). A similar change would take place in Phu Tho with acacia plantations. In both provinces, the area of agroforestry would increase significantly if the shifting-cultivation areas in the uplands were replaced with rubber-cassava agroforestry in Thua Thien Hue and acacia-cassava in Phu Tho. Figure 26 shows that under REALU, natural timber forests would remain the dominant land cover in Thua Thien Hue followed by rubber-forest plantations and rubber-cassava agroforestry. In Phu Tho, a large amount of land would be converted into rice and acacia plantations, with remaining timber forests in the southern part naturally protected thanks to difficult access owing to steep slopes.



Note: Black areas represent non-simulated areas. AF = agroforestry

Figure 26. Final land-cover distribution in the four provinces under the REALU scenario of 30 simulation years, as projected by FALLOW

Impact of land-use strategies on carbon stock and incomes

The provincial carbon stock and annual income per capita in Ben Tre under BAU were estimated at 6.3 Mton CO_2 eq and USD 167, respectively. Owing to the absence of degraded land for conversion, no difference in carbon stock was found between AFPE and BAU but income per capita with AFPE increased to USD 182 thanks to the annual-crop intervention program (Table 23).

Under REALU, the replacement of mixed crops with coconut-cacao agroforestry and restoration of degraded mangrove forests would significantly increase carbon stock to 17 Mton CO_2 eq but income per capita would be less, with a decline of as much as USD 60 compared to BAU. This would be because economic returns from the new agroforestry system were estimated to be less than income from mixed crops. At the provincial level, the total income loss reached USD 76 million.

Table 23. Estimated time-averaged carbon stock and annual income per capita for all scenarios in the four provinces

	Ben Tre			Gia Lai			Thua Thien Hue			Phu Tho		
	BAU	**AFPE**	**REA-LU**	**BAU**	**AFPE**	**REA-LU**	**BAU**	**AFPE**	**REA-LU**	**BAU**	**AFPE**	**REA-LU**
Estimated carbon stock												
Provincial stock (Mton CO_2 eq)*	6.3	6.3	17	212	210	240	80	79	88	20	20	34
Provincial stock compared to BAU (Mton CO_2 eq)	-	0.0	11	-	-2.2	28	-	-0.5	8.0	-	-0.2	14
Average C stock per ha (ton CO_2 eq ha^{-1})	27	27	75	137	136	155	159	158	174	57	57	97
Estimated income												
Provincial income (USD millions)	210	229	134	912	950	1197	129	134	168	72	107	73
Provincial in-come compared to BAU (USD millions)		19	-76		38	284		5	38		35	1.0
Average income per capita (USD)	167	182	107	167	174	218	115	119	149	53	79	54
Average income per capita com-pared to BAU (USD)	-	15	-60	-	7.0	51	-	4.0	34	-	26	0.9

Megaton CO_2 equivalent

The total carbon stock in Gia Lai would reach 212 Mton CO_2 eq under BAU (Table 23). The expansion of litsea plantations onto degraded land in protection forests as formulated in AFPE, however, would result in a slightly lower carbon stock compared to BAU. This indicated that in the long term the time-averaged carbon stock from the litsea plantations would not be higher than carbon stock in naturally-regenerated forests, such as in the case of degraded land in protection forests not being converted into forest plantations. The forestry and agricultural programs in this scenario, however, resulted in an increase in income of USD 38 million at provincial level. The REALU scenario in Gia Lai would substantially escalate provincial carbon stock by as much as 28 Mton CO_2 eq, with additional income of USD 284 million at provincial level. The high economic gain corresponded to greater economic benefits from the litsea-cassava agroforestry system than from shifting cultivation with cassava monoculture.

In Thua Thien Hue, the provincial carbon stocks were comparable between BAU and AFPE (Table 23). However, forestry and annual-crop interventions under the AFPE would bring an additional USD 5 million at provincial level. Compared to other provinces, the economic impact of AFPE would be less in Thua Thien Hue because there are less degraded forests and annual-crop land. As in Gia Lai, the REALU scenario in Thua Thien Hue would result in positive impact to both provincial carbon stock and income at provincial level, relative to BAU. The additional USD 38 million income at provincial level would be driven by the higher economic benefits of the rubber-cassava system compared to shifting cultivation with cassava monoculture.

In Phu Tho, as in the other provinces, the AFPE scenario would mainly bring economic benefit rather than increases in carbon stock (Table 23). REALU would increase both income and carbon stock although the impact on income at provincial level would be less compared to Gia Lai and Thua Thien Hue owing to comparable economic benefits between acacia-cassava agroforestry and shifting cultivation with cassava monoculture.

4. Discussion

Government targets for production forests

To meet the national demand for timber, national and sub-national governments set targets for timber production, supported by a planned increase in the land area of production forests.

In Ben Tre, which had almost no production forest by 2014, the provincial government targeted 18% of forest land to become production forest by 2020. In Gia Lai, where 70% of the total forest area was production forest in 2014, the target was to increase to 90% by 2020. In Thua Thien Hue, the target was an increase of around 17% of the area of production forest, from 43% in 2014 to 60% in 2020. In Phu Tho, however, the target was an increase in the area of production forest by just 1%, from 71% in 2014 to 72% in 2020.

From both biophysical and socio-economic perspectives, it is important that the Government select proven, suitable tree species for the planned expansion of production forests and forest plantations. In 2015, local media reported[3] that the Gia Lai provincial People's Council was informed of the failure of a rubber-based afforestation program. Local authorities and investors had aimed to convert 66,457 ha of forest land into rubber plantations by 2020. However, 10.20% of the young rubber trees died and 65.20% grew very slowly. The degraded and rocky soils of the converted forest land in the mountainous areas of Gia Lai were not suitable for rubber trees. Introducing exotic tree species to the province should be based on a sound land-suitability analysis or at least detailed local knowledge on tree suitability and historical tree cover. The same should applies for annual crops. In our study, the proposed agroforestry intervention for the uplands included only traditional crops that had been cultivated in monocultural practices or in mixed systems,

[3] http://english.vietnamnet.vn/fms/environment/148831/viet-nam-s-afforestation-program-fails.html

for example, cassava. Cassava is one of the main agricultural products in mountainous regions of Viet Nam. It is used for domestic consumption, sale, processed into fodder, flour or other food items, as well as ethanol (Hoang et al 2015). Agricultural interventions developed based on local practices usually bring less risk of failure and are more welcome by local people.

The targeted increase in the area of production forests by as early as 2020 is driven by national demand for timber, especially, from the country's furniture sector. Viet Nam still imports 80% of its timber for this sector. Short-rotation acacia plantations for pulp and paper dominate the production-forest sector, hence, the Government is seeking alternative models for long-rotation timber plantations to encourage farmers to shift systems. Chapter 4 explores some alternative forest plantation models for Central Viet Nam that can reconcile livelihoods and environmental pressures while providing early income for farmers. The main challenge of long-rotation systems is overcoming the gap in farm income before the timber is harvest. Thirteen alternative models are examined, including integrating native-tree species and forest understorey into traditional acacia-cassava systems.

Benefits of, and constraints to, agroforestry adoption in uplands

Depending on the available market, the economic benefits of agroforestry with annual crops in uplands can be either superior or inferior compared to monocropping. From the environmental side, however, the benefits from agroforestry are much more than merely carbon sequestration as projected by the model. For example, the traditional farming systems in the uplands of Viet Nam have been challenged by serious erosion problems. Agroforestry systems are proven to have a much lower erosion rate (for example, Nguyen et al 2008, Hoang et al 2013, The 2003). In many cases, poor indigenous farmers as well as migrants have no choice but to clear forests for staple-food farming systems, such as upland rice or maize. Multi-strata and multi-product farming systems, such as agroforestry, are thus more suitable to develop in these areas for environmental protection as well as income stability. Hoang et al (2013) reported an effort to replace maize monocropping with contour plantings of different kinds of timber or fruit species as well as grass strips. The early years of the plot-level trials proved the effectiveness of agroforestry systems in reducing soil erosion and provided insight for farmers and authorities on different types of farming systems that can achieve multiple benefits. There was also an increased awareness that introducing a more profitable and environmentally-sustainable agricultural practice like agroforestry was very important for the livelihoods of people in the uplands, which are the dwelling places of most ethnic minorities in Viet Nam (Viet Nam News Agency 2014).

In their study in three different mountainous regions of Viet Nam—Northeast, Northwest and Northcentral Coast—Mulia et al (2016) found that lack of knowledge of land suitability and plot-management skills were the main constraints to tree planting, followed by other factors such as poor market access, limited financial capital, low-quality seedlings, and limited land availability. Related to mixed systems like agroforestry, the lack of knowledge included poor information about suitable combinations of tree and crop species and plot-management practices such as shade and tree density. Both male and female farmers at the study sites identified these constraints. Farmers also acknowledged that they could not readily adopt agroforestry. For instance, Nguyen et al (2008) introduced contour planting and hedgerow systems to prevent soil erosion in the uplands of southern Viet Nam but only a few farmers implemented the new practices. The extra work in plot management and the costs of the intercropped systems compared to the traditional monocultural cassava practice were not overcome by the extra income. Moreover, sacrificing current production in the hope of improvement in the long term is a risk that most farmers, especially the poor, are reluctant to take. It has been reported that the transaction costs for agroforestry development are generally high but when well managed and designed with suitable trees and crops, agroforestry can bring a lot of benefits for both livelihoods and the environment (for example, van Noordwijk et al 2014, Hoang et al 2015, Mwalwanda et al 2011). Therefore, overcoming the barriers to agroforestry adoption should prioritize the dissemination of knowledge about selection of trees and crops, ways to decide on the suitability of land, and suitable plot-management techniques for mixed systems.

To date, high values for agricultural products in Viet Nam have been achieved through intensification and land sparing. Intercropping and mixed systems as a land-sharing approach are often perceived as unproductive, either by local authorities or farmers or both, thus, do not fit well with a high-productivity-oriented agricultural strategy. However, with rapid population growth—the country's population in 2020 is estimated to reach 100 million—that implies evermore limited land for agriculture and forestry, the need for developing intercropping and land-sharing approaches will become more pertinent in the near future. The trade-offs between the land-sparing and land-sharing are not well studied nor well understood, particularly at landscape level, in the different biophysical and socio-economic conditions of the agro-ecoregions of Viet Nam. From the point of view of households' livelihoods, land sharing might not seem attractive but from a wider perspective, such as that of a multi-functional landscape, combining land sparing and land sharing can reconcile the pressure on both livelihoods and environment and lead towards a more sustainable agricultural system and rural landscapes. The simulated scenarios provide insights on how to go about this both within, and outside, forests.

Rewards for environmental services

Sunderlin and Ba (2005) mentioned different ways forests could contribute to poverty alleviation: 1) conversion to agriculture; 2) sale of timber and non-timber forest products; 3) rewards for environmental services; 4) employment; and 5) indirect benefits, for example, local people can indirectly draw economic benefit thanks to the infrastructural or logistical requirements close to new production forests.

In this chapter, we have seen that economic benefits from smallholders' forests only come from product sales. However, since Viet Nam formulated a regulation for payment for environmental services (PFES) promulgated as Decree 99/2010/ND-CP, another economic benefit can be derived from increasing tree cover inside, and outside, forests.

Decree 99 and its recent revised version, Decree 147, however, only regulate payments for water services, not other forest environmental functions, such as carbon sequestration or biodiversity conservation. Owing to this, farmers receive more economic benefits if their forest land is located within a watershed and there is a buyer for the water service. Decree 99/147 sets a lower threshold for payment rates for forest watershed services that are mandatory for hydropower plants, drinking water companies, tourism activities or other water users. The thresholds are VND 36 (≈ USD 0.001) per kW for hydropower plants; VND 52 (≈ USD 0.002) per m^3 for drinking water companies; 1–2% of total revenue for organizations or individuals operating tourism businesses; and for industries using water directly from the source, the government will determine the rate after discussing with ministries or agencies, depending which sector the companies relate to.

A government body called the Forest Protection and Development Fund manages the funds and allocates them to individuals, communities or enterprises that manage forests. The Decree mentions carbon as one of the forest environmental services but does not specify a price. The Decree also permits a direct payment modality where forest owners directly link to, and negotiate with, buyers of environmental services, although it provides no guidance.

An evaluation was underway at the time of writing, with a possibility of amending the PFES law after about five years of implementation. A national workshop on PFES monitoring and evaluation reported that the total PFES fund in 2015, with data from 34 provinces, reached VND 1.15 billion (≈ USD 52 thousand). This was important income for the forestry sector although the amount that individual farmers received could indeed be very low (for example, Pham et al 2013). Hence, an amendment to the Decree to include other forest environmental services is very necessary.

There have been efforts to reward poor farmers in the uplands for the environmental services their forest land provided, such as the Rewarding Upland Poor for Environmental Services (RUPES) project. It was applied in some provinces of Viet Nam (for example, The et al 2004). This scheme was not specifically designated for forest land because although the dominant land type might be categorised as forest, in practice, the land was used by local people to cultivate annual crops. The rewarded environmental services could relate to watershed services, biodiversity conservation or carbon sequestration. Agroforestry interventions with their higher tree densities compared to monocultural crops, could belong to the scheme and attract some rewards for their additional environmental services.

5. Conclusion

It is possible for the authorities in the four study provinces to develop land-use strategies that promote both livelihoods and environmental benefits, more than are obtained from the current strategy. This can be achieved through land-sparing and land-sharing approaches, allocating some areas of land mainly for income generation and others for carbon sequestration and other environmental services.

We conclude that the following land-use strategies deserve serious consideration by the four provincial authorities. Further, the strategies could be adapted for deployment throughout Viet Nam.

1. The Government's target for production of timber from plantations should be achieved only from production forests because expansion into degraded protection forests will, in the long run, likely result in more inferior cumulative carbon storage compared to naturally generated forests, which is the case when degraded land was not converted to forest plantations.
2. In degraded land in protection and special-use forests, enrichment with native forest-tree species to accelerate restoration will confer higher carbon storage without any economic loss compared to the baseline. Co-investment schemes can be developed to cover the costs of tree seedlings. For the native tree species, quality seedlings are usually provided by local nurseries.
3. Integrated farming systems with trees on upland sloping land can provide substantial environmental and economic benefits, especially in the long term, while the monocrop systems are threatened by many environmental risks—such as degrading soil quality and

erosion—and economic risks owing to market volatility of the monocrop. Multi-strata and multi-product agroforestry systems can enhance local people and landscapes' resilience.

4. Positive impact on both household income and total carbon stock in a landscape compared to the baseline can be achieved through combining agricultural and forestry programs and planting trees both inside, and outside, forests.

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