TOWARDS LOW-EMISSION LANDSCAPES IN VIET NAM

The World Agroforestry (ICRAF) in Viet Nam

2018

World Agroforestry

Edited by

Rachmat Mulia
Elisabeth Simelton

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Preface

Southeast Asia, a very dynamic, rapidly growing and densely populated region, is one of the world's most exposed areas to the effects of climate change. Development achieved so far has often been at the expense of the environment and its natural resources.

The International Centre for Research in Agroforestry (ICRAF), also known as World Agroforestry, is celebrating 40 years since it was founded as an international organization headquartered in Nairobi, Kenya. ICRAF's vision is 'an equitable world where all people have viable livelihoods supported by healthy and productive landscapes', with a mission 'to harness the multiple benefits trees provide for agriculture, livelihoods, resilience and the future of our planet, from farmers' fields through to continental scales'.

In Southeast Asia, ICRAF was established about 25 years ago with a regional office in Bogor, Indonesia and sub-regional and country offices in Indonesia, Philippines and Viet Nam also working across the Mekong countries. During the years, the work has expanded from the roles of trees on farms into multi-functional landscapes and integrated landscape management and integration of agroforestry into regional, national and sub-national policies and strategies. This includes research on the roles of trees and agroforestry for ecosystem services, climate-change adaptation and mitigation and for improving food and nutrition security. The aim is to enhance smallholders' incomes and livelihoods, and contribute to the development and scaling out of low-emission development in the land-based sector and stimulate 'green' growth options. In a recent publication, ICRAF scientists estimated the total agroforestry area in Viet Nam to be about 900,000 hectares and that 10 million hectares are suitable for agroforestry expansion (see Chapter 1), showing the potential of trees outside forests in mitigating climate change, building resilience and providing livelihoods' options.

Agroforestry, understood as 'agriculture with trees' or trees with crops and/or livestock, is increasingly recognized as a sustainable and profitable land use in multi-functional landscapes across Southeast Asia (coastal zones, rice-production landscapes, uplands, peatlands and highlands). This is reflected in the recently endorsed[1] ASEAN Guidelines for Agroforestry Development and associated material promoting the role of agroforestry in simultaneously achieving economic, environmental and social outcomes at farm, household and landscape levels and helping ASEAN Member States achieve their targets related to food and nutrition security, sustainable growth, reduction of greenhouse-gas emissions, land restoration, watershed protection, gender equality, social or community forestry, climate-change adaptation and mitigation and, more generally, the Sustainable Development Goals.

Viet Nam is among the countries that will lose valuable farmland to sea-level rise while agriculture production is being at risk to disaster impacts as climate change continues. At the same time,

[1] The 40th Meeting of the ASEAN Ministers on Agriculture and Forestry, 11 Oct. 2018, Ha Noi, Viet Nam

agriculture and forestry are also playing an important role in mitigating the impacts of climate change. Since the early 2000s, Viet Nam has embarked on various measures to mitigate climate change and to adapt with its impacts.

Rapid economic growth in the last decades has placed Viet Nam among middle-income countries. Nevertheless, disparities exist in economic development within and across regions, and particularly, between urban and rural areas. In the context of climate change, economic development must be accompanied by a strong awareness and corresponding effort in mitigating, and adapting to, climate change to ensure sustainable economic development.

ICRAF officially started its operations in Viet Nam in 2007. Since its beginning, ICRAF Viet Nam has been actively involved in studies and research, covering different aspects of agroforestry's contribution to low-emission development pathways. It has become a well-known and respected institution in the country, contributing to research, capacity development and transformational change in rural landscapes. ICRAF Viet Nam has also been supporting policy development to include agroforestry in the Forest Law and help bridge the agricultural and forestry sectors.

The aim of this book is to give a picture of ICRAF Viet Nam's contributions to ASEAN and Viet Nam country commitments towards achieving the Sustainable Development Goals (SDGs) and green growth. Acknowledging that the 17 SGDs are interdependent, our main focus is on those to end poverty (#1), food and nutrition security and sustainable agriculture (#2), achieve gender equality and empower all women and girls (#5), combat climate change (#13) and sustainable use of terrestrial ecosystems and biodiversity (#15).

The book contains recent ICRAF Viet Nam studies linking the country's commitment on green growth and SDGs with ICRAF's vision on transformed lives and landscape with trees. It presents a compilation of ICRAF Viet Nam's research during the past decade that relates to low-emission development and describes a possible way the country can achieve its desired form of development, namely, through developing low-emission and integrated land-use planning with trees and agroforestry. It also provides reliable assessments of their possible impact on economic and environmental benefits. Using state-of-the-art methods in research, the authors provide insights in the spatial distribution of drivers of changes in forest types and conditions, in participatory low-emission land-use planning, in alternative systems to short-rotation plantation forests, in forests and crop-land intensification, and in developing participatory advisory services for agroforestry systems. Overall, the book sheds light on the development and maintenance of a low-emission landscape in rural Viet Nam.

With this book, ICRAF is also celebrating the 10th anniversary since its establishment in Viet Nam. We hope this book will be informative to our partners and donors and provide inspiration and examples of the opportunities that agroforestry can provide for landscape restoration, sustainable natural resources management, climate-change adaptation and mitigation and rural development and livelihoods' improvement, including linking smallholders to markets.

This publication would not be possible without the leadership and contribution of Hoang Minh Ha and Delia C. Catacutan, the two former country coordinators of ICRAF Viet Nam between 2007 and 2018. We would like to acknowledge their contribution to the work of ICRAF in Viet Nam and sincerely thank them for their great efforts in support of ICRAF Viet Nam's operations and growth.

Ingrid Öborn
Regional Coordinator for ICRAF Southeast Asia

Tan Quang Nguyen
Country Coordinator for ICRAF Viet Nam

Acknowledgments

This volume is a compilation of research by the World Agroforestry (ICRAF) Viet Nam in the past decade that relates to low-emission development in the country. Numerous people and institutions both public and private, including donors, were involved in the studies and provided their valuable comments and suggestions to add to the quality of the work. We wish to express our sincere gratitude to all these contributors. Although we cannot mention all individually, a few require specific recognition.

First, we gratefully acknowledge the donors who supported the projects and appreciated the value of our work. The studies in chapters 2, 4 and 5 were conducted as a part of the Sustaining Ecosystem and Carbon Benefits by Unlocking Reversal of Emissions Drivers in LANDSCAPES (SECURED LANDSCAPES) project. This followed on from the Reducing Emissions from All Land Uses (REALU) project, which was coordinated by the ASB Partnership for the Tropical Forest Margins. Both were funded by the Norwegian Agency for Development Cooperation.

The study presented in Chapter 3 was part of ICRAF's socio-economic, livelihoods and ecological assessment of the buffer zones of two natural reserves in the Central Annamites, namely, Song Thanh Natural Reserve in Quang Nam Province and Phong Dien Natural Reserve in Thua Thien Hue Province, funded by the United States Agency for International Development.

The study in Chapter 6 was carried out as part of the Climate-Smart, Tree-Based, Co-investment in Adaptation and Mitigation in Asia Tree-invest (Smart Tree-Invest) project, led by the World Agroforestry Southeast Asia Regional Program, in Indonesia, the Philippines and Viet Nam, with funding from the International Fund for Agricultural Development and the CGIAR Research Program on Forests, Trees and Agroforestry.

The study in Chapter 7 was implemented as part of the CGIAR Research Program on Climate Change, Agriculture and Food Security together with CARE Viet Nam. For both chapters 6 and 7, we acknowledge all donors who support research in development through their contributions to the CGIAR Fund. ICRAF is one of the 15 members of the CGIAR, a global research partnership for a food-secure future.

Numerous people have contributed in different ways with critical reviews and valuable and constructive comments to enhance the quality of the chapters. We recognise, especially, Dr Betha Lusiana, Dr Beria Leimona, Dr Peter A. Minang, Dr Atiek Widayati and Prof Meine van Noordwijk. The authors of Chapter 2 would like to thank Hoa Thi Nguyen and Bac Viet Dam who helped in data collection and analysis. The authors of Chapter 5 wish to thank Lisa Tanika who aided in conducting hydrological assessment.

Finally, our sincere gratitude to the project partners and local staff at the study sites where the works presented here were conducted. We appreciate, particularly, the endorsement and support from the provincial and district departments of Agricultural and Rural Development, departments of Natural Resources and Environment, provincial and district People's Committees, Forest Management Boards, forest rangers, extension services and the Farmer's Union. Ultimately, our work depends on the active engagement of village leaders and numerous smallholding female and male farmers, in surveys, discussions and other work at the field sites.

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Agroforestry and contour planting in Northwest Viet Nam (Photo: World Agroforestry/ Mai Phuong Nguyen)

Introduction

Rachmat Mulia and Elisabeth Simelton

Poverty, food security and climate change are central global issues and Viet Nam is no exception. The country's efforts to open its economy to foreign trade and investment have contributed to high GDP per capita growth rates over the past two decades and a drastic reduction in poverty: from nearly 70 percent of the population in the 1990s to less than 10 percent in 2015[2] . However, the multi-sector economic growth has also had unfavourable impacts on the environment, in particular deteriorating quality of land and water, and decreasing natural forest cover and biodiversity.

About 65% of Viet Nam's population lives in rural areas, with livelihoods highly reliant on the agricultural and forestry sectors. Thanks to the Đổi Mới reform, the agricultural sector has provided important contributions to the economy. Exports of major agricultural products such as rice, rubber, coffee, cashew nuts, and fishery products have steadily increased, resulting in substantial poverty reduction, at an impressive rate of 2% per year. Globally, Viet Nam is the biggest exporter of pepper, among the top-five rice exporters, and second only to Brazil for coffee. This achievement reflects the country's potential contribution to global food supply.

There are emerging risks in production and market volatility, disparity in economy among rural and urban areas and among regions in the country, as well as lack of knowledge of conservation techniques to limit soil degradation. Furthermore, extreme weather events and natural disasters related to climate change, such as storms, floods, droughts and associated outbreaks of pests and diseases, affect the country every year, resulting in substantial economic losses to the nation and rural communities, and degradation of land and water. The most vulnerable communities to such socio-economic and environmental shocks are those who live in mountainous and remote rural areas, which often are characterised by high poverty rates. Reconciling the economic and environmental pressures will require a low-emission development strategy that encompasses the whole landscape, both forestry and agriculture lands, and that incorporates the socio-economic targets in both sectors, as well as in national strategies on climate change, sustainable development, and environmental protection.

Forestry sector strategies and targets

In the forestry sector, Viet Nam is well known internationally for moving forward along the ‘forest transition curve’. The country’s target is a forest cover of about 42 percent by 2020, for both production and protection purposes. In terms of timber production, the Ministry of Agriculture and Rural Development (MARD) has an export target value of over USD 7.5 billion by 2020, to be met through sustainable forest management practices.

[2] Based on USD 1.25 per capita income per day following the World Bank’s poverty standard

The 2006-2020 National Forest Protection and Development Strategy which builds on the 2001-2010 Forestry Development Strategy approved by MARD outlines the direction of the forestry sector in different regions and lists targets to be achieved through the contribution of smallholders' tree plantations in the region.

The northern mountainous area consists of the Northwest and Northeast regions, which is the home to many ethnic minorities and also challenged by high pover.
Based on the 2006-2020 National Forest Protection and Development Strategy, in the Northwest, the targets aim to 'diversify income sources on the basis of social forestry development, gradually reduce and replace shifting cultivation by agroforestry for forest protection and development and improvement of livelihoods for communities' and to 'establish material supply areas for the timber-processing industry (paper, wood-based panels) and non-timber forest products'. For the Northeast, the targets aim to 'establish material supply areas linked with processing industries to meet essential demand for paper, woodchips, pit props, and furniture on the basis of intensive cultivation of 1.5 million hectares of production forests (including natural and plantation forests) and use high productivity sites on nearly 1 million hectares of bare land for establishment of industrial, concentrated, material plantations.' The role of smallholders is stressed to reach these aims.

In terms of forest plantations, one of the most popular systems is short-rotation acacia for the pulp and paper industry. Acacia has been promoted for about three decades in the afforestation programs to also restore soil fertility in degraded sloping land. Acacia has helped smallholders across the regions improve their economic condition.

To further improve economic returns as well as environmental benefits, such as carbon storage, that can be derived from the system, there is a need to design more permanent forest plantation systems for timber production. Currently, 80% of the national timber demand is satisfied by import. The main challenge facing farmers considering adopting more permanent forest plantation systems is to find ways to cover the income gap between investment and timber harvest, especially among those who depend on forest plantations as their main source of income.

Agriculture sector strategies and targets

Challenges in the agricultural sector include enhancing the resilience of farming systems and rural landscapes to climate change variability. Natural disasters reduce the agricultural productivity and pose extreme costs to the agriculture and forestry sector every year. In response, the National Strategy on Climate Change has set targets to 1) reduce greenhouse gas (GHG) emissions by boosting 'green' and low-emission agricultural production; 2) mitigate damage caused by natural disasters, including the prevention of erosion and degradation; 3) improve and strengthen institutions and rural communities, encouraging participation from non-governmental and civil society organisations; and 4) build communities that can effectively cope with climate change by developing and diversifying local production strategies that support adaptation.

The country's priority climate-change adaptation strategy for 2021-2030 aims at 'ensuring food security through protecting, sustainably maintaining and managing agricultural lands'. At the time of writing, the Government is in the process of reformulating targets for national GHG emissions to better comply with the Paris agreement on climate change. The GHG mitigation efforts have focused on the energy-related sectors, industrial and agricultural production, land-use, land-use change and forestry, and waste. The reformulated target is to reduce emissions by 8% by 2030, and by 25% with international support. The target for the a agricultural sector is to contribute to 10% of the national emission reduction, and 23% with international support. Recently, the significance of the agriculture sectors in adapting to and mitigating climate change has been officially acknowledged through the Koronivia joint work on agriculture decided at COP23.

Strategies and targets on biodiversity conservation and land degradation

Viet Nam's commitment to the Convention on Biological Diversity by formulated in conservation strategies promulgated by the Ministry of Natural Resources and Environment. For example, the National Biodiversity Strategy to 2020 and Vision to 2030 aims to conserve 'naturally important ecosystems (including forests), endangered, rare, and precious species, and genetic resources; that should be used sustainably, and contribute to the development of a green economy, and actively respond to climate change'. The Strategy also highlights the on-farm conservation and agro-biodiversity.

Viet Nam ratified the United Nations Convention to Combat Desertification (UNCCD) in 1998 and developed a National Action Plan for implementing the Convention in 2002. For Viet Nam, combating desertification is mainly about reducing deforestation, degradation of agricultural lands, and drought. Implementation has focused on 1) programmes and projects that prevent deforestation, soil erosion, moving sand dune, land salination and acidulation; 2) reclaiming degraded land; 3) sustainable land use and use of water resources; and 4) forecasting and preventing droughts and floods. At the Twelfth Conference of the Parties to the Convention, held in Ankara, Turkey in 2015, it was agreed that Sustainable Development Goal criterion 15.3, including Land Degradation Neutrality (LDN), should be one of the measures supporting the implementation of the Convention. The Convention parties establishes voluntary targets for LDN and integrate into their national action plans. The Viet Nam's Voluntary National LDN Targets for the period of 2017-2020 with vision to 2030 has formulated targets for 13,048 km^2 of degraded land in the country.

Low-emission development pathway

In 2017, the Government promulgated a new Law on Planning. Focuses on the integration of multi-sector development planning rather than individual sectoral master plans as before, to lead towards environmentally sensitive and sustainable economic growth.

Each province must develop an integrated master plan to formulate and harmonize strategies and targets for different sectors, and pathways to achieve the targets. The master plans should be oriented towards green growth, characterized by low-emission economic development. Natural resources, such as water, forests, soils, biodiversity and ecosystem services are to be safeguarded to speed adaptation to climate change.

Aims of this book

This book covers some of ICRAF Viet Nam's key research over the past decade. We selected work that contributed to integrated land-use planning for low-emission development strategies in rural landscapes.

Three studies (Chapter 2, 4 and 5) were conducted as part of a programme that was developing land-use options for reducing GHG emissions from all types of land, not only forestland. Although the chapters present results from 2012-13, the land-use strategies developed in these studies continue to be relevant nowadays.

For example, the results recommending agroforestry as a strategy for reducing emissions and enhancing livelihoods in the uplands (Chapter 5), can be found in the 2006-2020 National Forest Protection and Development Strategy, which states "to diversify income sources on the basis of social forestry development, gradually reduce and replace shifting cultivation by agroforestry for forest protection and development and improvement of livelihoods for communities". Furthermore, the new Law on Forestry in effect from January 2019, permits certain types of agroforestry in production and protection forests for development and conservation purposes. In the 2011-2020 National Strategies on Climate Change, agroforestry is taken as example for land-use that can reduce GHG emissions and boost 'green' and low-emission agricultural production, as well as strengthening resilience to natural disasters and prevent land degradation.

The other three studies (Chapter 3, 6 and 7) in this book are more recent (2015-2018) and ICRAF's work continues to bring evidence to policy dialogues, including assessing the possible roles of agroforestry for Viet Nam's targets to international conventions, such as the Nationally Determined Contributions.

The research has been *inclusive, integrative* and *informative*. *Inclusive* because the research includes strategies for both forest and agricultural land, for socio-economic and environmental objectives including hydrological functions, and was developed through participatory processes that took into account the perspectives and expectations of smallholders, local and national authorities, and scientists. *Integrative* because the research integrates diverse factors when assessing the impact of the strategies on the multiple functions of landscapes. *Informative* because the approaches were scientific and the findings were provided to national and provincial authorities and local communities.

The book consists of six chapters, formatted in the style of scientific papers. All research presented in this draws on original unpublished work from ICRAF's projects in Viet Nam with fieldwork conducted at different points in time.

The chapters encompass the main aspects to be considered when developing sustainable and low-emission development pathways. They also consider the projected impact of the strategies, mainly on the economic benefits as represented by smallholders' or provincial income; and environmental benefits as represented by carbon storage and hydrological functions.

- *Proximate and underlying factors, and actors of forest cover change* (Chapter 2). The chapter presents the case in Bac Kan province as one of the REDD+ pilot provinces in Viet Nam, with analysis of proximate and underlying factors, as well as actors of forest cover change between 1990-2010, and projected forest cover in the province by 2020.
- *Developing alternative forest plantation systems for enhanced economic and environmental benefits* (Chapter 3). This chapter highlights short-term acacia plantations for pulp and paper which is a popular forest plantation type. It describes eight alternative forest-plantation systems for Quang Nam Province, Southcentra Coast region that are expected to provide higher and more stable incomes and more environmental.
- *The role of participatory land-use planning in reconciling targets of conservation and economic development* (Chapter 4). This chapter demonstrates the use of the Land-use Planning for Low-Emission Development Strategies (LUWES) framework in multi-stakeholder negotiations for developing a participatory, low-emission, land-use plan for Bac Kan Province, Northeast region. Through LUWES, the different

impacts on conservation and economic development are compared using a 'top–down' approach and a participatory land-use planning approach.

- *Strategies to reduce emission from all land-uses* (Chapter 5). This chapter provides examples of strategies to reduce emissions from forest land as well as land outside forests at landscape level. The Reduced Emissions from All Land Uses (REALU) strategy which integrates the replacement of upland annual crops with agroforestry and restoration of degraded forests. The impact on economic benefits was assessed as income per capita and on environmental benefits as carbon storage.
- *Impact of land-use strategies on the hydrological function of a watershed* (Chapter 6). Many strategies for sustainable and low-emission pathways are concerned with carbon sequestration and economic benefits. However, when applied to a watershed the impact on hydrological functions also needs to be assessed. This chapter presents the case of Ho Ho sub-watershed, Northcentral Coast region of Viet Nam, where watershed functions were assessed for three forest-intensification strategies as part of provincial government plans. This case shows how expectations of local communities on the interventions and their watershed functions are included in the assessment.
- *Providing farmers with agro-climate advisories for integrated and agroforestry systems* (Chapter 7). Agroforestry has been widely recognized as a climate-resilient farming system. Still customized seasonal weather forecasts are needed combined with participatory agricultural advice, to reduce weather-related losses. This chapter demonstrates how farmers can be involved in co-producing agro-climate information, using the example of My Loi, a 'climate-smart village' in Northcentral Coast of Viet Nam.

Tree cover in Bac Kan province, Northeast Viet Nam (Photo: World Agroforestry/Rachmat Mulia)

CHAPTER 2

Drivers of forest changes: mapping actors and motivations in Bac Kan province, Northeast Viet Nam

Mai Phuong Nguyen, Delia C. Catacutan, Hoan Trong Do, Rachmat Mulia

Summary

Forest cover in Viet Nam has significantly increased since mid1990s, reportedly as a result of numerous policies and programs that support forest land allocation, protection and development. However, little has been understood about how such policies and programs, and furthermore local community affected local forests. Our research analysed the historical (1990-2010) and future (2010-2020) forest pathways in Bac Kan province, Northeast Viet Nam, as a pilot province for REDD+ and identified the proximate and underlying factors as well as the actors involved. Spatial analysis of time-series, land-cover and forest-ownership maps was conducted at provincial level with the support of household surveys in some communes and districts.

Results indicated that illegal logging and shifting cultivation, coupled with weak forest management, were the main causes of forest degradation between 1990 and 2000. Reforestation programs, followed by financial support and land allocation, were identified as factors driving reforestation and afforestation throughout the entire period. Moreover, Program 147, which supported the conversion of natural forest to planted forest, was the driver of both forest gain and loss from 2008 to 2020. Policy makers and households were, therefore, the key actors in the process. We expect the results of this study can help slow the process of forest loss by contributing to policy improvement. The criteria of natural forest to be converted to forest plantation under Program 147 should be clarified to avoid natural forest loss in the future.

1. Introduction

The Intergovernmental Panel on Climate Change (IPCC) reported in 2007 that more than 20% of global greenhouse-gas emissions came from tropical deforestation (Pachauri and Reisinger 2008). Compared to the 1990s, global deforestation between 2000 and 2010 decreased but still remained high. During this period, approximately 13 million hectares of forests were lost each year, according to the Global Forest Resources Assessment Report in 2010 by the Food and Agriculture Organization (FAO 2010a).

Subsequently, forest carbon stocks decreased by 0.5 Gt/year. A key driver of this forest decline was agricultural expansion. This process was counterbalanced by large-scale reforestation and afforestation in many parts of the world, particularly, in China. Positive results from reforestation programs included a reduction in global forest loss from 8.3 million hectares per year between 1990 and 2000 to 5.3 million hectares per year in 2010. Planted forest accounted for 7% of the global forest area in 2010 (FAO 2010a).

Viet Nam is among the world's nations in which forest cover has been increasing. The total forest area of the country has increased from 28% in 1990 to 38% in 2006. According to FAO, Viet Nam's forest cover increased 0.5% annually during the period 2000–2005 (FAO 2010b). Reforestation activities were implemented in mountainous areas since the 1990s (Castella et al 2002). Meyfroidt and Lambin (2008), indicated that the increase in forest cover was caused by regeneration of natural forest and forest plantation and that the area of forest restoration was larger than the area of deforestation. Their research also found that forest biomass changed owing to forest degradation and regeneration.

Most studies on forest transition in Viet Nam have focused on reforestation and the impact of policies on the increase of forest plantation (Clement 2009), as well as the roles of farmers in decision-making related to reforestation. Researchers have focused on either the spatial aspects of forest transition or on a theoretical approach to analyse the relations between forest changes and policies and farmers. However, there has been a lack of analysis of actors involved in the transition process.

To meet this gap, this study focused on the proximate and underlying factors as well as actors with respect to forest change. There are a number of studies focusing on drivers of forest changes such as proximate causes of deforestation (Rademaekers et al 2010, Müller et al 2012), illegal logging in South East Asia (Rosander 2008) drivers of deforestation and forest degradation (Hosonuma 2012, Kissinger 2012) or causes of reforestation (Meyfroidt and Lambin 2008). However, forest-cover changes are not only the result of complex interactions between, and amongst, biophysical, social, economic and policy factors but also agents, including households, government, organizations, trading companies and others (Meyfroidt et al 2008). Our study was guided by the hypothesis that drivers of forest-cover transition are space- or time-dependent and that knowledge of past drivers in a certain landscape cannot be directly extrapolated into the future yet there may be predictability in the succession of drivers. The study was implemented in Bac Kan Province, in Northeast Viet Nam as one of pilot provinces for REDD+.

Forest gain and forest loss in Bac Kan province were identified by using spatial analysis, surveys, and focus group discussion. There are various factors, such as agricultural expansion or governmental policies, which have affect the cover of forests. Those factors can be categorized into underlying factors or proximate factors. The proximate factors provide a direct link with the changes of forests while underlying drivers made their own impacts through proximate factors.

Forest restoration and reforestation policies in Viet Nam (1990-2010)

Viet Nam's forests are divided into three categories: 1) special use; 2) protection; and 3) production forests. The function of special-use forests is to preserve natural forest resources and to protect ecosystems, biodiversity, sources of species, natural beauty for ecotourism, and sources of livelihoods. Protection forests' main purpose is to protect and enhance landscape functions, such as water regulation, control of soil erosion, and mitigation of natural disasters. Both special-use and protection forests are managed by the Community People's Committees at sub-provincial level, the Department of Agriculture and Rural Development (DARD) at the provincial level or the Ministry of Agriculture and Rural Development (MARD) at the national level. Production forests, which include planted and natural forests, are expected to address the demand for timber and are allocated to households, individuals, state forest enterprises and private concessionaires (MARD 2012).

Forest policies began in 1986 with Đổi Mới, a program that aimed to reform the economy, followed by a number of forest and land laws (Table 1). Based on these provisions, forest and agricultural land was allocated to smallholders. Decree 327 focusing on barren land restoration (Government of Viet Nam 1995), Program 661 supporting 5 million hectares of forests (Government of Viet Nam 1998) and Decree 147 (Government of Viet Nam 2007) about improving natural and planted forest are the three main forest policies and programs. Through those programs, the government provided credit and distributed seedlings to stimulate the establishment of plantation forests as well as improvement of the quality of existing natural forests with native timber tree species. Other stakeholders-such as provincial, district and commune governments, village leaders, military, forest management boards, non-governmental organizations and forest enterprises-also engaged in the process. Many overseas development assistance funds, such as from Germany and Belgium and international organizations, were mobilized for both restoration and reforestation. As a result of all these efforts, the area of planted forest increased from 425,504 hectares in 1990 to 3,218,388 hectares in 2010 (MARD 2010).

Table 1. Summary of land and forest policies in Viet Nam (1990-2010)

Year	Policy	Key provisions
1986	Renovation program (Đổi Mới)	Economic reform was implemented, which led to substantial development in agriculture and rural livelihoods (Kerkvliet and Porter 1995)
1991	Forest Protection and Development Law	Allocation of forestland and uplands to farmers

1992	Decree 327	Reforestation initiative with the aim of increasing tree cover on barren land and enhancing agricultural production. The program introduced contracts between government and households to protect forests (Clement 2009)
1993	Land Law	Land in agricultural, forestry and aquacultural sectors was allocated through contract to organizations, households and individuals (Tan et al 2008). The law provided more detail for the process of forest land right allocation
1994-1995	Decree 01-CP, Decree 02-CP	
1998	Decision No. 661-CT/1998	Also known as the Five Million Hectare Restoration Program, objectives were to enhance forest protection and to plant 5 million hectares of forest: 2 million of production forest; 2 million of protection and special-use forest; and 1 million of fruit and industrial trees
2002	Decision No. 78/2002/QD-BNN (Ministry of Agricultural Development)	Forest tenure was classified into several groups 1. State enterprises 2. Management boards for special-use forest 3. Management boards for protection forest 4. Joint-venture companies 5. Households and individuals 6. Collectives 7. Armed forces 8. Commune people's committees
2003	Land Law (modified)	Communities were recognized in forest-land tenure
2004	Forest Protection and Development Law (modified)	Provided more detail on forest rights, ownership and development of the forestry sector but did not mention the presence of communities in the list of legal forest owners (Tan et al 2008)
2007	Decision No. 147/2007/QD-TTg	Approved the development plan for forests until 2015, with supporting polices. The plan included forest protection and development, that is, afforestation, zoning for regeneration, plantations of scattered trees, rehabilitation of critically-poor natural forest, and improved quality of forests Decision 147 also encouraged the allocation of forestland to communities, households, individuals, organizations and enterprises and allowed the conversion of poor-quality natural forest to forest plantation

Figure 1 shows the forest transition in Viet Nam over 60 years, linked with the key forest policies described above. In 1943, forests accounted for almost half the total land area. Forest cover was at its lowest from the late 1980s to the early 1990s, with a total area of just 27.2% in 1990. With Decree 327 in 1992, and forestland allocation policies, the percentage of forest cover increased rapidly from to 33.2% in 1999. Following this, forest cover gradually reached 39.5% of total area in 2010 with support from Program 661 (1998–2007) and Program 147 (2007–2010) (de Jong et al 2006, Viet Nam Forestry 2007, 2008, 2009, 2010, 2011).

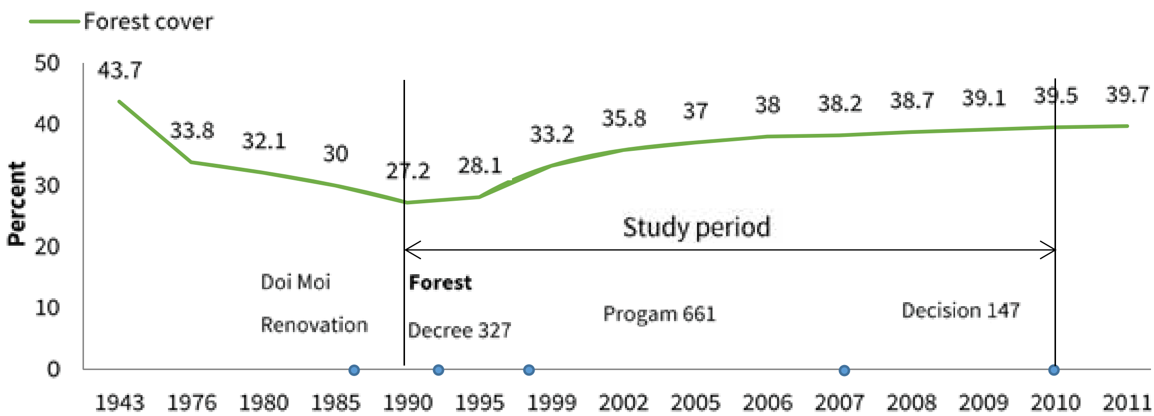


Figure 1. Percentage of forest cover in Viet Nam and key forest policies, 1943–2011

2. Methodology

Study site

Bac Kan is a mountainous province in the Northeast region of Viet Nam, with more than 60% of its area covered by forests in 2010 (Figure 2). The main ethnic groups in Bac Kan are Tay, Dao and Nung. In 2009, the province had the highest poverty rate in the country, with an average monthly income per capita of VND 669,000 (approximately USD 35) (GSO 2010). Only 5% of the land is arable and water shortages are common. Income is mainly derived from small-scale agricultural production.

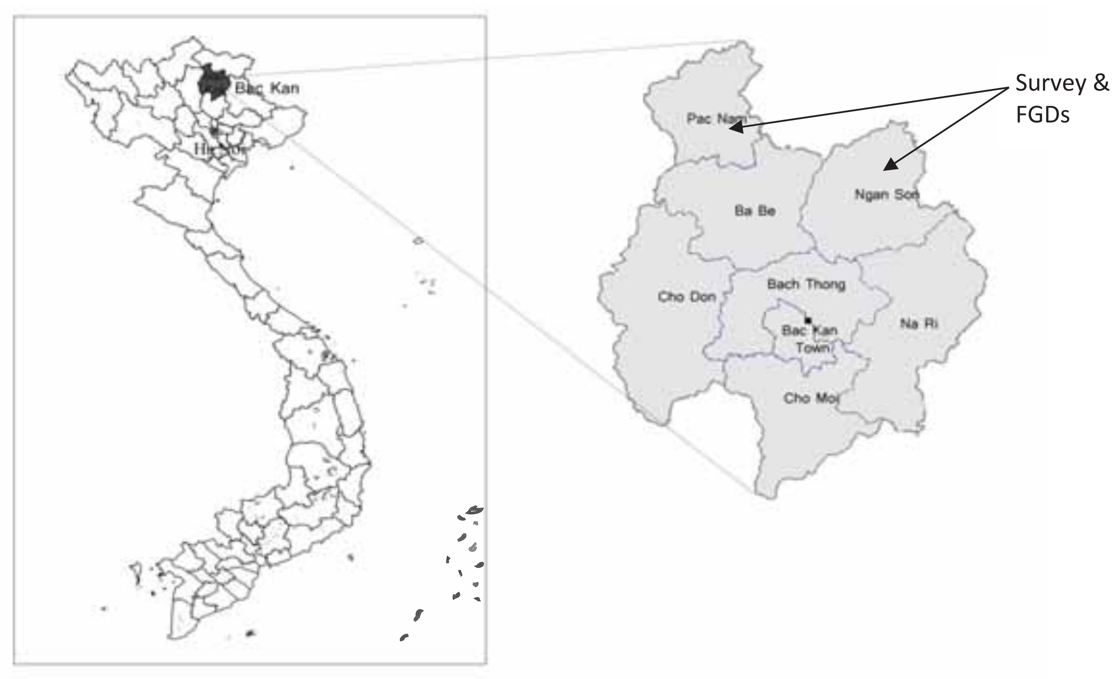


Figure 2. Bac Kan Province and study sites

Methods

Figure 3 displays our analytical framework. The spatial analysis included two data sets: 1) land-use-change data with the status of forest volumes for 20 (1990-2010) years as well as the spatial distribution of forest owners and forest-management types; and 2) supporting data, such as roads, hydrology and settlements. Overlaying time-series maps provided a broad characterization of forest-cover change along with identification of the different actors and proximate drivers.

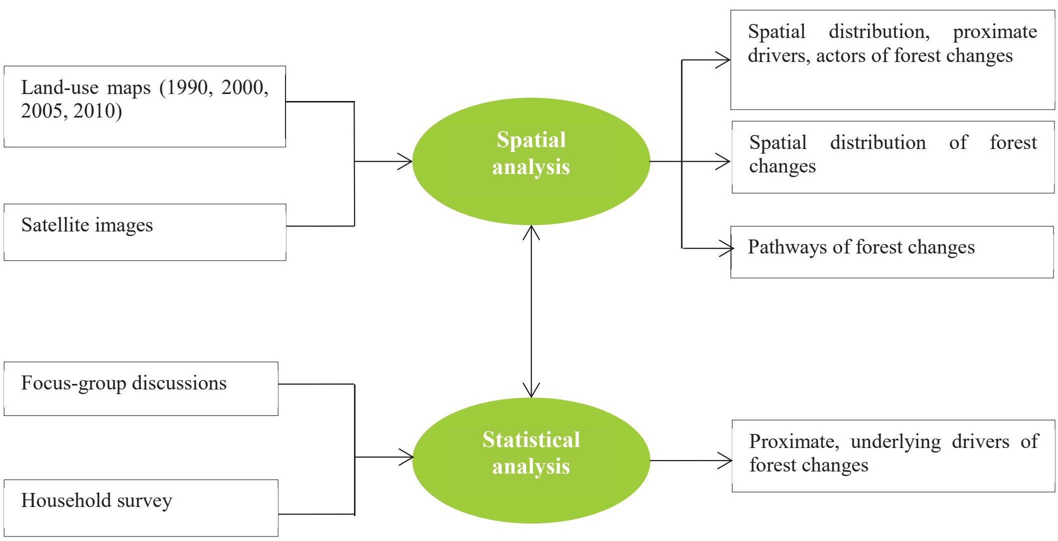


Figure 3. Analytical framework of the study

Figure 3 displays our analytical framework. The spatial analysis included two data sets: 1) land-use-change data with the status of forest volumes for 20 years (1990-2010) as well as the spatial distribution of forest owners and forest-management types; and 2) supporting data, such as roads, hydrology and settlements. Overlaying time-series maps provided a broad characterization of forest-cover change along with identification of the different actors and proximate drivers.

After examining the spatial changes in forest cover, links with proximate drivers and other GIS layers, the next step was to examine these in relation to the data obtained from household surveys, focus-group discussions (FGDs), and interviews with government officials. Based on the forest-change analysis, the areas of forest gain and loss were identified. Four villages in two communes in the districts of Ngan Son and Pac Nam, which had significant forest gains and losses, were selected for household surveys.

The FGDs at the provincial, district and commune levels helped to clarify land-use types and better understand forest-cover changes and their drivers. FGDs at the district and commune levels were carried out with partners and at the village level with farmers and village leaders. The general information gathered from the FGDs at all levels was used to design the household survey. The survey focused on the underlying factors of forest changes during 2000–2010. Interviews with commune and district officials focused on the impact of both internal and external factors on identified forest changes up to 2000. Survey data were analysed using a correlation test to identify the relationship between changes in forest cover and the drivers of those changes. Multivariate linear regression was also used to further understand the contribution of different land uses and factors to forest-cover change.

A final workshop at the provincial level was organized to evaluate the findings with the participation of 30 representatives of district people's committees, policy makers and forest-plantation companies.

3. Data

Spatial data

We developed consistent time-series, land-cover maps for 1990, 1995, 2000, 2005 and 2010 at the scale of 1:100.000 based on the forest maps of MARD and land-use maps of the Ministry of Natural Resources and Environment (MONRE). Forest maps were overlaid with forest planning map of Bac Kan province (DARD 2009) to see the trend in forest cover in the future. SPOT images were used to correct the differences between the two mapping systems. Our map classification covered a wide range of forest types and non-forest land uses. Additional layers included road and settlement distribution, forest-management boundaries and forest ownership.

Survey data and FGD information

We surveyed four villages in Ngan Son and Pac Nam districts in 2013 with a total 256 respondents-30% of the village populations-and held FGDs in communes. At each meeting, we presented a land-use map with figures of forest changes. The land-use maps showed no village boundaries because the commune is the smallest administrative unit in Viet Nam. Village heads delineated their villages' boundaries on the maps during the FGDs. Village boundaries are important for understanding what occurs on each plot of forestland. Through the FGDs, the impact on reforestation, afforestation and deforestation of forest policies and support programs, and village accessibility (road network and quality to the village and distance from the village to the district capital), were better understood.

Secondary data

To further understand the causes of forest changes in Bac Kan, we reviewed forestry policies and laws promulgated since the 1990s. Relevant information on forest fires, illegal logging, forest conversions, forestland allocation status, and forest protection were also generated. These data made it possible to analyse the relationships between the forest-cover changes, the identified factors and the political, social, and economic conditions of the province over two decades.

4. Results

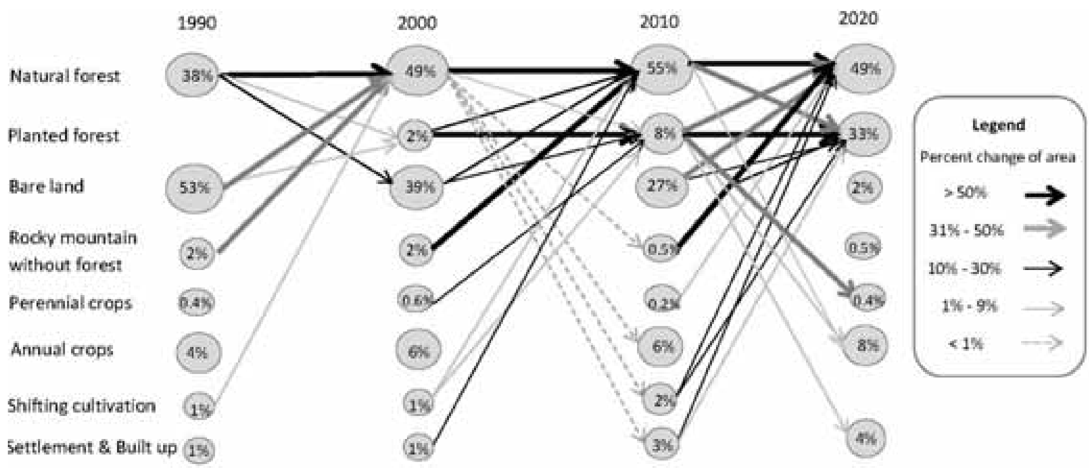


Figure 4. Pathways of land-use changes in Bac Kan Province, 1990-2020

Figure 4 shows the pathways of forest changes in Bac Kan over the 30 years between 1990 and 2020 as a result of overlaying land-use maps of 1990, 2000, 2010 and the land-use planning map toward 2020. There was little change over the period 1990–2000. Natural forest, which accounted for 38% of the total area of the province, increased rapidly, reaching 49% in 2000. Primary trends during that time included 1) the growth of natural forest by regeneration from existing natural forest and bare land; 2) planted forest increased by gaining 2% from natural forest and 2% from bare land; 3) forest was lost through conversion to bare land.

By 2000, the majority of land use was natural forest, 48%, and bare land, 39%. Planted forest accounted for only 2% and tree-based, or agroforestry, land was 1%.

After 10 years, natural forest had increased to 55%, of which 88% was existing natural forest and from 26% of bare land and 7% of rocky mountain, respectively. Those conversions represented regeneration of natural forest. Simultaneously, 3% of natural forest was converted to other land-use types, such as shifting cultivation. Projections until 2020 showed that 31% of the natural forest area of 2010 will have been converted to planted forest and less than 1% to agricultural, settlement and infrastructural land. Only 63% of natural forest from 2010 will remain after ten years.

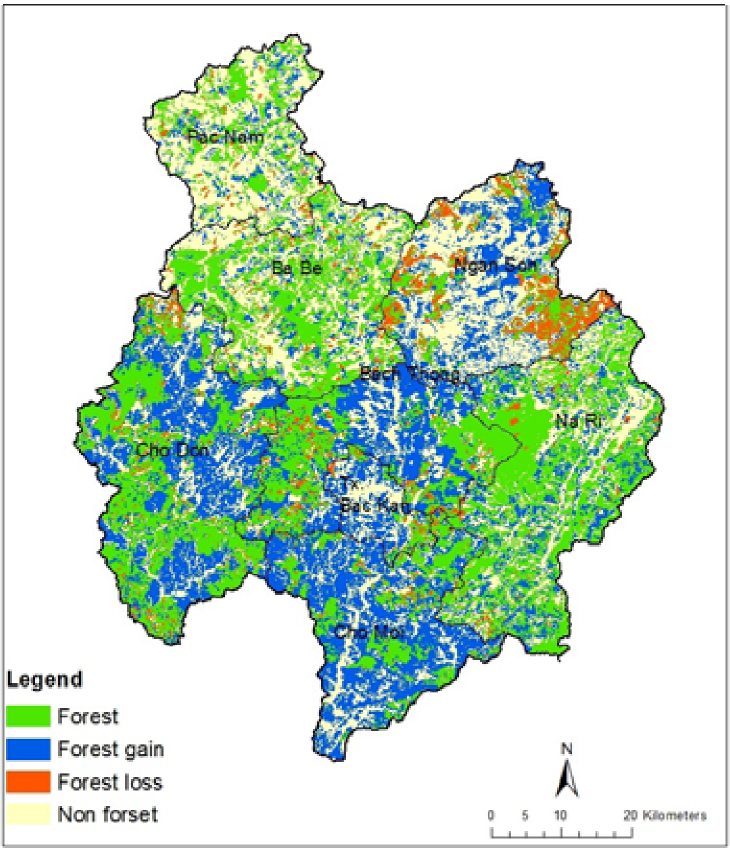
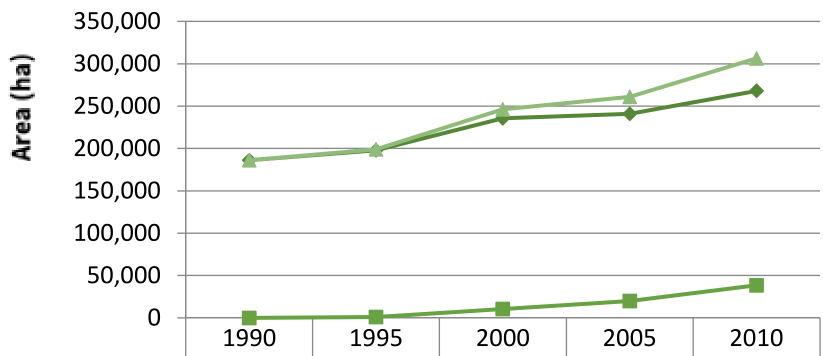


Figure 5. Spatial distribution of forest changes in Bac Kan, 1990-2010



	1990	1995	2000	2005	2010
Natural forest	186,087	197,972	235,411	240,978	267,896
Planted forest	-	829	10,631	20,054	38,515
Total forest area	186,087	198,801	246,042	261,031	306,410

Figure 6. Forest transition in Bac Kan, 1990-2010

Figure 5 shows the spatial distribution of forest-cover changes in Bac Kan from 1990 to 2010. Results of spatial analyses of land-cover data showed remarkable changes over 20 years. Forest cover in Bac Kan increased significantly by approximately 120,000 hectares, accounting for 65% of the province's land area in 1990. Of the two forest types, planted forest changed the most dramatically, with a staggering increase from almost nothing in 1990 to 38,537 hectares in 2010. Simultaneously, natural forest grew by 44 % from its total area in 1990 (see Figure 6). It is notable, however, that while there was a dramatic increase in area, forest quality fluctuated.

Changes in high and low carbon-stock forests

To assess the change in quality of forests in Bac Kan, those that had above 150 m^3 per hectare average standing volume were categorized as high carbon stock and, therefore, good quality from a carbon perspective; lower than this average were considered to be of poorer quality. The carbon values of each forest type can be found in the report of the forest inventory project carried out by the Japan International Cooperation Agency and the Forest Inventory and Planning Institute.
Figure 7(a) shows that between 1990 and 2000 there was a substantial decline of 1) high carbon-stock (defined as rich or medium) timber forests; and 2) forests on rocky mountains. After 2000, high carbon-stock forests experienced a recovery and increased to the original area of 1990.
There was a contradictory trend in low carbon-stock forests. These included poor-quality timber, bamboo, mixed bamboo with timber, and recovered timber forest types. Recovered forest was defined as young secondary forest that naturally regenerated from bare land in forest areas. It can be seen from Figure 7(b) that the area of low carbon-stock natural forests, except for recovered timber forests, fluctuated around 1990.
By 1995, the area of poor-quality timber forests had almost doubled from 1990 but gradually decreased in subsequent years. However, recovered timber forests increased significantly from 57,251 hectares in 1995 through 134,546 in 2000 to 151,387 in 2010.

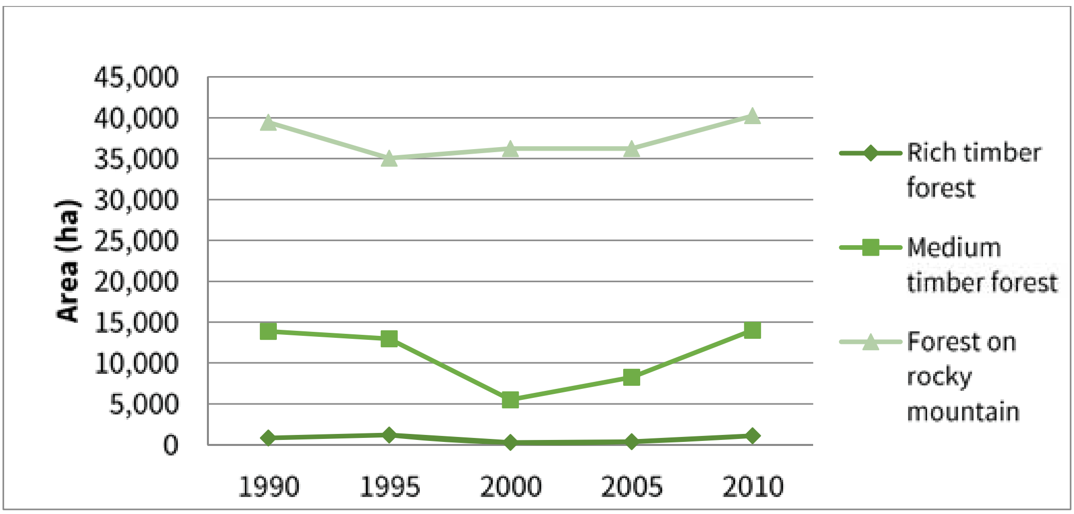


Figure 7 (a). Changes in high carbon-stock natural forests in Bac Kan, 1990–2010

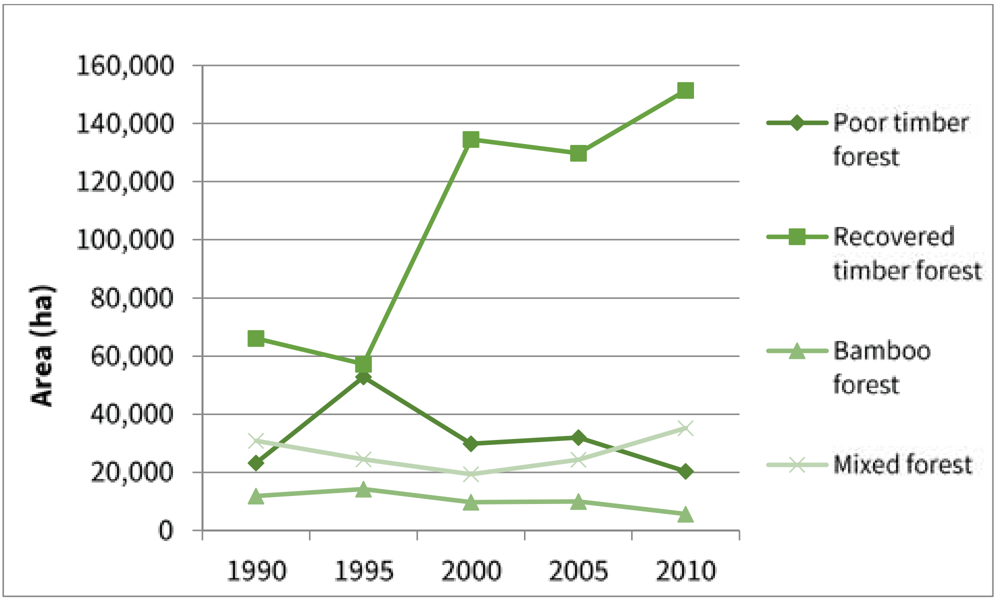


Figure 7 (b). Changes in low carbon-stock natural forests in Bac Kan, 1990–2010

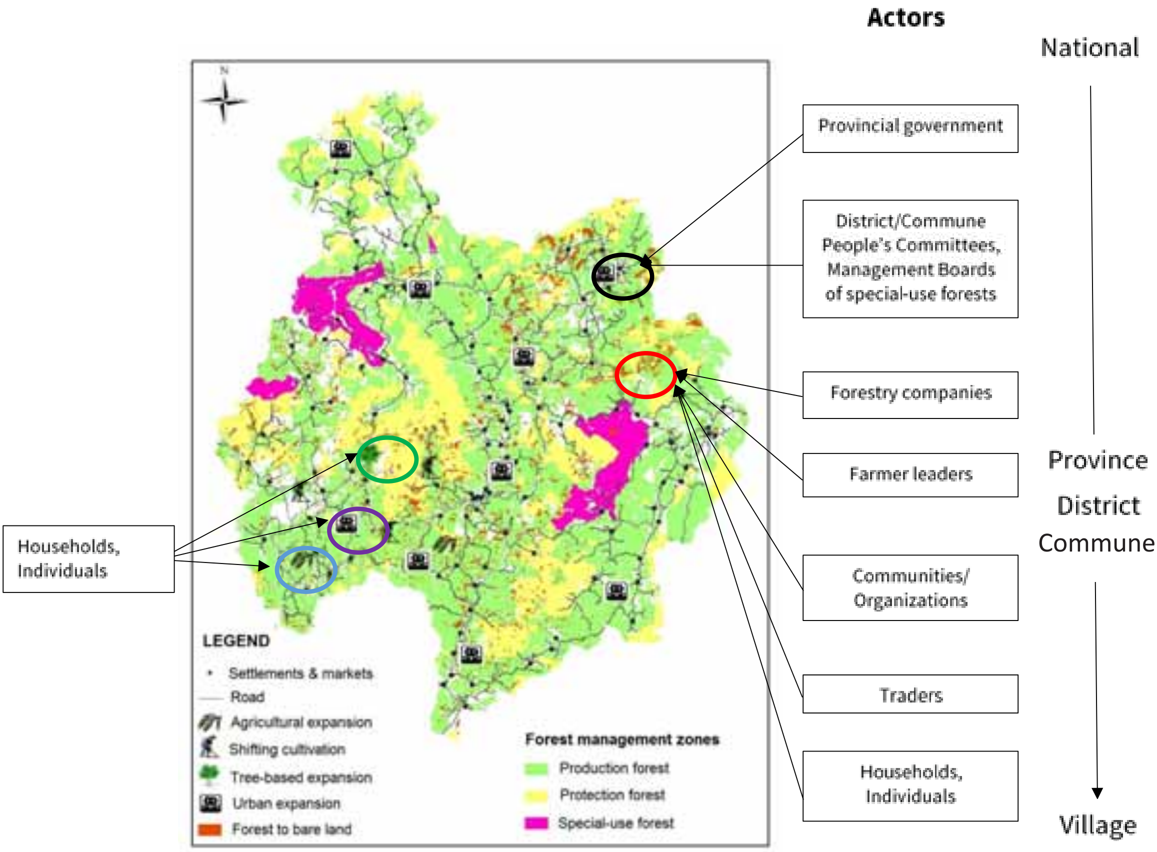


Figure 8. Spatial distribution of deforestation during 2000-2010, its proximate drivers and actors

According to Nguyen (2009), there were eight major groups involved in forest activities. During FGDs in communes, we verified those groups with farmers and categorised generally, as shown in Figure 8. The majority of lost forest area was from natural and production forests. The conversions listed in Table 2 include direct drivers and related actors as found during the spatial analysis and FGDs. The most dominant trend was abandonment of forest land or conversion from forest to bare land, which accounted for 94% of the deforested area. The conversions from forest to bare land occurred primarily in easy-to-access forest areas near roads, settlements or markets.

Second, the area of forest converted to agricultural land was 168 hectares, 0.8% of the deforested area; and to shifting cultivation 246 hectares or 1.1%. These conversions were caused by agricultural expansion to meet demand for food, indicating that the underlying factor was the growth of population in the province. According to the FGDs, farmers had converted poor-quality forest to upland rice or other annual crops long before the conversions were recorded by the provincial government. Further, the demand for settlements and infrastructure had been increasing, which led to conversion of forest land for these purposes as per land-use plans responding to the pressure of a growing population.

Table 2. Proximate drivers and actors of deforestation

No.	Conversion	Area (ha)	%	Drivers	Actors
1	Forest to agriculture	168	0.7	Agricultural expansion, population increase	Households, provincial/ district people's committees
2	Forest to infrastructure and built-up area	152	0.7	Urban expansion, land-use planning, population increase	Provincial/district people's committees
3	Forest to settlement	551	2.5		
4	Forest to rocky mountain	106	0.5	Natural factors	
5	Forest to bare land with scattered trees	20,997	94.3	Illegal logging, legal concessions, natural deforestation, conversion of natural forest to planted forest, timber market demand	Households, traders, timber companies
6	Forest to shifting cultivation	246	1.1	Traditional cultivation, economic benefits	Households
7	Forest to tree-based/agroforestry	36	0.2	Economic benefits, timber market demand	Households
Total deforested area:		22,259 ha			

Underlying factors

The conversion of forests to bare land with scattered trees was the most significant process, accounting for 94.3% of the deforested area. This process was partially clarified through surveys and statistical analysis (Pearson correlation and multiple regression) to determine the underlying causes. The regression model showed that the area of natural forest converted to plantation forests and annual crops under Program 147 strongly explained the change in natural forests (Table 3). A p value less than 0.001 indicates that the variable has a significant influence to the decrease of natural forest.

Table 3. Underlying factors of deforestation (n = 42)

Variables	Decrease in natural forest	p value
The area of poor-quality natural forest and agroforestry converted to plantation forest and annual crops under Program 147	1.11	<0.001
Household size in 2000	0.112	>0.05
Constant	-0.531	
R^2 adj	0.373	

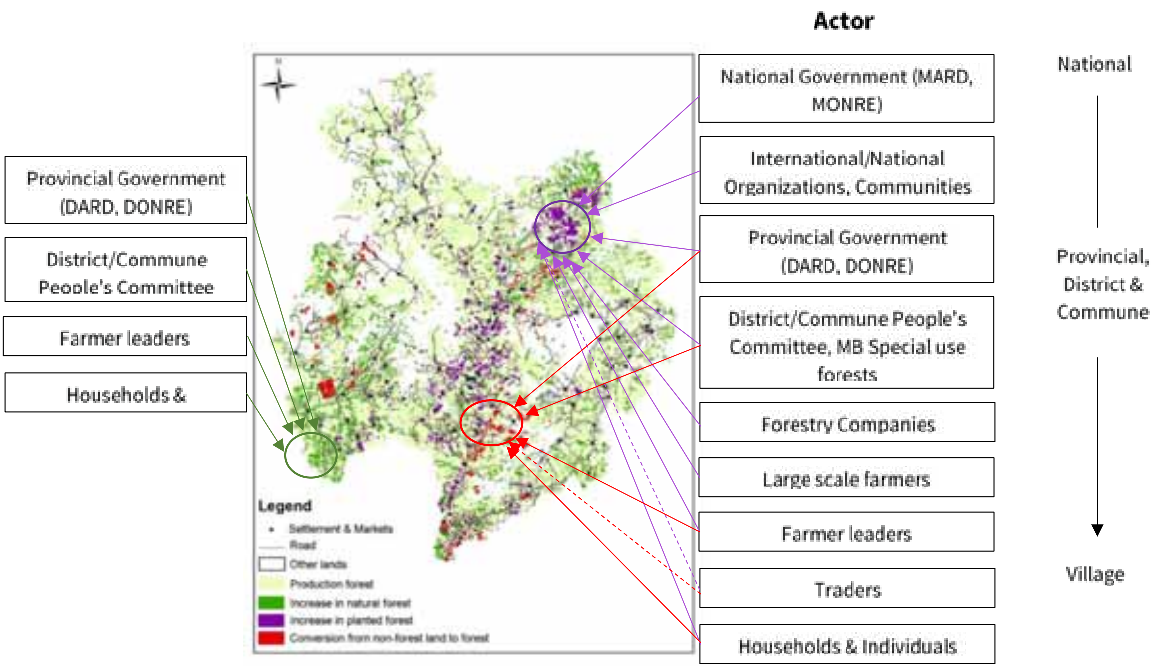


Figure 9. Spatial distribution of reforestation and actors in Bac Kan province, 2000-2010

Spatial distribution of reforestation and actors

The amount of forest cover in Bac Kan since 1990 saw a reversal of the trend compared to previous decades. The most significant period was 2000–2010. For that reason, we focused on reforestation, drivers and actors in that ten-year period.

As mentioned above, the net forest area in Bac Kan increased by 61,000 hectares while total forest area rose by 82,628 hectares, owing mainly to natural forest regrowth (60.2%) under the forest protection policies of the government (Table 4). This was a result of the reforestation programs (summarized in Table 1), which financially supported households to protect forests. Figure 9 shows that most of the naturally regenerated forests are in the production-forest category, management of which was allocated to households. Nearly 30% of the reforestation area in 2010, which was mostly production forest, was bare land in 2000 (Table 4).

Table 4. Reforestation process, drivers and actors, 2000–2010

No.	Conversion	Area (ha)	%	Drivers	Actors
1	Non-forest land to production forest	10,687	12.9	Land-use planning; policies	Government, provincial/ district/commune people's committees, households
2	Bare land (with scattered trees) to natural forest	49,780	60.2	Natural forest regrowth; land-use planning; Program 661	Provincial/district/ commune people's committees, village leaders, households
3	Bare land to planted forest	22,160	26.9	Programs 661, 147 and 135; NGO activities	Government, provincial/ district/commune people's committees, NGOS, village leaders, households
Total reforested area:		82,628 ha			

Area of planted forest and drivers

To identify the cause of the dramatic increase of planted forests in Bac Kan, we conducted household surveys in the districts of Ngan Son and Pac Nam. Pearson's correlation coefficient (Boslaugh 2012) was used to analyse the linear relationship between the increase of planted forest and other factors (Table 5). Positive value shows same trend of the increasing planted forest and factors. Among the different factors tested, the area of natural forest converted by household to plantation forest under Program 147 provided the highest contribution to the increase of planted forest. Other factors such as household income from rice negatively correlated with the areas of planted forest.

Table 5. Pearson's correlations between the increase in the area of planted forest and the drivers in Bac Kan

Variables	Pearson's R	p value
General policies		
Area of natural forests converted by households to plantation forests under Program 147	0.861	<0.001
Total land allocated to households	0.442	<0.001
Total land owned by households in 2012	0.405	<0.001
Amount of money provided by the government for planted forests since 2000	0.298	<0.001
Number of seedlings provided by the government since 2000 for planted forests	0.255	<0.001
Accessibility, physical aspects and infrastructure development		
Proximity from home to the closest urban area	-0.276	<0.01
Proximity from home to the closest tree nursery	-0.223	<0.001
Agricultural intensification		
Household income from growing rice, 2012	-0.261	<0.001
Household income from growing rice, 2000	-0.188	<0.01

Results from multiple regression analysis (Table 6) show that Program 147 was the strongest factor determining the increase of planted forests in comparison to distance from home to urban area).

Table 6. Multiple linear regression of increase in planted forests, with driving factors

Variables	Decrease in natural forest	p value
Area of poor-quality natural forests and bare land converted to planted forests under Program 147	0.831	<0.001
Proximity from home to the closest urban area	-0.053	<0.05
Constant	0.707	<0.05
R^2 adj	0.47	
N	30	

Forest transition trend

Several transitions occurred simultaneously in Bac Kan during the study period: reforestation, deforestation, and forest degradation. Forest degradation was represented by the change in area of high carbon-stock forests. Between 1990 and 2000, forest quality and area had opposite trends. While forest area was increasing, forest quality declined. During the following ten years, the trend reversed, with forest quality recovering remarkably since 2000 and the forest area continuing to grow steadily. Both forest quality and forest area were planned to maintain the same trend until 2020 (Figure 10).

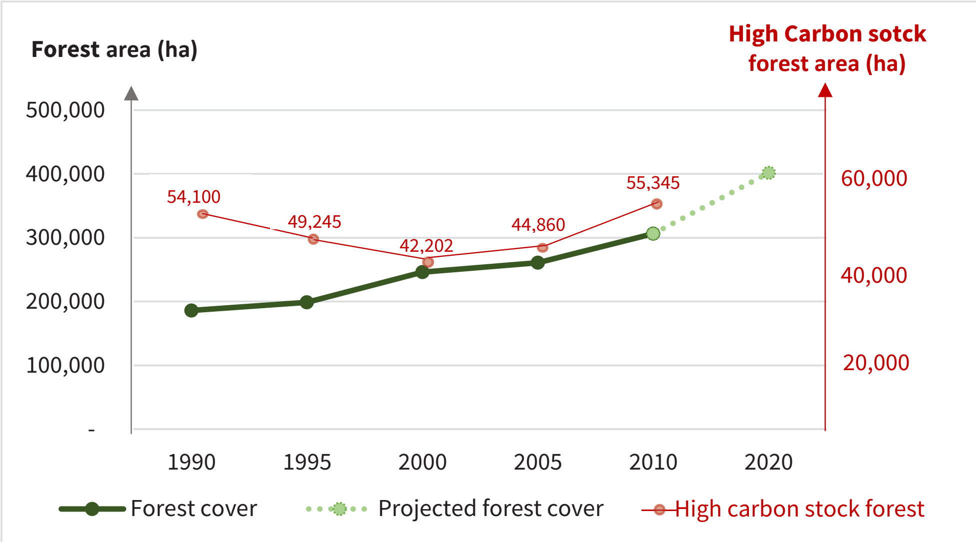
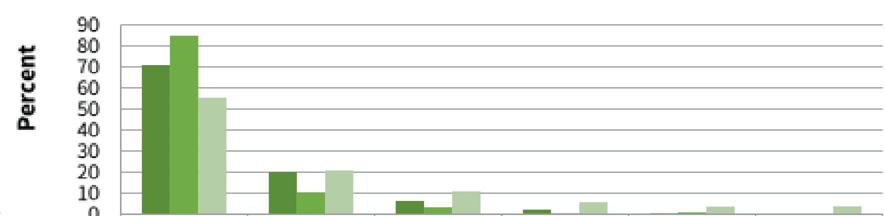


Figure 10. Forest transition curves in Bac Kan

Forest cover change and accessibility

The results of FGDs at a provincial workshop in Bac Kan showed that forest-land allocation played an important role in protection by prohibiting use of forests for shifting cultivation, illegal logging, and plantations. The more land that was allocated to households, timber enterprises and organizations, the more natural forests were protected and new plantations were planted. Households' perceptions about forest protection had an impact on forest-cover changes as well. From 1990 until the present, farmers' knowledge and information about forests, carbon, climate change, and markets have been improving through the reforestation programs of the government and other organizations. Accessibility to forest plots had a high ranking with participants of the provincial workshop when they were asked to choose the most important factors. To examine the relationship between accessibility, reforestation and deforestation, a forest-changes map was combined with roads and settlements' maps. A strong correlation between accessibility and changes is presented in Figure 11.



Distance to road	0-1km	1-2km	2-3km	3-4km	4-5km	>5km
Reforestation	71	20	6	2	1	0
Natural forest conversion	85	10	3	0	1	0
Deforestation	55	21	11	6	4	4

Figure 11. Forest changes by accessibility in Bac Kan, 1990–2010

Policy-makers' perspective on drivers of forest change

During the provincial workshop, the drivers of forest gain and loss over 20 years were examined and evaluated. The participants were asked to choose the five most important drivers and score them from 1 to 5, with 1 indicating the most importance.

Table 7 shows the results. Only three factors of deforestation were picked and the most important one was shifting cultivation before 2000, owing to poor economic conditions. Forest gain, including afforestation and reforestation, was driven by the reforestation programs from 1994 until the present. Factors receiving equally high rankings are demarcated by 1a and 1b, and 2a and 2b.

Table 7. Most important factors driving forest changes, according to policy makers

Forest loss		**Forest gain**	
Ranking	Drivers	Ranking	Drivers
1	Shifting cultivation owing to poverty and low agricultural production	1a	Financial and seedlings support from reforestation programs (327, 661 and 147; overseas development assistance)
		1b	Accessibility (distance to roads and settlements)
2	Allowance of natural forest harvest before 2000	2a	Forest development program of province and district
		2b	Farmers' knowledge increase through training and workshops
3	Weakness in forest management before 2000	3	Forest-land allocation since 1994

5. Discussion

Owing to the lack of forest-cover statistics before 1999, our results were compared with trends reported in a study conducted by the Forest Inventory and Planning Institute related to forest cover and greenhouse-gas emissions in Bac Kan in 1990, 1995, 2000, 2005 and 2010. The Institute concluded that forest volume—represented by area of medium forests, rich forests, and recovered forests—declined remarkably from 1990 to 1995. Similar to our findings, in the next decade, from 1995 to 2010, they witnessed the reversal of the trend. The areas of recovered forests, including planted forests, increased dramatically.

Our study indicates that deforestation and degradation of natural forests between 1990 and 2000 were mainly caused by shifting cultivation and illegal logging. Based on their study in Bac Kan province, Castella et al. (2002) reported similar results that farmers were among the actors, and they claimed that the farmers in the province were actually conscious of the need for forest protection, and they were aware on the rapid deforestation and forest degradation that occurred in their area along with potential risk to their livelihood. The farmers also witnessed a declining abundance of forest wildlife that was important part of their livelihood. Thanks to the implementation of land allocation policy, farmers claimed that they could now protect their lands including from forest degradation and resource deterioration caused by other forest dwellers, and they felt more secure in cultivating the lands, including under the support of forest plantation programs.

In Bac Kan province, above all other factors and under the period of analysis, government reforestation programs such as 327, 661 and 147, or forest-development policies were the most important factors resulting in forest protection and plantation expansion in the province. Thanks to these, naturally regenerated forest contributed to 60% of the total reforested area. As indicated by local people, governmental project management units at the local level provided technical support to farmers on trees and plantations and, therefore, facilitated planting by households and improved their knowledge of the role of forest protection and development.

The reversal trend from forest loss to regrowth took place generally in the country from 1990s due to the major changes in environmental and socio-economic policy (Cochard et al 2017). There has been a disparity, however, among regions in the trend of forest transition curve. For example, Cochard et al 2017 who studied changes of forest cover that took place in Viet Nam between 1993 and 2013, reported that, especially between 1993 and 2003, reforestation was clearly apparent in northern mountainous areas, while deforestation continued to prevail in the Central Highlands and Southeast region of the country. The authors claimed that the continuing deforestation in the Central Highlands and Southeast region was particularly driven by an expansion of commercial crops such as coffee and rubber plantation, along with immigration and population growth.

A similar pattern of forest policies with afforestation campaigns and devolution of forest land-use right was also found in many tropical countries (Clement and Amezaga 2009). This resulted in a trend of reforestation led by smallholder households and particularly apparent in some countries of the Asia-Pacific region particularly Viet Nam and China (Sandewall et al 2010) that have similar reforestation policy. For Viet Nam's case, based on the reports from FAO (2005, 2006) and MARD (2006), Sandewall et al (2010) stated that the annual increase in area of productive forest plantation in the country reached 5% between 1990 and 2005, and there had been a substantial increase of farm-based plantations.

The trend of forest regrowth in the country has continued in the 2010s. For example, the General Directorate of Forestry reported that forest encroachment had decreased by 9 percent between 2015 and 2016; and by 2016, up to 222,000 hectares of forestland had been afforested and 58 million trees planted in different areas. The country's target is forest coverage of about 42 percent by 2020, both for production and protection purposes.

The strategy of developing smallholder's forest plantation as part of forest protection program, is also apparent in the Viet Nam's 2006–2020 National Forest Protection and Development Strategy that has formulated targeted contribution from smallholders' forest plantations in different regions, including the northern mountainous areas like Bac Kan province. In addition to forest protection's purpose, the Strategy targets contribution from productive forest plantations to meet national demand for materials such as paper, woodchips, pit props, and furniture.

The success in promoting sustainable smallholder's forest plantation along with the protection of natural forests will move Bac Kan province further along the forest transition curve, as expected to take place in a pilot province of REDD+. Do and Mulia (2018) emphasized however that smallholder farmers generally have to face constraints in tree planting either in 'input', 'knowledge', or 'output' domain. For the 'knowledge' domain, lack of knowledge in tree management practice was still found in Bac Kan province, including to tree species promoted by afforestation programs. Therefore, the targeted contribution from smallholder's forest plantations should be accompanied by improvement in extension service, especially in mountainous and remote areas like many of communes in Bac Kan province. Furthermore, while the province targets 82% of forest coverage by 2020, it's important to reconcile the forest protection and livelihood purpose. The study presented in the next chapter (Chapter 3) explored different alternative systems of acacia forest plantation that can potentially provide higher carbon stock as an ecological objective without compromising farmer's livelihood.

6. Conclusion

Analyses show that deforestation and degradation of natural forests between 1990 and 2000 were caused by shifting cultivation followed by illegal logging. In the next period, the main causes were conversion from poor-quality natural forests to planted forests under Program 147 and to agriculture, settlements and other land-use types. While Program 147 was the driving factor behind the loss of natural forests, it was also one of the main reforestation programs during 1990–2010. Thanks to financial and seedlings support from reforestation programs, planted forests rapidly increased from 2% of total land area in 1990 to 27% in 2010. Forest-land allocation was also one of the driving factors of reforestation in Bac Kan.

The spatial analysis of historical and planning maps found that planted forest is continuing to increase and that the area of forest cover for the whole province will reach 75% by 2020. In this context, development activities should place greater focus on farmers' livelihoods. Not all forest conversion is bad. If natural forests provide little economic value and their carbon stock is typically less than planted forests, it is recommended they be transformed. Approximately 4,000 hectares of rich- and medium-timber forests will be allocated to households under forestry plans. These types of forests—which 2020 are the core of natural forests—located near roads, markets and settlements are 'vulnerable' because they are easily encroached upon for conversion to planted forests. On the other hand, the results of overlaying a forest-ownership map of 2010 with land-cover maps from 2010–2020 show that around 49% of forest gain and loss was, and will likely be, on land owned by households and individuals. Around 45% of this is under the management of district and provincial people's committees. Thus, individuals, households and the committees are likely to continue to be the most important actors making changes to forests in Bac Kan in the next 10-year period.

This chapter provides understanding of what caused changes to forests in terms of both quality and area in Bac Kan over 20 years and provides a projection for the next 10 years. The results support the hypothesis that changes to forests are dependent on time and spatial location. Drivers of changes are temporal and they change accordingly at certain periods of time. Prediction of the trend is possible but drivers in the future might be different from those in the past. Government policies and programs are always the most important and leading factor. Our research results could be improved by using high-resolution satellite images to examine changes to forests, especially quality. Moreover, the drivers and actors of the processes were identified but the correlation among the factors is the limit of this study. The next challenge will be to determine the impact of each factor on the others as well as livelihoods' options that can maintain a balance between environmental and economic benefits for the sustainable development of the province.

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Acacia logs in Ha Tinh province, Northcentral Coast of Viet Nam (Photo: World Agroforestry/Ha My Tran)

CHAPTER 3

Alternative forest plantation systems for the Southcentral Coast of Viet Nam: projections of growth and production using the WaNuLCAS model

Rachmat Mulia, Ni'matul Khasanah, Delia C. Catacutan

Summary

Short-rotation (3-4 years) and high density (4,500-10,000 trees per hectare) acacia for pulp and paper purpose is one of the most popular forest plantation systems in Viet Nam, including in the Southcentral Coast region. There is a need however to find alternative designs to further improve the economic return and environmental benefits such carbon storage that can be derived from the system, and to develop forest plantation systems for other purposes, such as timber production. We used the Water, Nutrient and Light Capture in Agroforestry Systems (WaNuLCAS) model to assess the performance of eight forest plantation systems for Quang Nam province that could be expected to provide higher and more stable income and higher levels of carbon storage, including timber production. The systems combined different spacings and rotations of acacia with cycles of cassava as intercrop.

Among the different systems, for farmers who largely rely on forest plantation as the source of income, the four-year rotation system with 3 x 3 m tree spacing for pulp and paper purpose and three seasons of cassava is the most feasible option as it leaves no income gap between investment and tree harvesting. In terms of carbon storage however, this system is inferior than the four-year rotation systems and the baseline. Among the systems for timber, the highest income per year, time-averaged carbon storage and timber production were obtained from 3.5 x 3.5 m and 4 x 4 m acacia spacing, in 12-year rotations. For these options, farmers need other sources to cover the income gap between investment and timber harvest and to the loan.

We conclude that the performance of current short-rotation forest plantation system can be improved by selecting appropriate tree spacing and include more cycles of intercrop. Systems with long rotations for timber, however, need to offer other income sources for farmers to maintain cash flow. Furthermore, since smallholder farmers with few resources generally are risk-averse, local authorities need to develop demonstration trials of selected alternative systems with the farmers, whilst improving micro-finance and loan system, and access to markets for other products than pulp and paper.

1. Introduction

In the last few decades, a similar pattern of forest policy has emerged in tropical countries, namely the decentralisation of forest management and afforestation programs with timber trees (Clement and Amezaga 2009, Pietrzak 2010, Sandewall et al 2010). In Viet Nam, a program to allocate forests to communities started in the 1990s, supported by a series of policies (Clement and Amezaga 2009, Sandewall et al 2010, To et al 2013).

One of the most popular forest-plantation systems in the country is short-rotation acacia for pulp and paper (Trieu et al 2016), usually densely planted in three to four year-rotations. The system dominates production forests in many regions in Viet Nam, including the Central Coast region (Tran et al 2014). The system rehabilitates soils (Tran et al 2014) since acacia is a nitrogen-fixing species and makes an important source of income for farmers (Pietrzak 2010, Nambiar et al 2015, Trieu et al 2016).

The short-rotation acacia system, especially in the Central Coast region, was developed primarily as monoculture with high density from 4,500 to 10,000 trees per hectare with inter crops such as cassava, only in the first year after planting before the closing of tree canopy. Like other monocultural practices however, this system can potentially harbour an economic risk for smallholder farmers without other income sources, and due to uncertainty in product price as well. For the latter, comparing the price of acacia in Thua Thien Hue province in 2015 and 2017, there was a drop of about 17% (Catacutan et al 2017). With increasing labour cost, the income benefits of short-rotation acacia will become questionable (Pistorius et al 2016).

There is a need for Viet Nam to move further along the forest-transition curve by introducing more permanent or longer-rotation forest plantation systems (Pistorius et al 2016). This is expected to enhance forest quality, economic performance and environmental services including carbon storage for climate change mitigation purpose. Meanwhile, Viet Nam imports 80% of its timber requirement as raw material for an export-oriented furniture industry (Pistorius et al 2016). The country is also committed to implement REDD+ and biodiversity conservation. Developing more permanent and longer-rotation forest-plantation systems could produce greater benefits for livelihoods and environment aligned with these commitments.

The sub-national, such as provincial authorities have targets for the area long-rotation timber plantations. Such plantations are expected to improve household incomes, contribute to climate change mitigation and reduce the intensity of shifting cultivation, especially in upland regions. For example, the National Forestry Program of the Forest Protection Department in collaboration with the Viet Nam Administration of Forestry plans to provide financial support for an initial 55 hectares of long-rotation timber plantations in Thus Thien Hue province.

In view of the above, we explored alternative forest plantation systems that were expected to generate higher and more stable income as well as greater environmental benefits such as greater carbon storage and control of soil erosion. The soil erosion hazard from short-rotation acacia systems was reported e.g. in Quang Nam and Thua Tien Hue province (Catacutan et al 2017) and took place especially during the replantation stage. The alternative systems combine different spacings and rotations of acacia with seasons of cassava as intercrop.

We assessed the growth, productivity and carbon storage of eight alternative acacia systems for Quang Nam province using the Water, Nutrient and Light Capture in Agroforestry Systems (WaNuLCAS), a tree–crop growth and interaction model (van Noordwijk et al 2011) as compared to the short-rotation and high density acacia system as baseline assumed to be of four-year rotation with a density of 10,000 trees per hectare and cassava in the first year after tree planting. The profitability and net present value (NPV) of all alternative systems were calculated to highlight the business cases of the alternative systems, compared to the baseline.

2. Materials and methods

Description of the study sites

The study was conducted in 2017 and the study sites were in Song Thanh Natural Reserve in Quang Nam Province, Southcentral coast of Viet Nam (Figure 12), within the Central Annamites, more specifically in the two buffer-zone communes—Ta Bhing and Phuoc My—of the Reserve. The communes were prioritized

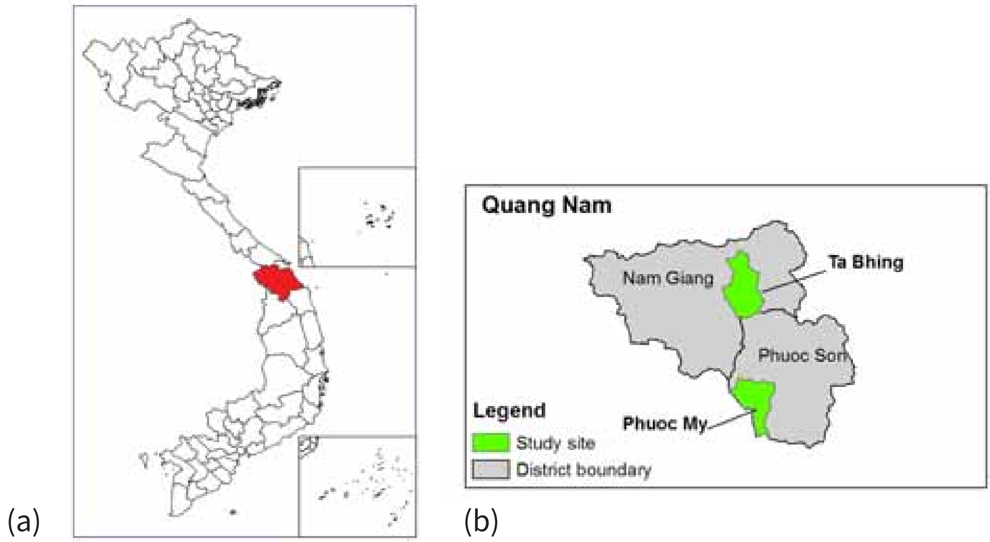


Figure 12. Location of (a) Quang Nam province, Southcentral Coast of Viet Nam and (b) the two sampled communes, in Nam Giang and Phuoc Son district

by the provincial Department of Agriculture and Rural Development (DARD) and the forest management boards, for livelihood assessment and improvement.

Phuoc My commune has an elevation range of 223-446 masl. More than 70% of the commune lands are mountainous with narrow plain stretches between mountain ranges (People's Committee of Phuoc Son District 2015). Consequently, the commune is prone to flooding and landslides, which affect agricultural productivity.

Ta Bhing commune is located at a lower elevation, approximately 100 masl. The commune is also dominated by mountainous areas (People's Committee of Ta Bhing Commune 2015). The flat areas are concentrated at the feet of the mountains, along riverbanks and streams. The river system flows through steep terrain.

Based on commune statistics from 2014, Phuoc My had in total 1,590 people in 410 households belonging to various ethnic groups such as Gie Trieng (Bhnong), Kinh, Tay, Nung and Co Tu, with 95% from the

Bhnong group. There were 952 people of working age, of whom 820 or 86% worked in the agricultural sector. In terms of socio-economic status, 58% of all households were classified as poor.

Ta Bhing is larger than Phuoc My in terms of land area and population. In 2014, the commune had 2,500 people in 625 households (People's Committee of Ta Bhing Commune 2015). From the total population, 1,315 people (53%) were of working age, and in terms of socio-economic status, 58% of all households were, like Phuoc My, classified as poor.

In 2015, forest lands in Phuoc My covered 93% of the total area whereas in Ta Bhing it was 76% (Table 8). Among the forest lands, 1,706 ha or 15% of the total forest area in Phuoc My, were designated as production forest grown as plantations; in Ta Bhing, 227 ha or 3% of the total forest area was designated as production forest. The remaining forest areas were designated as protection or special-use forests. In both communes, the quality of natural forests was generally low after years of overexploitation. Timber for house construction was no longer available and non-timber forest products were limited. Agricultural land occupied 3% and 16% of the total area of Phuoc My and Ta Bhing, respectively.

Table 8. Land-use distribution and area in Phuoc My and Ta Bhing communes in 2015

Commune	Total land area (ha)	Agricultural land (ha)	Forestry land (ha)	Production forest (ha)
Phuoc My	12,281	351	11,407	1,706
Ta Bhing	15,886	2,567	7,151	227

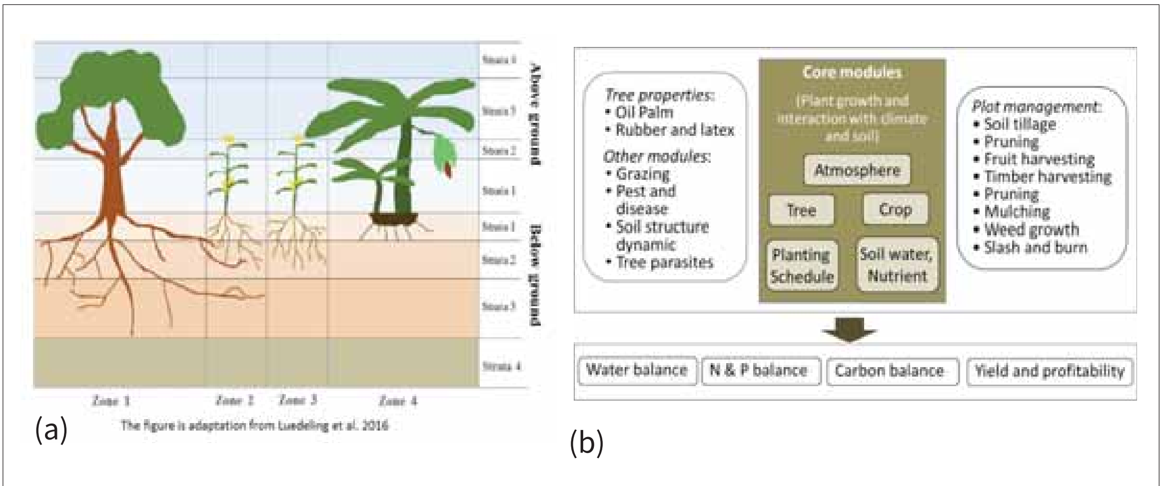
Source: People's committees of Phuoc My (2015) and Ta Bhing (2015) communes

Based on a household survey that involved 103 households in Phuoc My and 153 households in Ta Bhing, Catacutan et al (2017) reported that acacia systems provided the main source of income to 26% of surveyed households in each Phuoc My and Ta Bhing. In other households, it was secondary to cash crops.

Tree–crop interaction model

WaNuLCAS is a generic tree–crop growth model that considers both aboveground (e.g. light availability) and belowground (e.g. soil water and nutrients) interaction as factors determining plant growth. It represents a system in four horizontal zones and four vertical soil layers (Figure 13a) and estimates the growth of plant components and plot productivity following the daily balance of above- and belowground resources. Figure 13b describes the main modules and outputs of the model.

In this study, the model was used to simulate the growth and interaction among acacia and cassava in the different systems under observed climatic and soil conditions in the study sites, to estimate plot productivity. We used the model outputs, namely growth and production of each plant component to estimate the economic return of the systems.



Source: the spatial arrangement figure was adapted from Luedeling et al 2016

Figure 13. (a) Spatial arrangement of a tree–crop system in WaNuLCAS into four lateral zones and four vertical soil layers; (b) The main modules and outputs

Soil and climate data

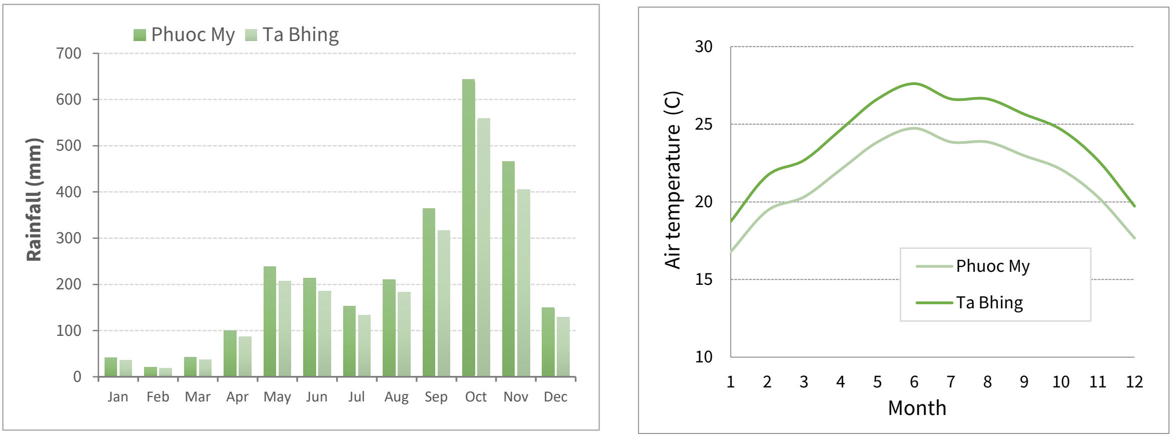
The model needs information on local soil and climatic conditions as well as plant characteristics to perform the simulations. Table 9 describes the soil chemical and physical characteristics in the two study communes based on soil sampling and analysis. In each commune, soil sampling consisted of eight replications conducted in four villages, down to 1 m soil depth. The samples were analysed by the Soils and Fertilizers Research Institute in Ha Noi city. A statistical test found that the two sampled communes had similar soil characteristics: sandy loam on top with sandy clay loam in the sub-soils. Hence, for the simulations, we used averaged soil data to represent both communes.

Table 9. Soil physical and chemical properties of the two study communes

Thickness of soil layer (cm)	Sand (%)	Silt (%)	Clay (%)	pH	C (%)	N	P-Bray (ppm)	CEC[1] (cmol kg^{-1})	Bulk density (g cm^{-3})	Texture[2]
0–10	66	19	14	4.2	2.3	0.15	40	8.7	1.256	Sl
10–30	60	18	20	3.9	1.3	0.10	31	8.2	1.280	SCL
30–60	57	16	26	3.9	0.7	0.06	26	8.6	1.346	SCL
60–100	57	14	28	3.9	0.5	0.04	28	9.3	1.365	SCL

[1] Cation exchange capacity; [2] SL = sandy loam, SCL = sandy clay loam

Figure 14a shows the monthly rainfall data in the two communes. As no weather station was available in either commune, the rainfall and temperature data were generated with WorldClim *(http://www.worldclim.org/)*. The annual rainfall was estimated to 2,650 mm in Phuoc My and 2,300 mm in Ta Bhing. In both communes, the rainy season usually occurs between September and November with flood risks and the dry season with drought risks in the first months of the year. The highest temperatures occur during May and July (Figure 14b).



a) b)

Figure 14. (a) Monthly average rainfall and (b) Air temperatures in the two study communes in Phuoc My, Quang Nam. Source: data generated from WorldClim.

Alternative acacia-based systems

The short-rotation and high density acacia system with four-year rotation and a density of 10,000 trees per hectare with cassava in the first year after tree planting was assumed as the baseline system. Compared to the baseline, the eight alternative systems were designed as alley cropping with wider tree spacing wherein cassava is intercropped between acacia trees for up to five years. The systems with rotation more than eight years are intended for timber. For the assessments with the WaNuLCAS model, we assumed that the systems are free of weeds, fully controlled in terms of pest and disease, and with no synthetic fertilizer application. Parameter values representing plant and growth characteristic of acacia and cassava are available in the tree and crop library of the WaNuLCAS model. The parameters include those representing the ability of acacia trees as nitrogen-fixer. Table 10 describes the characteristics of the eight alternative systems.

Table 10. Alternative acacia-based systems for Quang Nam province

System	Tree spacing (m)	Tree density (trees ha^{-1})	Rotation (years)	Purpose	No. of cassava seasons
1	2 x 2	2,500	4	pulp & paper	2
2	3 x 3	1,111	4	pulp & paper	3
3	3 x 3	1,111	8	timber	3
4	4 x 4	625	8	timber	4
5	3.5 × 3.5	816	12	timber	3
6	4 x 4	625	12	timber	4
7	5 x 5	450	14	timber	5
8	6 x 6	278	14	timber	5

Comparison with the baseline

The alternative systems were compared with the baseline in terms of timber production, time-averaged carbon storage, income per year and Net Present Value (NPV). Based on the interview with farmers and local authorities in both communes, the total production and maintenance costs of the baseline practice range from USD 200 to USD 1,000 per hectare and the average gross income range from USD 1,000 to USD 2,000 per hectare. The wide range in production costs could be owing to the presence or absence of tree seedling subsidy from the Government. The variance in gross income could be attributed to variation in transport costs determined by the location of the plantation, usually relative to main roads. Furthermore, based on a direct measurement of 75 acacia trees of different ages in Phuoc My commune, the average stem diameter of 3.5 year-old acacia trees in the baseline system was 8 cm (±0.5 cm). We assumed comparable acacia growth in Ta Bhing due to relatively similar soil and rainfall condition.

Profitability analysis

Net income per year and NPV were used as two indicators of economic benefits. The NPV (USD per hectare) was calculated as follows:

$$NPV = \sum_{t=0}^{t=n} \frac{R_t - C_t}{(1+i)^t}$$

Where R_t is revenue at year *t* (USD per hectare), C_t production cost at year *t* (USD per hectare), and *i* is the annual discount rate set as 6.5% (Viet Nam Agribank 2017 interest rate). Both net income per year and NPV were considered costs for land preparation and plot management to include seedling costs and labour costs for weeding. The cost for transporting timber can vary depending on plot location. In this study, we used USD 20 per ton or cubic metre (the former for pulp and paper, the latter for timber) for average transportation cost, as informed by local authorities. For the profitability analysis, we used VND 1,450 (≈ USD 0.06) kg^{-1} as the price of fresh cassava and VND 200,000 (≈ USD 9) m^{-3} for the acacia logs as farm gate price. For acacia timber, according to local authorities, the price of 8, 12 or 14-year acacia timber was VND 2 million (≈ USD 90) m^{-3}. The detail of cost components is given in Table 13 below.

3. Results

Growth and production of acacia

The stem diameter at breast height of four-year old acacia trees in the baseline system according to the WaNuLCAS model was 9 cm (Table 11), which is comparable to the observed value. The wider tree spacings produced larger stem diameter under the same rotation length. The stem diameter in the systems for timber purpose ranged between 27-31 cm for those with 8-year rotation, 35-37 cm with 12-year rotation, and 44-47 cm with 14-year rotation (Table 11).

The timber production per tree was higher with wider tree spacing and longer rotation, but this is not the case in terms of timber production and time-averaged carbon storage per hectare. For example, System 5 (3.5 x 3.5 m) and System 6 (4 x 4 m) with 12-year rotation provided higher timber production and time-averaged C stock per hectare than System 7 (5 x 5 m) and 8 (6 x 6 m) with 14-year rotation.

Table 11. Production and economic return of different acacia-cassava systems

System	Tree spacing (m)	Initial density (trees ha^{-1} year^{-1})	Rotation (years)	Stem diameter (cm)*	Timber production (m^3 tree^{-1})*	Total timber production (m^3 ha^{-1})*	C stock** (ton ha^{-1})*	Income of the system# (USD ha^{-1} year^{-1})	NPV (USD ha^{-1})
4-year rotation									
Baseline	1 × 1	10,000	4	9	0.03	287	37	175	221
1	2 × 2	2,500	4	15	0.07	187	23	311	824
2	3 × 3	1,111	4	19	0.12	136	16	364	972
8-year rotation									
3	3 × 3	1,111	8	27	0.24	271	39	1,028	4,689
4	4 x 4	625	8	31	0.33	208	30	875	4,900
More than 8-year rotation									
5	3.5 × 3.5	816	12	35	0.42	346	53	1,188	6,489
6	4 × 4	625	12	37	0.49	304	46	1,077	5,824
7	5 × 5	400	14	44	0.68	273	42	889	4,833
8	6 × 6	278	14	47	0.77	213	33	774	4,107

**Projected by WaNuLCAS. The figures for stem diameter and timber production are the model's projection at the end of rotation year. ** Time-averaged carbon stock in the system. #Total income divided by rotation year and includes income from cassava.*

Net income

Although System 1 and 2 generated lower timber production per hectare, the annual incomes that could be derived from these systems were higher compared to the baseline because of reduced costs for labour. The baseline incurs higher labour cost because of the high tree density (10,000 trees per hectare). However, if labour cost was borne by the household in all systems, then System 1 would have lower profitability compared to the baseline while the income of System 2 would be comparable to the baseline. Among the eight alternative systems, System 3, 5 and 6 returned higher incomes per year, NPV, time-averaged C stocks and timber production per hectare compared to other systems (Table 11).

Income share from cassava

Income per year from cassava was low in the baseline system because of stronger interaction in above and belowground resources with adjacent acacia trees (Table 12). The wider tree spacing in System 1 and 2 that have similar rotation year with the baseline system induced a higher cassava growth resulting in higher annual income. However, a wider tree spacing in systems with longer rotation than four years not necessary led to higher cassava production and income per year. For example, in System 5 wherein acacia trees are planted 3.5 m apart for 12-year rotation, the income per year from cassava was low due to a strong competition in resources with mature acacia trees. This resulted in the lowest income share from cassava in System 5, compared to the other systems. The highest income share from cassava was found in System 2, wherein the acacia trees are planted 3 m apart with four-year rotation and three seasons of cassava.

Table 12. Income share from acacia and cassava

System	Tree spacing (m x m)	Rotation (years)	No. of cassava seasons	Total income (USD ha^{-1} year^{-1})	From acacia (USD ha^{-1} year^{-1})	Cassava (USD ha^{-1} year^{-1})	% Income Acacia	% Income Cassava
Baseline	1 x 1	4	1	175	138	37	79	21
1	2 × 2	4	2	311	206	105	66	34
2	3 × 3	4	3	364	137	227	38	62
3	3 × 3	8	3	1,028	915	113	89	11
4	4 × 4	8	4	875	689	186	79	21
5	3.5 × 3.5	12	3	1,188	1,090	99	92	8
6	4 × 4	12	4	1,077	953	124	88	12
7	5 × 5	14	5	889	731	158	82	18
8	6 × 6	14	5	774	561	214	72	28

Investment cost

Among the alternative systems, the lowest investment cost (the total of establishment and maintenance cost) belongs to System 2 and 3, namely when the acacia trees are planted 3 m apart with three seasons of cassava (Table 13). The other systems have higher investment cost than USD 1,000 ha^{-1}. The highest investment cost belongs to System 7, especially due to the establishment cost for five seasons of cassava. According to farmers, the maintenance cost for weeding and forest protection are only necessary in the first three years of short- or longer-rotation acacia systems.

Table 13. Investment cost of the alternative acacia-cassava systems

Cost component	Systems 1	2	3	4	5	6	7	8
Establishment cost								
I. *Labour cost*								
Land preparation (USD ha^{-1})	139	139	139	139	139	139	139	139
Digging the pit for acacia (USD ha^{-1})	132	59	59	33	43	33	21	15
Filling the pit for acacia (USD ha^{-1})	66	29	29	16	21	16	11	7
II. *Seedling cost*								
Seedling cost (USD ha^{-1})	125	56	56	31	41	31	20	14
Transportion for acacia seedlings (USD)	78	35	35	19	25	19	12	9
Maintenance cost								
I. *First year*								
Labour for replanting dying acacia (USD)	11	5	5	3	4	3	2	1
New acacia seedling (USD)	13	6	6	3	4	3	2	1
1st weeding (USD ha^{-1})	89	89	89	89	89	89	89	89
2nd weeding (USD ha^{-1})	62	62	62	62	62	62	62	62
Forest protection (USD ha^{-1})	10	10	10	10	10	10	10	10

II. *Second year*	62	62	62	62	62	62	62	62
1st weeding (USD ha^{-1})	89	89	89	89	89	89	89	89
2nd weeding (USD ha^{-1})	62	62	62	62	62	62	62	62
Forest protection (USD ha^{-1})	10	10	10	10	10	10	10	10
II. *Third year**	62	62	62	62	62	62	62	62
1st weeding (USD ha^{-1})	89	89	89	89	89	89	89	89
2nd weeding (USD ha^{-1})	62	62	62	62	62	62	62	62
Forest protection (USD ha^{-1})	10	10	10	10	10	10	10	10
Cost for cassava as intercrops								
Number of season	2	3	3	4	3	4	5	5
Total cost (USD ha^{-1})	75	162	162	338	253	338	542	542
Total establishment cost of trees (USD ha^{-1})	539	317	317	239	270	239	203	183
Total maintenance cost (1st year) (USD ha^{-1})	185	172	172	167	169	167	165	164
Total maintenance cost (2nd year) (USD ha^{-1})	161	161	161	161	161	161	161	161
Total maintenance cost (3rd year) (USD ha^{-1})	161	161	161	161	161	161	161	161
Total investment cost for the system (USD ha^{-1})	1,121	973	973	1,066	1,014	1,066	1,232	1,211

**no maintenance cost for the system after the third year*

Feasible alternative systems for farmers and tradeoff with carbon storage

Comparing the baseline with the other four-year rotation acacia systems (i.e. System 1 and 2), the alternative systems provided higher income if the labor cost was borne by households, and thanks to income from cassava in the second or third year after tree planting. If the priority is to provide higher and more stable income in terms of longer cash flow, then System 2 is a feasible option. Between System 1 and 2, the latter has no income gap between investment and timber harvest, and much smaller gap between investment cost and total income from cassava before timber harvest (Table 14). Both in System 1 and 2, however, the loan return period should not be shorter than four years. In terms of time-averaged carbon storage, System 2 has lower carbon storage compared to the baseline and System 1, resulting in a tradeoff between economic and mitigation objectives.

Among the systems with eight-year rotation, the income from System 3 is higher than System 4, but the latter provided longer cash flow due to more cassava seasons. The longer cash flow resulted in a smaller gap between investment cost and total income from cassava before timber harvest (Table 14). In case the priority is to reduce the income gap between years, System 4 is a more feasible option for farmers. Similar to the 4-year rotation systems, System 4 is preferable in terms of income stability, but inferior in terms of time-averaged carbon storage compared to System 3.

Among the systems with longer than 8-year rotations, the systems with more cassava seasons are preferred options if farmers are short of cash flow, for example System 7 and 8, although the total income from these two systems was lower than from System 5 and 6, which have shorter rotations and fewer cassava seasons. A tradeoff between economic and mitigation occurred as System 7 and 8 were more feasible options for farmers than System 5 and 6.

Table 14. Gap between investment cost and total income from cassava in the alternative systems

System	Tree spacing (m x m)	Rotation (years)	No. of cassava seasons	Investment cost (USD ha^{-1})	Total income from cassava (USD ha^{-1})	Gap between investment and income* (USD ha^{-1})
1	2 × 2	4	2	1,121	210	911
2	3 × 3	4	3	973	681	292
3	3 × 3	8	3	973	339	634
4	4 × 4	8	4	1,066	744	322
5	3.5 × 3.5	12	3	1,014	297	717
6	4 × 4	12	4	1,066	496	570
7	5 × 5	14	5	1,170	790	380
8	6 × 6	14	5	1,211	1,070	141

** Gap between investment cost and total income from cassava before timber harvest*

4. Discussion

Informal interviews with farmers in the two study communes they preferred short-rotation acacia systems to longer rotations, because the current acacia seedlings were only suitable to harvest within four years after plantation. They claimed that exceeding this period the wood quality declined and the logs could not be sold. Furthermore, they reported that the communes generally experienced a four-to-five-year cycle of extreme weather events, particularly heavy storms, that damaged longer rotation acacia systems.

The common acacia variety in the two study communes was the hybrid *Acacia mangium x auriculiformis*. Sein and Mitlohner (2011) highlighted the superior quality of this hybrid variety compared to its 'parents' *Acacia mangium* and *Acacia auriculiformis*, indicating that the hybrid could be cultivated in longer rotations. The qualities included a slightly higher wood density (Kha 2000) compared to its parents; deeper root system than either of the parents and therefore more resistant to strong winds (IUFRO 2000) and suitability to stabilize sloping land and reduce the risk of soil erosion (Sein and Mitlohner 2011). Furthermore, the wood of the hybrid could produce higher paper quality, and the hybrid has two-to-four times more rhizobium nodules (in weight and number) compared to its parent species which increased its capability for soil improvement (Kha 2000). Such documented benefits call for further discussion with farmers and local authorities to understand their perspective on why they consider variety in suitable for longer-rotation forest plantation.

Another constraint in introducing the alternative systems that smallholder farmers are generally risk-averse, and reluctant to test alternative forest-plantation systems without successful demonstration trials. This response was understandable since many of the farmers in the two study communes were living below the poverty lines and forest plantations generated substantial income especially for those with small landholdings and without income from other sources (Catacutan et al 2017). Therefore, trying new, unproven systems carried a high economic risk. The initiative to establish demonstration trials should come from local government by allocating suitable lands, to show the benefits of timber-based systems.

Pistorius et al (2016) mentioned that the income gap between investment and timber harvest is the main challenge in encouraging smallholder farmers to adopt longer-rotation forest plantation systems. In the systems evaluated in this study, the income gap was reduced by enabling more seasons of cassava. Furthermore, the longer and accumulated cash flow from cassava still could not fully cover the investment cost until the timber harvesting time. Therefore, it will be difficult to adopt forest plantation systems with longer rotation than four years, let alone if they had to engage in loan systems with short payback period to cover the investment. Among the eight alternative systems, only System 3 provided no income gap due to cash flow from cassava, followed by income acacia logs in the fourth year.

Considering inputs from local authorities in Quang Nam and Thua Thien Hue province, Catacutan et al. (2017) designed five complex alternative acacia-based systems integrating acacia, native tree species, cassava as annual crop, and understorey. Examples of native tree species considered for the systems were *Melia azedarach* and *Litsea glutinosa*, with purple amomum (*Amomum longiligulare*) as understorey. Both tree species were chosen based on farmers and local authorities' knowledge that melia could grow well in Ta Bhing and litsea in Phuoc My. Farmers also considered these two species as native to the communes. A tree-suitability analysis confirmed that both species had high to moderate suitability in Ta Bhing and Phuoc My (Catacutan et al 2017).

The complex alternative systems consisted of three designs namely double-row, block-design, and two systems with gradual transition from short- to long-rotation timber plantation. The first two have a design with melia and with litsea as the tree species, whereas the third was only with acacia. The spatial and temporal cover of annual crop and understorey in the systems are dynamic adapting to tree canopy's development. For example, Figure 15 describes a partial layout of the double-row design that alternates two rows of acacia with two rows of litsea, with 3 m apart. The spacing for acacia trees is 4 x 4 m and 2 x 2 m for litsea. Acacia is planted for 12 years for timber and litsea for bark production. Cassava is planted with 0.5 x 0.5 m spacing and amomum with 1 x 1 m between trees and between the double rows. Over time, along with an increase in tree canopy's cover, the cassava density is reduced and eventually replaced by amomum as understorey. Another double-row design is with melia, where the trees are planted with 2 x 3 m spacing.

In the block design, acacia is also planted with 4 x 4 m and litsea with 2 x 2 m spacing. In one hectare, there are 12 rows of acacia within its block and 24 rows of litsea or melia within respective block. The distance between blocks of acacia and litsea or melia is 3 m. The alley between trees is planted with cassava for four years and then replaced by amomum in the fifth year. Similar to the double-row design, cassava density is reduced as the canopy closes and ultimately replaced by amomum in the fifth year. The spatial arrangement from year 2 to 12 in this design is similar to the pattern in the double-row design.

In the gradual transition system, 2,500 acacia trees are initially planted 2 x 2 m. In year four, 50% thinning is reducing the density to 1,250 trees per hectare. In the eighth year, a subsequent 50% thinning is applied, further reducing tree density from 1,250 to 625 trees per hectare. The remaining trees are harvested for timber in the twelfth year. The harvested acacia trees in the fourth and eighth years are marketed for pulp and paper.

Due to their complexity, especially the dynamic cover of annual crop and understorey over time, these alternative systems could not be properly simulated by the WaNuLCAS model. By relying on secondary data, without assessing

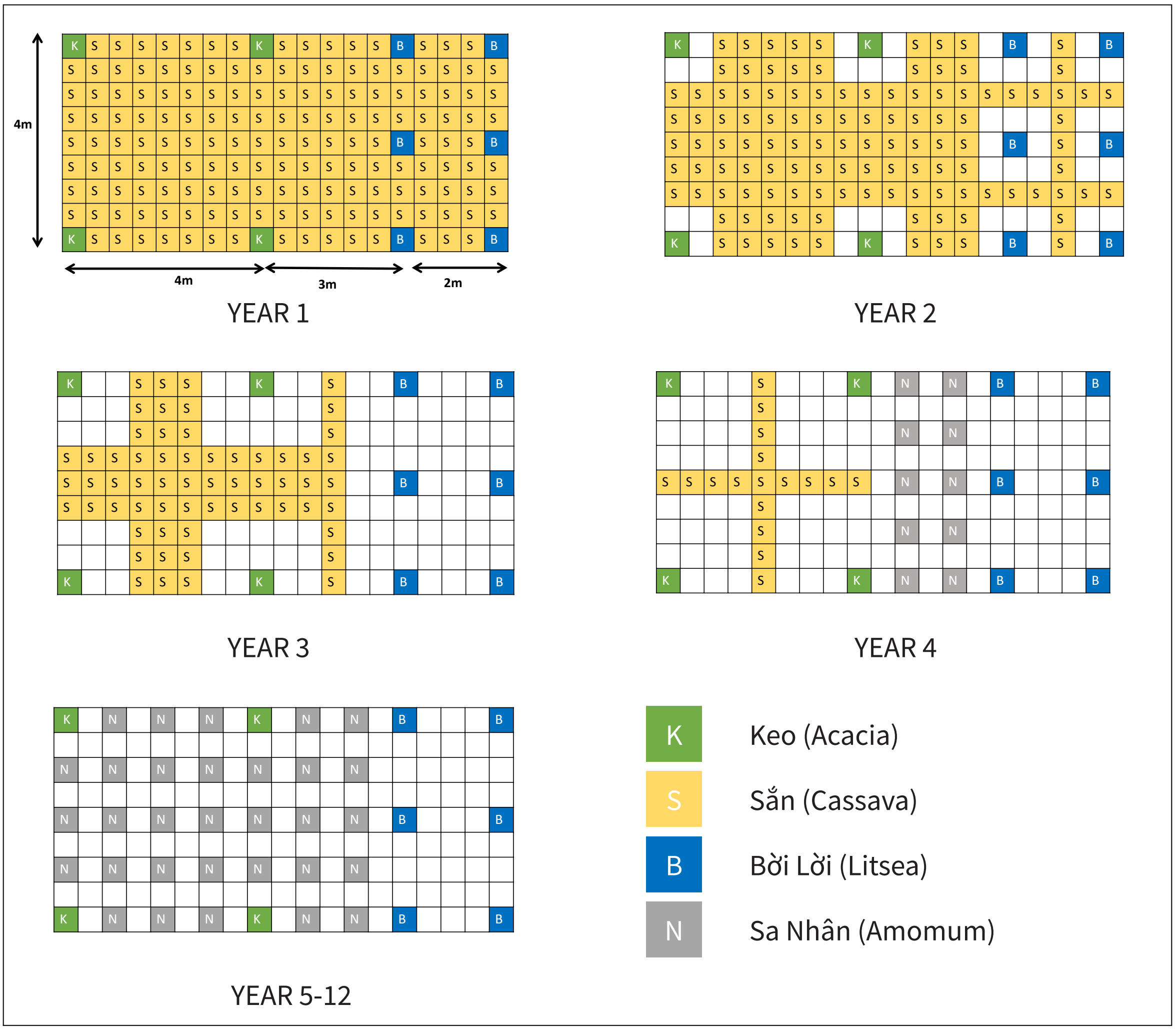


Figure 15. Partial layout of 1 ha double-row acacia-litsea-cassava-amomum system with 12-years rotation cycle for acacia trees.

interaction among plant components with the model, the authors provided the first estimation of potential economic return and carbon storage of the systems. Comparisons among the systems informed that owing to early bark harvesting of the litsea, the double-row and block design of the acacia-litsea-cassava-amomum system could potentially reduce the income gap and return the investment six years after planting. Systems with melia provided investment return after within eight years, whereas a gradual timber-transition system after seven years. The authors concluded that optimizing the space in the system with dynamic spatial and temporal distribution of annual crop and understorey, and the integration of tree species, such as litsea for bark production, that can provide earlier income to farmers is worth to explore further by establishing demonstration trials. Improving micro-finance and loan systems that can provide more flexibility in terms of payback, and providing opportunities and access to farmers to engage in other sources of income, are still deemed as very necessary.

Related to alternative designs of forest plantation systems with native tree species, a project by UNIQUE forestry and land use GmbH, Climate Focus and the Institute of Resources and Environment of Hue University, developed silvicultural models for Thua Thien Hue and Quang Nam provinces with three native-tree species—*Tarrietia javanica*, *Dipterocarpus alatus* and *Hopea odorata*—to provide options the short-rotation acacia monocultural system (Pistorius et al 2016). They proposed three systems, with six-year acacia plantations for wood chips as the baseline. The first system was an acacia sawlog production system extending to a 12-year rotation. The second was a rapid transition from acacia monoculture into a silvicultural model with native-tree species replacing acacia in the fourth and sixth years after planting. The third was a slow transition to native-tree species' plantations that could be harvested within 16 years. The Biodiversity Conservation Corridor (BCC) project in Quang Nam and Thua Thien Hue provinces had similar programs for forest-plantation improvement, testing some 'pure' forestry models with acacia, *Machilus odoratissima* Nees and *Mangletia glauca*. All these long-rotation plantation systems however shared similar concern the need to cover farmer's income gap between investment and timber harvesting, either by integrating profitable short-term crops into the systems or by enhancing access to other income sources, either farm or non-farm, and loan system with more flexible date of payback.

Finally, the trade-off between economic and mitigation purpose can be potentially reconciled if a scheme that provides rewards to higher carbon storage in forest plantation systems exists. The rewards can provide a solution to overcome the income gap in case they are relatively substantial in terms of financial value, and farmers can receive on e.g. annual or shorter-term basis. In Viet Nam, there is a scheme for indirect payment for forest ecosystem service (PFES) promulgated as a national Decree (namely Decree 99/147), with fixed reward/payment rate to ecosystem service provided by forests. At the moment, however, the Decree only regulates payment for forest water service, not other services, such as carbon storage for mitigation. Efforts to amend the regulations provided in the Decree, or through REDD+ schemes for C-reward are therefore necessary for combining afforestation programs with mitigation interventions more effectively, especially in the regions with production forest areas in Viet Nam. The reward and more permanent forest plantation systems, through better control of soil erosion and sedimentation, higher sub-surface and ground flow, as well as enrichment of on-farm biodiversity, above and belowground, will contribute to the maintaining or restoring the multiple functions of the National Reserve.

5. Conclusion and Recommendation

The forest plantation systems discussed in this chapter represent alternative designs to short-rotation acacia-cassava systems for pulp and paper, the most popular forest plantation system in Viet Nam.

If farmers largely depend on acacia system as source of income, the four-year rotation for pulp and paper purpose with 3 x 3 m tree spacing that allows three seasons of cassava is the most feasible option. This is due to longer cash flow until the third year after tree planting, followed by income from acacia logs in the fouth year. In this case, there is no income gap between investment and tree harvesting, and the loan payback can be set at the fourth year. In terms of time-averaged carbon storage, however, this system is inferior compared to other four-year rotation system including the baseline.

Forest plantation systems for timber with rotation longer than four years, can be introduced to farmers with opportunities and access to other sources of income, either farm or non-farm, that can be used to cover the income gap between investment, timber harvesting and loan payback. Under this condition, the forest plantation system with 3.5 x 3.5 m or 4 x 4 m acacia spacing, both with 12-year rotations, provide the highest income per year, time-averaged carbon storage and timber production.

Since farmers are risk averse, encouraging them to adopt selected alternative forest plantation systems will need the local authorities to establish demonstration trials to provide on-ground examples. In the same time, improvement in micro-finance and loan system for farmers to meet the loan payback and developing market links for products other than acacia for pulp and paper are necessary. Combined efforts will encourage the adoption of better-performance forest plantation systems in Viet Nam in general.

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Landscape in Bac Kan province, Northeast Viet Nam (Photo: World Agroforestry/Mai Phuong Nguyen)

CHAPTER 4

Participatory low-emissions land-use planning: the case of Ba Be landscape in Northeast Viet Nam

Hoan Trong Do, Delia C. Catacutan, Bac Viet Dam, Mai Phuong Nguyen

Abstract

Land-use planning plays an important role in reconciling the often contradictory targets of conservation and economic development. This study demonstrates the use of the Land-use Planning for Low-Emission Development Strategies (LUWES) framework in multi-stakeholder negotiations for developing a low-emissions land-use plan for Ba Be District, a poor rural landscape in northern Viet Nam. Twenty-year land-use scenarios were created for each of four planning zones: production forest; protection forest; special-use forest; and land outside forest. By comparison with the LUWES approach, 'top–down' land-use planning tends to maximize the potential for conservation and mitigation by restricting certain forest uses and encouraging forest plantations without due consideration of local livelihoods. Land-use plans developed in a participatory way, albeit offering moderate carbon benefits, are more practical and feasible through incorporating the interests of local communities in rehabilitating landscapes through carbon-rich land-use practices.

We suggest that Ba Be's low-emissions development strategy should include approaches for 'land sharing' to balance trade-offs between conservation targets, mitigation benefits and the livelihoods of forest dwellers. Benefits from 'carbon farming' within a broader carbon-accounting framework should also be fully recognized and equally shared among stakeholders across the landscape. The chapter highlights the vital role of local stakeholders in emissions-reduction planning and the need to aggregate land-use strategies. Finally, we conclude that provincial and district governments need to address discrepancies in forest allocation and management and engender greater stakeholder participation to develop more realistic low-emissions land-use development plans.

1. Introduction

Land-use planning has been recognized as a key policy instrument for sustaining rural landscapes and improving the livelihoods of rural communities (Rydin 1998, Bourgoin and Castella 2011, Bourgoin et al 2012), ensuring landscape multifunctionality and ecosystem services (Nelson et al 2009, Reyers et al 2012), and enhancing efficiency in carbon sequestration, in particular (Cathcart et al 2007, Bourgoin et al 2013). It is also considered critical to the successful implementation of land-based climate mitigation efforts, such as Reducing Emissions from Deforestation and Forest Degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries (REDD+) (Venter et al 2009, Lin et al 2013). However, in many developing countries, conventional 'top–down', centralized planning approaches have been widely practised with very little success, as a result of a lack of flexibility in adapting to local peculiarities (Kauzeni et al 1993, Amler et al 1999, Ducourtieux et al 2005). Participatory practices, on the other hand, often enhance planning quality and feasibility (Trung et al 2006, Reed 2008, Luyet et al 2012). Thus, enhancing the participation of local stakeholders should be earnestly sought as part of larger debates on local empowerment and decentralization of decision making in REDD+ (Chhatre and Agrawal 2009, Phelps et al 2010, Toni 2011, Bourgoin et al 2013).

It has also been well noted that mitigating climate change through land-use management will likely incur trade-offs between economic benefits, for example, delivering more food and employment opportunities, and environmental benefits, such as saving, restoring and managing forests for climate benefits, including carbon sequestration (Chan et al 2006, Chhatre and Agrawal 2009, Dewi et al 2011, Lin et al 2013, Mulia et al 2013). Hence, an inclusive, integrated and informed planning approach is required that considers ecosystem dynamics to simultaneously achieve conservation and development goals (Dewi et al 2011, Hein and van der Meer 2012). The challenges is how to reconcile these two seemingly contradictory dimensions (van Lier 1998, Müller and Munroe 2005, Jackson and Baker 2010).

'Land sparing' and 'land sharing' have been the two main approaches in meeting these demands (Fischer et al 2008, Phalan et al 2011, Chandler et al 2013). 'Land sparing' separates land for conservation from land for crops, striving for high productivity of farm land to reduce the need for agricultural expansion into preserved areas. 'Land sharing' integrates conservation and food production on the same land. Either of the two can result in positive conservation outcomes depending on local conditions (Chandler et al 2013, Grau et al 2013). A combination of the two strategies could be deployed (Dewi et al 2013). Literature on the land sparing versus sharing debate has mostly focused on the trade-offs inherent in biodiversity versus production (Lusiana et al 2012). Similar issues were raised in debates around forests and carbon (Minang et al 2011). Unfortunately, there a limited number of studies that compare the impact of land sparing and sharing on landscape carbon stock. In any event, outcomes are usually necessarily specific to each case presented.

Viet Nam is a part of large REDD+ initiatives under the United Nations Collaborative Programme on REDD and the World Bank's Forest Carbon Partnership Facility. In 2012, the Government announced an ambitious National REDD+ Action Programme (called the National REDD Strategy in many international documents) that orders the development, and implementation, of provincial REDD+ action plans. However, as REDD+ is under development and pilot activities are only at early stages, provinces are struggling with setting up REDD+ targets and, more importantly, mainstreaming such targets into their own socio-economic development plans, particularly, land-use and forestry plans. This is a challenging assignment considering a long history of traditional top–down planning in the land-use and forestry sectors (Castella et al 2005, Ohlsson et al 2005, Lambin and Meyfroidt 2010) and the implementation of poorly designed incentive mechanisms in afforestation, reforestation and protection that often left out the poorest groups (Landell-Mills and Porras 2002, Clement and Amezaga 2009). Additionally, while emissions and emission reductions are relatively well studied at global and national levels, such data and assessments are unavailable at provincial and lower levels in Viet Nam.

This chapter reports on the use of participatory land-use planning as a platform for mainstreaming local priorities and demands into a district-level emission reduction plan. A broader approach addressing all land uses, that is, Reducing Emissions from All Land Uses (REALU), which promotes emission reductions through the establishment and maintenance of high carbon-stock land uses (van Noordwijk et al 2009), was employed to develop future land-use scenarios. Our study objectives were twofold: (i) observe how a participatory land-use planning process can lead to more realistic emission-reduction/sequestration targets compared to the existing top–down land-use plan; (ii) explore land-use scenarios that provided mitigation potential; and (iii) explore the suitability of the land sparing and sharing approaches in the context of agricultural production, forest conservation, and climate mitigation in a rural landscape in Viet Nam. The results provide valuable insights into local land-use planning for REDD+ and other low-emission development strategies that are drawing considerable attention in many developing countries.

2. Methods

Study site description

Ba Be District is located in Bac Kan Province, Northeast Viet Nam (Figure 16). The district size is 68,545 ha, with a population of approximately 47,000 in 11,000 households (Bac Kan Statistical Office 2011). Agriculture and forests play a central role in households' livelihoods. Eight-eight percent (88%) of the total area is forest land and most of the district is mountainous. Productive agricultural land is in short supply, which has impeded local livelihoods and led to a poverty rate as high as 37.17% in 2010 (Bac Kan Statistical Office 2011). In the past, forests were either converted to shifting cultivation or heavily logged for economic purposes, thus, a major part of 'forest land' (66%) is now either regenerated forest with limited tree density or bare land. Forest planting started in the middle 1990s as a part of national reforestation programmes to simultaneously improve ecological functions and local livelihoods (Sikor 2001, Meyfroidt and Lambin 2008). Up to 2010, the total area of planted forest was about 4,600 ha (7.6% of total forest land), mostly monocultural plantations of fast-growing species, such as *Acacia mangium* and *Manglietia glauca*. There were concerns that monocultural plantations did not provide biodiversity benefits (Lambin and Meyfroidt 2010).

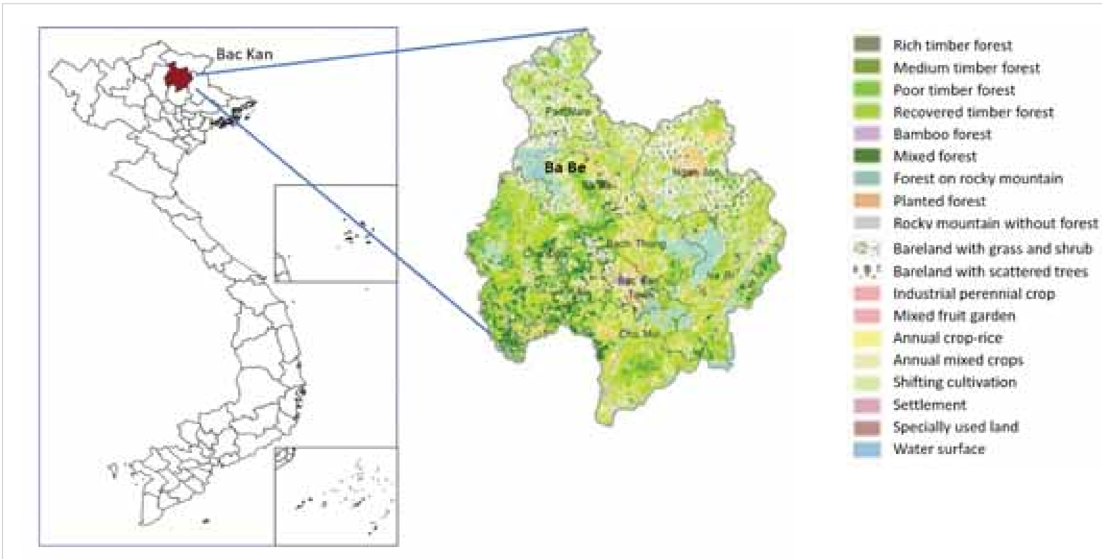


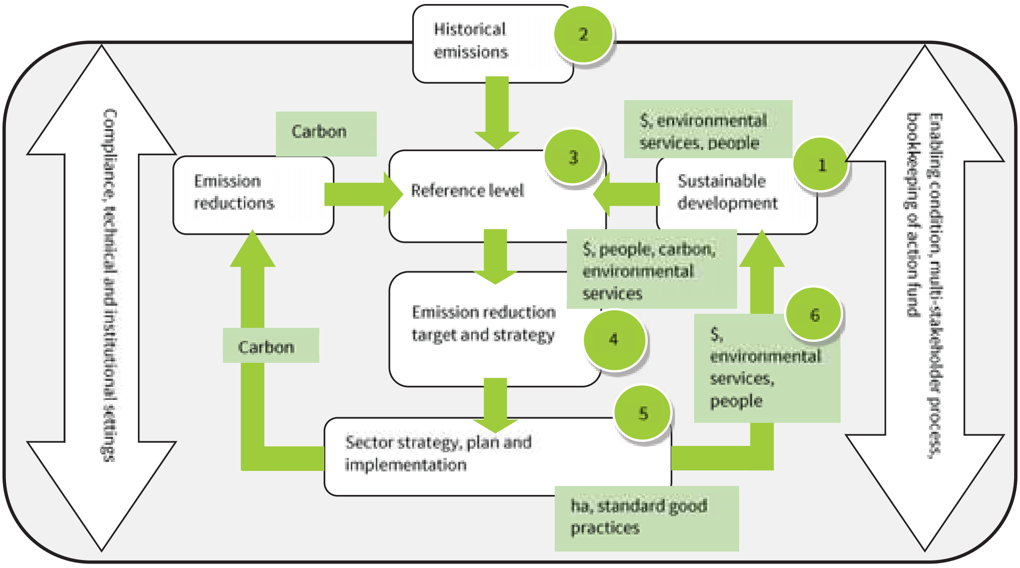
Figure 16. Location of the participatory land-use planning study site in Ba Be District, Bac Kan Province

A sizeable part of the Ba Be landscape, Ba Be National Park, is dedicated to biodiversity conservation. The core zone consists of 7610 ha of forest on limestone along with lowland evergreen forest. This is an unique ecosystem with many endangered flora and fauna (Hill et al 1997, Hill 2000).

Ba Be can be seen as a hotspot for REDD+ for several reasons: (i) its large forest area with high potential for carbon sequestration and other environmental services; (ii) its reliance on unsustainable subsistence agriculture that threatens an upland forest ecosystem valuable for conservation; and (iii) it is economically one of the poorest, but ecologically one of the richest, districts of Bac Kan, which was chosen to pilot REDD+ in Viet Nam.

Methodological framework

We applied the Land-use Planning for Low-Emission Development Strategies (LUWES) method, a participatory planning framework developed by Dewi et al (2011), to enhance emission reductions and removals while providing economic benefits to local communities (Figure 17). We also used the REDD ABACUS SP software (version 1.1.4) developed by ICRAF to (i) estimate the historical greenhouse-gas emissions and carbon sequestration from all land-use changes in Ba Be District and develop baselines; (ii) analyze trade-offs between emissions and financial gains of land-use conversions (opportunity cost analysis) and produce abatement cost curves to project ex-ante emissions and financial impacts of land-use changes; and (iii) compare zone-specific policies and other emission-reduction scenarios within the landscapes and estimate their potential for reducing emission.



Source: Dewi et al 2011

Figure 17. LUWES framework

The LUWES cycle consists of several steps.

1. Compilation of the district's land-use (2010–2020) and forestry (2010–2015) plans and identification of planning zones
2. Analyse past land-use changes (1990–2010) and calculate opportunity costs as the trade-off of financial gain and emissions from land-use changes based on baseline scenarios
3. Develop baseline scenarios for each zone and the whole landscape based on a linear projection of historical land-use changes
4. Develop participatory land-use scenarios and estimate ex-post emission reduction
5. Revise scenarios based on analysis of cost–benefits, the feasibility of selected scenarios and identification of development priorities across the landscape
6. Identifiy policy interventions needed to support local strategic and action plans for emission reduction in order to implement the agreed scenarios

Assessment of land-use carbon stock

To assess the impact of land-use change on a landscape's carbon stock, the typical carbon-stock value is needed for each land use (IPCC 2000 called this 'time-averaged carbon stock'). A typical carbon stock value integrates the gains and losses over a life-cycle of a land use and, thus, reflects the equilibrium of carbon stock of a particular land use (Merger et al 2012). It also allows for a comparison of land-use systems with different rotation times (Ziegler et al 2012). In this study, we calculated aboveground carbon stock of land uses using ICRAF's Rapid Carbon Stock Appraisal method developed by Hairiah et al (2011). Typical aboveground carbon-stock values (in ton C ha^{-1}) of all land uses in Bac Kan are presented in Table 15.

Assessment of land-use profitability

The profitability of land uses was assessed based on Net Present Value (NPV) which is the discounted future cash flow (benefits–costs) during the life cycle of the land-use system. In our study, NPV was calculated for each land-use type as per hectare discounted future cash flow, expressed in USD per hectare (Table 15).

$$NPV = \sum_{t=0}^{n} \frac{(B_t - C_t)}{(1+r)^t}$$

Where: r = discount rate, B_t = total benefit of year t, C_t = total cost of year t, t = year (t ranges from 0 to n). In this study we applied a discount rate of 10% for all land-use types.

Land-use change analysis

In order to analyze both current and past land-use changes and predict future changes, spatial analysis was employed. Spatial analysis used Landsat TM, ETM data, recent SPOT-5 images and land-use maps from 1990 to 2010 for every 5 years to increase accuracy at the same point in time. ArcGIS software was used to produce digital land-cover maps with consistent classification and overlays. We combined every two time series to find the rate and area of deforestation, reforestation and the conversion within Ba Be district's forest boundary between natural forest and planted forest. Land-use maps were obtained from the Ministry of Natural Resources and Environment (MONRE) and combined with forest maps from the Forest Inventory and Planning Institute of Viet Nam to cover the wide range of forest classifications. To identify the boundary of forest management units—including special-use forest, protection forest, production forest and other land—we overlaid our updated land-use map with the forest management map from the Ministry of Agricultural and Rural Development (MARD) for Bac Kan. We used the scale of 1/10,000 for commune level, 1/50,000 for district level, and 1/100,000 for provincial level through the periods 1990, 1995, 2000, 2005 and 2010.

Land-use/-cover classification

In Viet Nam, two land-use classification systems exist (Hoang et al 2010, Pham et al 2013). One is managed by MARD and the other by MONRE. In this study, we combined the two. MARD's land-use classification was used to describe forest land uses while MONRE's was used to describe agricultural and other land-use types. There are 20 land-use types in total, of which 11 are different types of forest (from bare land to rich timber forest), five are agriculture (from paddy rice to perennial crops) and four are other land-use types (Table 15). Although agroforests are not officially recognized as a land-use class, in this study we used it as an independent land-use type separate from both forest and agriculture given the practice's distinguishable typical carbon stock and NPV values as well as its importance from local perspectives. The most common agroforestry system found in Ba Be was maize and/or cassava intercropped with timber species, such as *Melia* and *Acacia* spp.

Table 15. Observed time-average carbon stock and profitability of each land-use type in Ba Be

Land-use type	Time-averaged carbon stock (ton/ha)	NPV (USD ha^{-1})			
		Production forest	Protection forest	Special-use forest	Non-forest
Rich timber forest	203	265	62	48	265
Medium timber forest	157	221	49	40	221
Poor timber forest	118	177	37	32	177
Recovered timber forest	58	110	25	16	110
Bamboo forest	13	132	37	16	132

Mixed forest	85	132	37	16	132
Forest on rocky mountain	117	88	12	8	88
Planted forest	85	296	49	40	296
Rocky mountain without forest	13	0	0	0	0
Bareland with grass and shrub	6	0	0	0	0
Bareland with scattered trees	17	0	0	0	0
Industrial perennial crop	11	8,490	8,490	8,490	8,490
Mixed fruit garden	10	2,184	2,184	2,184	2,184
Annual crop, rice	5	142	142	142	142
Annual mixed crops	5	152	152	152	152
Shifting cultivation	4	234	234	234	234
Settlement	0	0	0	0	0
Specially used land	0	0	0	0	0
Water surface	0	0	0	0	0
Agroforest	11	1,299	1,299	1,299	1,299

Engaging local stakeholders in the land-use planning process

Participatory land-use planning was conducted through field surveys and local consultations at provincial, district and village levels. Two consultation meetings at provincial level were carried out for the same group of policy makers (land-use planning, forestry, forest protection, planning and investment) and forestry enterprises to gain insights into the province's land-use and forestry planning processes. The provincial and Ba Be district's land-use and forestry planning documents, including maps, were also collected in this step. Three consultation meetings at district level (representatives of local land-use department, forestry department, Ba Be National Park, forestry enterprises, district's people committee and some commune's people committees) aimed at adding to results from village-level consultations and facilitating two-way discussions between villagers and district authorities on the development of land-use scenarios. At the commune and village levels, we organized six consultation meetings with representatives (farmers) from three communes and 35 villages to develop, and/or revise, low-emission land-use plans for each commune. During the meetings, concepts of REDD+, carbon payments, land-use planning and the impact on carbon emission and sequestration were introduced. In developing future scenarios with carbon payments, we asked the participants to provide their preferred development and conservation activities, grouped them into categories, and then asked them to rank activities individually as well as in groups (Table 16). Participants also located sites on the maps for interventions when possible or indicated areas of land where interventions were feasible according to their knowledge and experience. We also used visual media, including photos of different land-use and land-cover types, maps and terrain simulations, to stimulate discussion. At the final stage, a consultation workshop was held with participation from all levels to validate the locally-developed land-use plans and extrapolate the district's plan. In total, 159 people were consulted.

We then translated existing government land-use plans and results of local consultations into land-use transition matrixes in REDD+ ABACUS SP by adjusting the land-use transition matrix of the ‘business as usual’ scenario (linear projection of past land-use change). Projections were made for a 20-year period (2010–2030). The government’s land-use and forestry plans were made only for 2010–2020 and 2010–2015, respectively, so we assumed linear projections of these for post-2020 and -2015. Carbon emission and sequestration in each scenario were recorded and compared.

3. Results

Planning zones and issues

Consultation on land zoning for emission-reduction purposes led to the division of the Ba Be landscape into four planning zones: 1) special-use forest; 2) protection forest; 3) production forest; and 4) land-outside forest (Figure 18). Geographically, three of these forest zones precisely corresponded with three forest types categorized by MARD. Managing land outside forests was not the mandate of MARD’s forestry sector, hence, forest conversion (if any) in this zone was inadvertently tolerated.

The choice of planning units was homogeneous among the participants. Two reasons were given: (i) a management policy for each of the three types of forest (three zones) had been developed and imposed by the Government and local authorities and communities had no choice but to accept this; and (ii) land-use and forestry plans had been developed earlier based on the forest zones regulated by the provincial and central governments and any future planning had to be based on the same zoning. More specific characterization of the four zones is shown in Table 16.

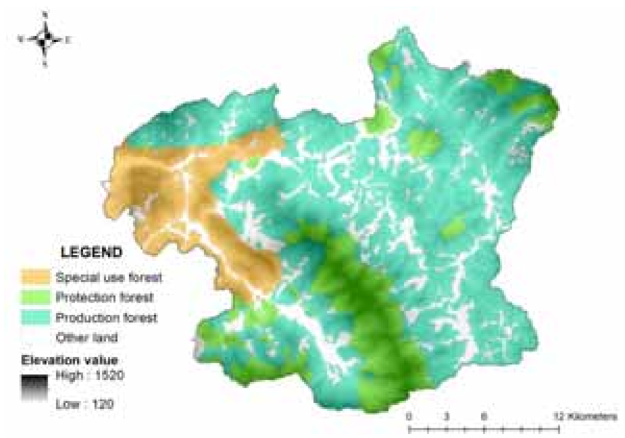


Figure 18. Planning units of Ba Be landscape

Table 16. Characteristics of planning unit of Ba Be landscape

Planning units	Production forest	Protection forest	Special-use forest	Outside forest
Area (ha)	37,034	11,528	8,796	10,838
Main land-use types	A combination of regenerated forests, bare land with shrubs, and planted forests	A combination of regenerated forests, medium and poor forests, bare land with shrubs or scattered trees	Forests on rocky mountains and bare land with shrubs	Annual crops (mainly terraced rice) and bare land with shrubs
Management policy by the Government	Natural forest exploitation and forest plantations for economic purposes by land tenants	Conservation for watershed protection; (very) limited exploitation, mostly non-timber products	Strict protection for biodiversity conservation, no exploitation or conversion allowed	Agricultural production and settlements
Tenure type	Individual households and state forest enterprises	Communal people's committees (for unallocated forest land) and state entities	Ba Be National Park (state entity)	(Mostly) individual households

Emissions from past land-use changes for each zone and impact on carbon emission/sequestration

An opportunity cost analysis of land-use changes in the Ba Be landscape from 1990 to 2010 (Figure 19) showed that net emissions from land-use changes had been reducing over time. From 2005 to 2010, the carbon sequestration rate outweighed the emission rate. The Ba Be landscape had a net carbon credit owing to reforestation efforts. Both emission and sequestration rates were positively correlated with the total land-use change rate (Figure 20). From 2005, both total emissions and sequestration were reducing as the rate of land-use change stabilized. However, total emissions for the whole period of 1990–2010 were still larger than total sequestration, resulting in average net emissions of 30,370 tCO_2eq per year. From an economic perspective, almost all emissions were avoidable at a carbon price of USD 5 per tCO_2eq.

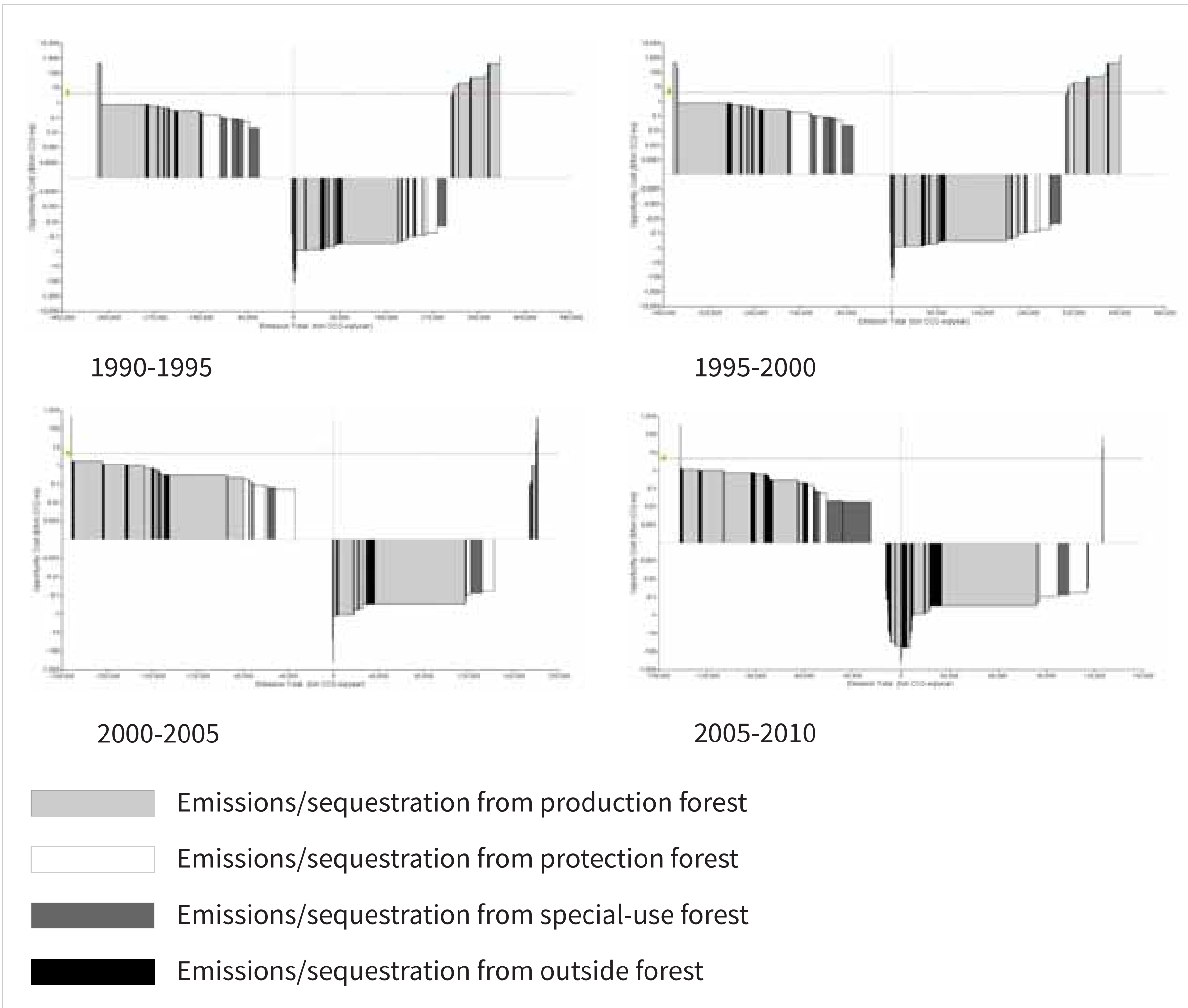


Figure 19. Opportunity cost curve of land-use changes in Ba Be landscape, 1990-2010

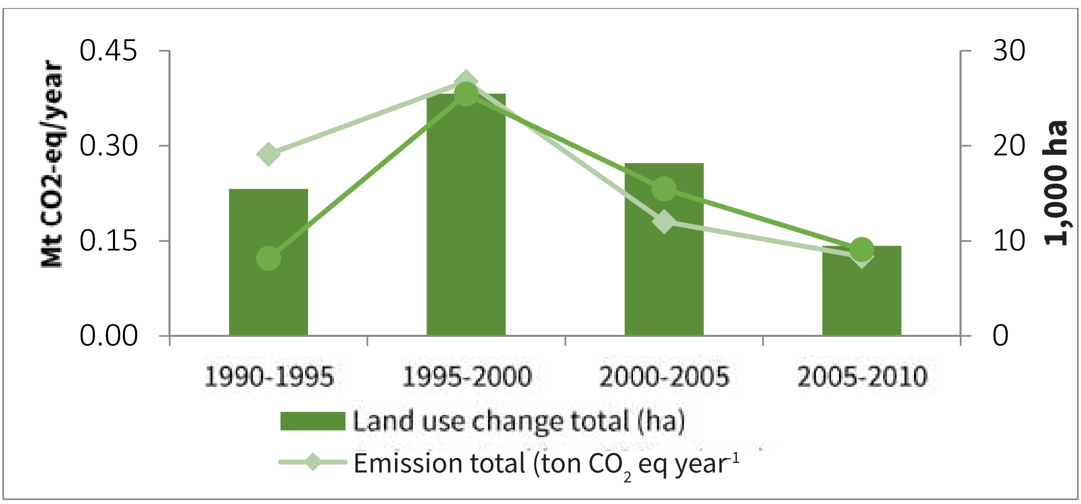


Figure 20. Net greenhouse-gas emissions from the Bac Kan landscape in Viet Nam, 1990–2010

The largest emissions in all periods were caused by conversion of poor timber forest to regenerated timber forest. FGDs at the village level revealed two reasons for this change: (i) clear cut or heavily logged forest; and (ii) slash-and-burn practices for a short period (3–5 years) on poor timber forest land. This emitting land-use conversion also resulted in a loss in economic benefits in the long term and, therefore, had a negative opportunity cost. Conversion of poor timber forest to bare land, and forest degradation from medium timber forest to poor timber forest, were also important sources of emissions. On the other hand, forest plantations on bare land and natural forest regeneration (for example, regenerated forest to poor timber forest) were the two land-use changes accounting for carbon sequestration.

Land-use change in the production forest zone was both the largest carbon sink and the biggest source of emissions (relative to other land uses) from 1990 to 2005. However, during 2005–2010 land-use changes in the protection forest zone became the largest emission source while those in the special-use forest zone became the largest sequestration source. Such changes in land-use-change patterns can be explained by the national reforestation program phasing out during this period along with government-supported forest plantations and protection projects being scaled down in the production and protection forest zones. Forest protection was, however, maintained in the special-use forest zone because it received a separate budget from the Government. Finally, the contribution of land-use changes outside the forest zones was not significant in all periods.

Land-use plans and scenarios

Land-use scenarios

We developed four land-use scenarios (Table 17). In the first, the Optimistic Plan scenario, we assumed that all poorly-managed land uses in the forest zones, for example, bare land or land under shifting cultivation, would be rehabilitated by either establishing forest plantations on bare land or converting shifting cultivation into agriculture. In the Department of Agriculture and Rural Development (DARD) Plan scenario (Scenario 2), we assumed land-use changes as imposed by the provincial DARD. The District Plan (Scenario 3) was an outcome of the consultations with local authorities in Ba Be District. Finally, the LUWES scenario (Scenario 4) was that produced through the consultation process wherein local people were asked to rank their preferred activities with REDD+ support and the feasibility and potential of such activities on the ground according to their perceptions. We also developed a Business As Usual (BAU) scenario, which was a linear projection based on land-use-change rates for 2005–2010.

Table 17. A brief description of the four scenarios

	Production forest	Protection forest	Special-use forest	Land outside forest
OPTIMISTIC PLAN	Production forest plantations on 7,084 ha of bare land (grass and shrubs)	Protection forest plantations on 1,226 ha of bare land (grass and shrubs)	Special-use forest plantations on 1,113 ha of bare land (grass and shrubs)	Enrichment of recovered timber forests to poor timber forests (area same as BAU)
	Production forest plantations on 5,863 ha of bare land (scattered trees)	Protection forest plantations on 1,236 ha of bare land (scattered trees)	Special-use forest plantations on 689 ha of bare land (scattered trees)	Enrichment of poor timber forests (small area, ignorable)
	Enrichment of 2,517 ha of recovered timber forests (to poor timber forests)	Enrichment of 884 ha of recovered timber forests (to poor timber forests)	Enrichment of all 723 ha of recovered timber forests (to poor timber forests)	Conversion of 646 ha of bare land (grass and shrubs) to mixed fruit gardens
	Enrichment of 689 ha of poor timber forests (to medium timber forests)	Enrichment of 774 ha of poor timber forests (to medium timber forests)	Enrichment of all 99 ha of poor timber forests (to medium timber forests)	Conversion of 358 ha of bare land (grass and shrubs) to agroforestry
	Conversion of 245 ha of shifting cultivation to agroforestry (maize and timber trees)	Conversion of 44 ha of shifting cultivation to agroforestry (maize and timber trees)	Conversion of 51 ha of shifting cultivation to agroforestry	Conversion of 490 ha of bare land (scattered trees) to agroforestry
	Forest plantations on 171 ha of shifting cultivation	Complete stop of degradation (rich and medium timber forests) from 2010	Complete stop of degradation of all types of forest (rich and medium timber forests) from 2010	Conversion of 312 ha of shifting cultivation to agroforestry (maize and timber trees)
	Conversion of 220 ha of shifting cultivation to mixed fruit gardens (mandarin orange, persimmon etc)	Reduction by 50% of deforested areas in all forest types in the first 5 years		Conversion of 203 ha of shifting cultivation to mixed fruit gardens
	Reduction by 50% of deforested areas in all forest types in the first 5 years	Reduction by 50% of deforested areas in all forest types in the next 5 years		Complete stop of degradation of the small remaining forest area
	Reduction by 50% of deforested areas in all forest types in the next 5 years	Complete stop of deforestation from 2020		
	Complete stop of deforestation from 2020	Other land uses: as for BAU scenario		
	Other land uses: as for BAU scenario			

	Production forest	**Protection forest**	**Special-use forest**	**Land outside forest**
DARD PLAN	Production forest plantations on 5,980 ha of bare land (grass and shrubs) Production forest plantations on 5,972 ha of bare land (scattered trees) Enrichment of 600 ha of recovered timber forests (to poor timber forests) Conversion of 1,600 ha of recovered timber forests to planted forests Enrichment of 1,850 ha of poor timber forests (to medium timber forests) Complete stop of deforestation from 2010 Other land uses: as for BAU scenario	Protection forest plantations on 1,185 ha of bare land (grass and shrubs) Enrichment of 1,319 ha of bare land (scattered trees) to recovered timber forests Enrichment of 1,995 ha of recovered timber forests (to poor timber forests) up to 2020 Enrichment of 1,730 ha of poor timber forests to medium timber forests up to 2020 Complete stop of deforestation from 2020 Other land uses: as for BAU scenario	Special-use forest plantations on 60 ha of bare land (scattered trees) Enrichment of 48 ha of bare land (scattered trees) to recovered timber forests Protection and natural regeneration of 1,057 ha of recovered timber forests Complete stop of deforestation from 2010	As for BAU scenario
DISTRICT PLAN	Production forest plantations on 6,877 ha of bare land (grass and shrubs) Production forest plantations on 4,605 ha of bare land (scattered trees) Enrichment of 7,680 ha of recovered timber forests (to poor timber forests) Conversion of 35 ha of shifting cultivation to mixed fruit gardens (mandarin orange, persimmon etc) Forest plantations on 35 ha of shifting cultivation	Protection forest plantations on 136 ha of bare land (grass and shrubs) Protection forest plantations on 62 ha of bare land (scattered trees) Enrichment of 1,770 ha of recovered timber forests (to poor timber forests) Conversion of 23 ha of shifting cultivation to agroforestry Complete stop of deforestation and forest degradation from 2020	Special-use forest plantations on 700 ha of bare land (grass and shrubs) Enrichment of all 527 ha of recovered timber forests (to poor timber forests) Complete stop of degradation of all types of forest (rich and medium timber forests) from 2010	Enrichment of 841 ha of recovered timber forests to poor timber forests Enrichment of 34 ha of poor timber forests to medium timber forests Conversion of 402 ha of bare land (grass and shrubs) to mixed fruit gardens Conversion of 818 ha of bare land (grass and shrubs) to agroforestry Conversion of 490 ha of bare land (scattered trees) to agroforestry

	Production forest	Protection forest	Special-use forest	Land outside forest
	Complete stop of deforestation and forest degradation from 2010	Other land uses: as for BAU scenario		Conversion of 11 ha of bare land (scattered trees) to planted forest Conversion of 74 ha of shifting cultivation to agroforestry (maize and timber trees) Conversion of 177 ha of shifting cultivation to mixed fruit gardens Complete stop of degradation of small remaining forest areas Other land uses: as for BAU scenario
LUWES	Production forest plantation on 6,877 ha of bare land (grass and shrubs)	Protection forest plantations on 135.7 ha of bare land (grass and shrubs)	Special-use forest plantations on 902 ha of bare land (grass and shrubs)	Enrichment of 840 ha of recovered timber forests to poor timber forests
	Production forest plantations on 4,605 ha of bare land (scattered trees)	Protection forest plantations on 62 ha of bare land (scattered trees)	Protection contracts for natural regeneration of 523 ha of bare land (scattered trees)	Protection contracts for natural poor and medium timber forests
	Enrichment of 1,010 ha of recovered timber forests (to poor timber forests)	Protection contracts for natural regeneration of 1,770 ha of recovered timber forests (to poor timber forests)	Protection contracts for natural regeneration of 523 ha of recovered timber forests	Conversion of 402 ha of bare land (grass and shrubs) to mixed fruit gardens
	Conversion of 245 ha of shifting cultivation to agroforestry (maize and timber trees)	Conversion of 23 ha of shifting cultivation to agroforestry (maize and timber trees)	Conversion of 41 ha of shifting cultivation to natural forests	Conversion of 817 ha of bare land (grass and shrubs) to agroforestry
	Forest plantations on 35 ha of shifting cultivation	Protection contracts for 187 ha of rich timber forests	Protection contracts for 64 ha of medium timber forests and 537 ha of recovered timber forests	Conversion of 284 ha of bare land (scattered trees) to agroforestry
	Conversion of 86 ha of shifting cultivation to mixed fruit gardens (mandarin orange, persimmon etc)	Protection contracts for 418 ha of medium timber forests		Conversion of 74 ha of shifting cultivation to agroforestry (maize and timber trees)

	Production forest	Protection forest	Special-use forest	Land outside forest
	Natural regeneration of 7,680 ha of recovered timber forests Protection contracts for 40% area of medium timber forests (67 ha) Protection contracts for 10% area of recovered timber forests (1,097 ha) Other land uses: as for BAU scenario	Other land uses: as for BAU scenario		Conversion of 177 ha of shifting cultivation to mixed fruit gardens

The impact of land-use changes in each planning zone, and in each scenario, on Ba Be's carbon stock are shown in Figure 20. For reasons of simplicity, the BAU was used as a Reference Emission Level to estimate carbon benefits generated by each land-use scenario.

Emission reductions by land-use scenarios

Emission reductions as a result of land-use changes in the whole Ba Be landscape and in each planning zone are shown in Figure 20. The Optimistic Plan scenario resulted in the highest net sequestration for the whole landscape, as much as 1,425,281 tCO_2eq in a 20-year period (2010–2030). This was followed by thae DARD (1,193,432 tCO_2eq), District (1,153,022 tCO_2eq) and LUWES (926,913 tCO_2eq) scenarios. A similar trend of emission reduction was found for the two largest planning units, Production Forest and Protection Forest. In these zones, DARD tended to impose an ambitious forest plantation and forest care program on almost any available plot. The DARD scenario is, therefore, similar to the Optimistic Plan scenario. Interestingly, for the Special-use Forest zone, local authorities and others were even more ambitious than the provincial DARD that directly manages this zone (Ba Be National Park) and were often found to be more aggressive in special-use forest protection planning.

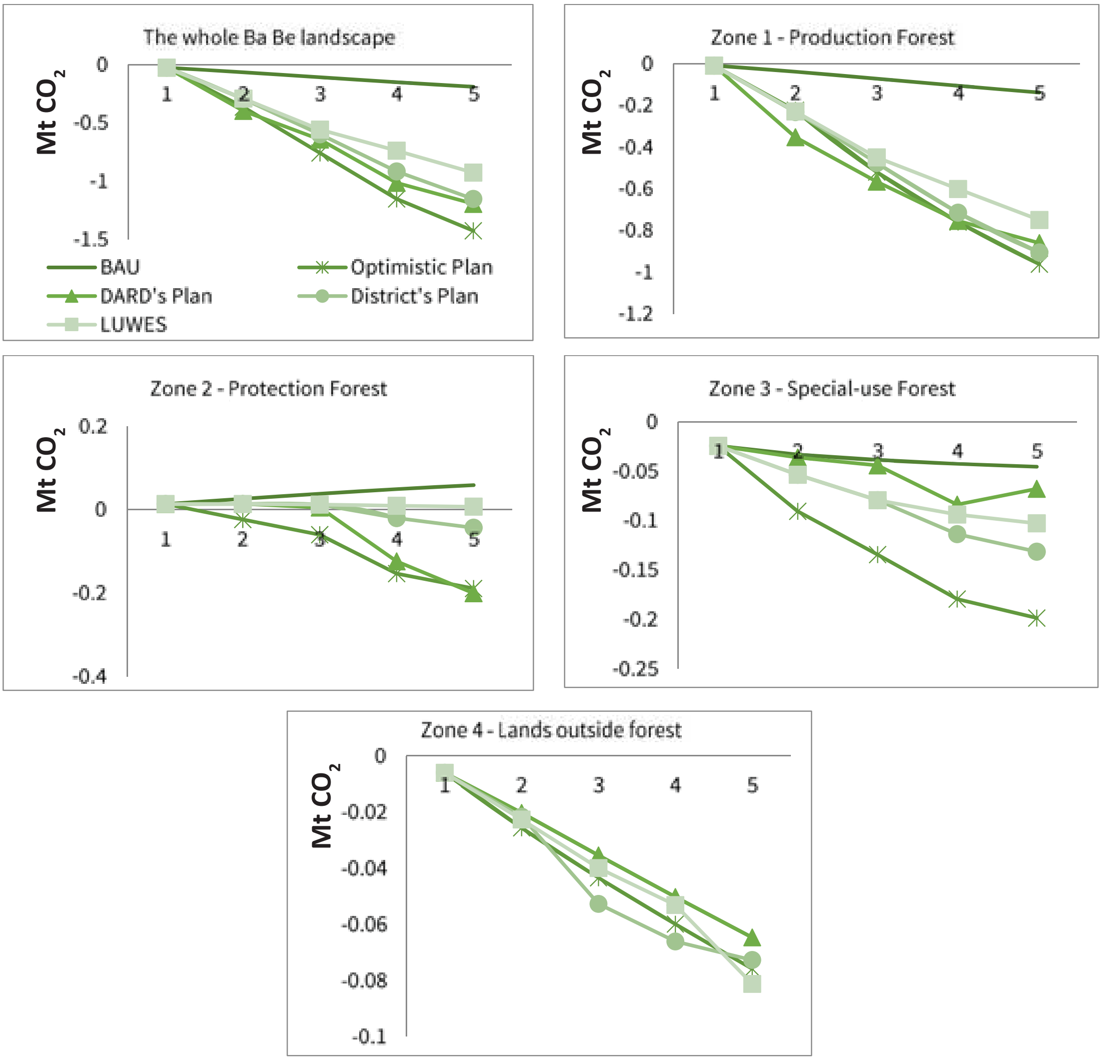


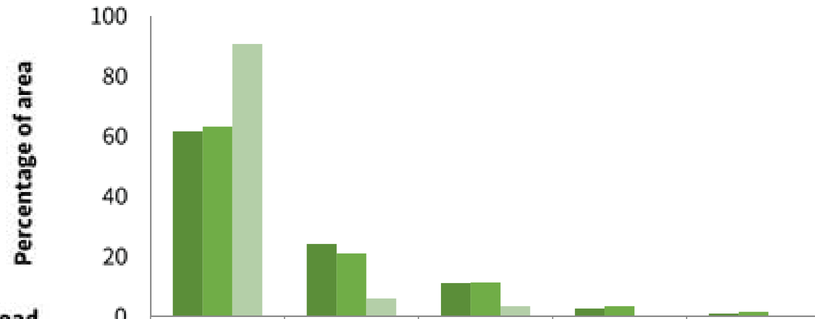
Figure 21. Net emissions from land-use changes in the Bac Kan landscape and each of planning units from 2010 to 2030 under different scenarios

4. Discussion

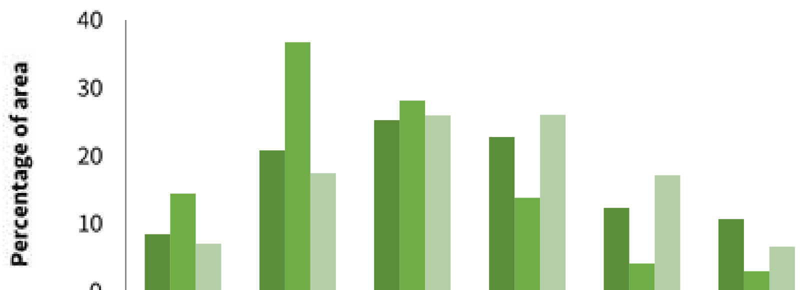
Our study illustrated the trend of decreasing the amount of potential land-based emissions through the increased participation of local people in land-use planning (Figure 21). Literature reporting this correlation is thin, although mismatches between top–down forestry and rural planning and actual land-use practices and local wishes in Bac Kan Province and elsewhere have been pointed out in earlier studies (Hibbard and Tang 2004, Castella et al 2005, Ohlsson et al 2005, Trung et al 2006, Castella et al 2007, Friederichsen and Neef 2010, Bourgoin et al 2012). Moreover, we found significant discrepancies between the top–down forestry plan and local willingness to put such a plan into practice. DARD planned to keep Ba Be a conservation landscape. Policy priorities seemed to be maximizing the extent of the forested area by planting more trees in forest zones wherever and whenever possible. On the other hand, local communities seemed hesitant to take large-scale interventions into forest zones.

It was revealed in local consultations that forest plantations, forest enrichments and even deforestation for agricultural land were only feasible in locations near roads and on slopes less than 25°. We verified this argument by examining the past distribution of both reforestation, afforestation and deforestation areas in Ba Be District for the period 1990–2010 (Figure 22). It was found that reforestation/afforestation and deforestation occurred mostly within 1 km from roads and hardly ever in areas more than 3 km. Similarly, more than 80% of reforestation/afforestation and deforestation areas were distributed on slopes ranging 5–25°. Therefore, it was likely that the participatorily-developed scenario (LUWES) was more realistic than the DARD and District scenarios as these limits were included in the LUWES scenario. Ohlsson et al (2005) studied the forest planning process in northern Viet Nam and found a similar result: that official planning data did not reflect reality and, therefore, it would be difficult for the 5 million hectare reforestation programme to materialize.

Such disparities between centralized and participatory planning have several implications for landscape conservation for



Distance to road	0-1km	1-2km	2-3km	3-4km	4-5km
Reforestation/Afforestation	61.56	24.03	11.05	2.54	0.82
Natural forest to planted forest	63.14	20.93	11.24	3.28	1.41
Deforestation	90.69	5.85	3.29	0.17	0.00



Slope	0-5	5-10	10-15	15-20	20-25	> 25
Reforestation/Afforestation	8.40	20.74	25.21	22.72	12.29	10.63
Natural forest to planted forest	14.39	36.71	28.10	13.78	4.07	2.94
Deforestation	7.00	17.41	25.91	26.01	17.08	6.58

Figure 22. Distribution of reforested, afforested, deforested, converted natural forest areas in Ba Be district from 1990 to 2010

both ecosystem services and livelihoods' improvement. First, as rational landscape planning is key to engaging people in their implementation (Bourgoin 2012), any future land-based low-carbon development programs should be developed in a participatory manner. Reconciling top–down and bottom–up approaches will be fundamental for benefits to be shared effectively and fairly. If these programs are only aimed at maximizing carbon storage, they will alienate communities and, hence, be less feasible (Bourgoin et al 2013). Furthermore, any such programs under the United Nations Framework Convention on Climate Change (UNFCCC) must comply with the principle of free, prior and informed consent where local communities' involvement is integral (Kanowski et al 2011, Bourgoin et al 2013). Second, there is a risk that the additionality of any further land-based low-carbon development program, such as REDD+, will be very likely minor in the Ba Be landscape. In other words, the DARD plan itself has already 'maximized' the land-based emission reduction potential of the landscape. DARD's ambition, thus, may be jeopardized by the rule of 'additionality' under the UNFCCC where credit can only be given for new actions, not ones already taken (Grainger et al 2009a). Viet Nam has already declared a national approach to REDD+ and it is likely that the REDD+ program will be mainstreamed into forestry and land-use plans rather than the other way around. Thus, the issue of additionality should be considered not only for the Ba Be landscape but also at wider scales. Third, if a future REDD+ program keeps focusing heavily on monocultural plantations, as in these scenarios, it will likely not help to promote but rather reduce biodiversity overall. Such unexpected outcomes of REDD+ programs solely based on carbon values, or of plantations on biodiversity, have been warned against (Grainger et al 2009b, Miles and Dickson 2010, Paoli et al 2010, Phelps et al 2012).

Therefore, although plantations on bare land have contributed to the largest emission reductions in Ba Be, a more diverse set of actions (for example, mixed species' plantations with native species, natural forest generation etc) should be considered in future low-emission development strategies. Fourth, low-emission development and emission reductions should not be achieved only by restricting access or the use options of forests (Larson 2011, Hein and van der Meer 2012), for example, the DARD plan for Protection Forest. People living near to protection forests area have rights to benefit from their resources and services (for example, timber for household construction, non-timber products or other livelihoods' activities). So far, there seems to be no option but abiding by the very tight restrictions on protection forests, which are under the management of state entities. Hence, a future REDD+ program should consider enhancing tenure rights and matching local priorities to maintain communities' interests (Mustalahti et al 2012). For instance, it was suggested during consultations that instead of being solely entitled to either state entities or communal people's committees, a certain area of protection forest could be entitled to communities where community-based forest management could be applied. This could be considered a step toward creating incentives to change land-management practices from less intensive swidden systems and encouraging greater carbon sequestration in complex, mosaicked landscape (van Noordwijk et al 2008, Bourgoin et al 2013).

Land sparing or land sharing for REDD+: community choice

In the foregoing discussion, it appears that the four scenarios have income trade-offs. Achieving a balance between carbon sequestration and food production and increased income needs a different approach. The LUWES scenario, which not only reflects the aspirations of local people but also addresses their food and income needs while sequestering carbon through land sharing, such as agroforestry, tend to offer a more realistic picture.

In the Ba Be landscape, it appears that ‘segregation’ has been used as the key Government strategy during the last 20 years. The landscape has been distinctively zoned for forest preservation and agriculture development. In general, forest has been preserved in less accessible or protected areas while agricultural practices have been allowed on lowland near water sources and paved roads. This strategy has achieved certain success in maintaining, and indeed increasing, the district’s forest area but modest in improving local livelihoods. For example, the poverty rate was still high (37.17%) as of 2010 and food scarcity was common. More importantly, even if Ba Be had obtained sufficient productivity from agriculture as the only strategy for forest conservation, it would have been unsure that its conservation targets could be achieved because increasing agricultural yields may not result in land ‘spared’ for nature but may instead favour further agricultural expansion and non-conservation uses (Grau et al 2013). There is considerable evidence supporting this argument (Matson and Vitousek 2006, Phelps et al 2013). Indeed, Ba Be seemed to fall into a trade-off between agricultural production and conservation: the more successful the policy was in halting agricultural expansion and reducing deforestation, the larger the reduction in production (Angelsen 2010). This trend was found in a similar landscape in Nghe An Province, Viet Nam by Jakobsen et al (2007), who showed that while the changes imposed on land use certainly lead to an increase in forest cover they would also likely lead to declining yields and reducing labour productivity.

Challenges for a future land-use plan for Ba Be, which aims at both emission reductions and multiple co-benefits, therefore relate to optimal mixes between ‘sparing’ and ‘sharing’ (Minang and van Noordwijk 2013). A more ‘sharing’ approach can be used here for reconciling conservation and development through interventions in different components of a landscape matrix (Sayer et al 2013) and may help to improve carbon stock of conservation areas (Lusiana et al 2012). Land sharing has actually been practised by farmers in the context of policy restrictions. The *de facto* use of degraded production forests, protected forests and even a small part of special-use forests for shifting cultivation and cattle grazing have been common practices in Ba Be. On the other hand, 21.82% area of the Land outside Forest zone is forest (as of 2010) and was being managed as forest rather than ‘non-forest’. Although a part of this forest could be a result of mapping errors by DARD, its existence was confirmed by both local governments and forest users. Considering landscape multi-functionality, the use of ‘degraded’ or ‘unused’ forest land for agriculture may be acceptable if well managed. Restoration of ‘degraded’ land by a combination of afforestation and agricultural production can even reduce further degradation and eventually increase the provision of selected ecosystem services (Matson et al 2012, Rey Benayas and Bullock 2012, Verburg et al 2013).

The LUWES scenario in this study demonstrated local wishes to further rehabilitate a part of production and protection forests and land outside forests by promoting higher carbon-stock land uses, such as agroforestry on bare land and mixed fruit gardens on land formerly used for shifting cultivation. This shows a potential for ‘carbon farming’ both inside and outside forest. According to Thangata and Hildebrand (2012), agroforestry is capable of sequestering a large amount of carbon on farms while at the same time meeting the demand for other household food requirements and socioeconomic activities. Lin et al (2013) reviewed revegetation of agricultural landscapes as offsets to emissions and found that agroforestry offered reasonable co-benefits while reducing the likelihood of disadvantages, compared to plantation styles of revegetation. This range of practices is also likely to be suitable for Ba Be. 'Carbon projects' on degraded land were found to be much less disputed—and often successfully generated and sold offsets—than those sites with more favourable natural conditions, owing to their lower opportunity cost (Reynolds 2012).

However, the locally-developed LUWES scenario does require a broader scope of carbon accounting than REDD+. Figure 23 presents the contribution of REDD+-eligible emission reductions (that is, those related to forest land-use changes) of the whole landscape (that is, REALU) according to different land-use plans. The lower the level at which the plans are developed, the greater the contribution of non-forest land to total emission reduction. In the LUWES plan, about 8% of total emission reductions comes from non-forest land while in the District, DARD and Optimistic Plan it was only 6% and 5%, respectively. This provides empirical evidence for an increasing demand for REDD+ going beyond institutional forest and includes the role of eco-friendly tree farming (Bourgoin et al 2013, Dewi et al 2013, Minang and van Noordwijk 2013). It is also important to note that even in a participatory scenario, such as LUWES, local choices were still very much limited by laws and regulations on forest conservation. If such policy constraints are loosened, emission reductions from non-forest land could even be higher. A well-designed incentive scheme would then be needed for Ba Be to yield win-win outcomes where targeted emission reductions were met and agricultural production sustained and improved.

Figure 23. Proportion of emission reductions eligible for REDD+ in land-use planning scenarios

5. Conclusion

Our study discussed the use of LUWES for low-emission land-use planning in a rural landscape in Viet Nam, providing insights into the land-use planning process and how it affect a landscape's climate mitigation potential. The study showed that well-facilitated stakeholder engagement can lead to a more realistic emission reduction/carbon sequestration plan, thus, offering greater additionality and sustainability of REDD+. It also pointed to how people can shape their future low-emission development strategy, that is: (i) pursuing a more 'sharing' approach in forest conservation to achieve livelihoods' targets without harming the carbon-sequestration capacity of a landscape; (ii) paying due attention to local needs of sustainable carbon farming on degraded land inside forests and agricultural land outside forests; and (iii) applying a whole landscape carbon accounting framework to maximize local benefits from REDD+ and other mitigation programs. The lesson learned from this study is that provincial and district governments need to address the discrepancies in forest allocation and management and engender greater stakeholder participation to develop realistic low-emission land-use plans.

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Sloping land without tree cover in Northwest Viet Nam. (Photo: World Agroforestry/Thuong Huu Pham)

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 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).

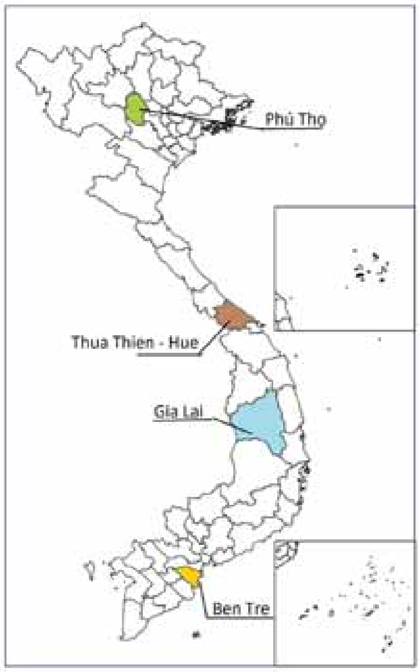


Figure 24. Geographic location of the study sites representing four agro-ecological regions

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

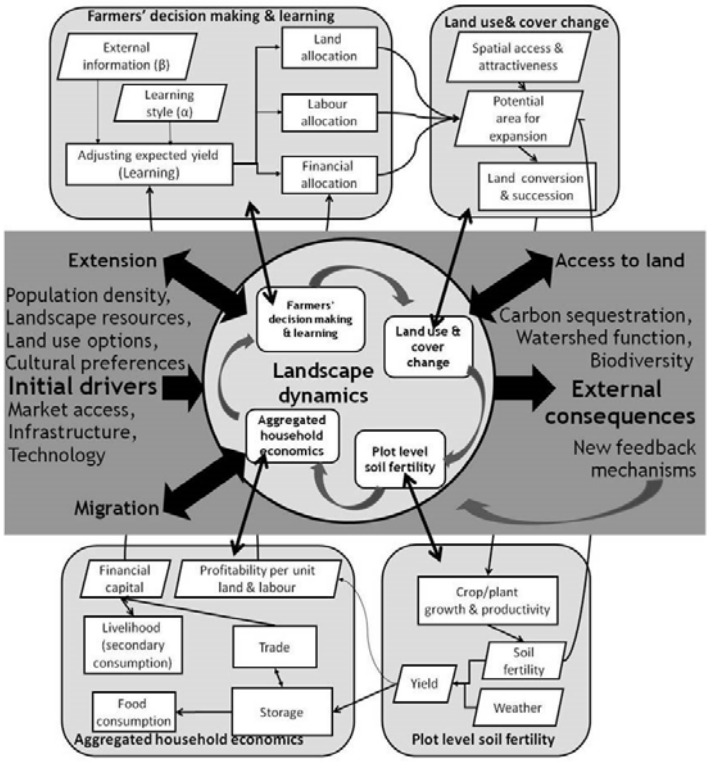
FALLOW

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

Land-use type	Scenarios			
	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	REA-LU	BAU	AFPE	REA-LU	BAU	AFPE	REA-LU	BAU	AFPE	REA-LU
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

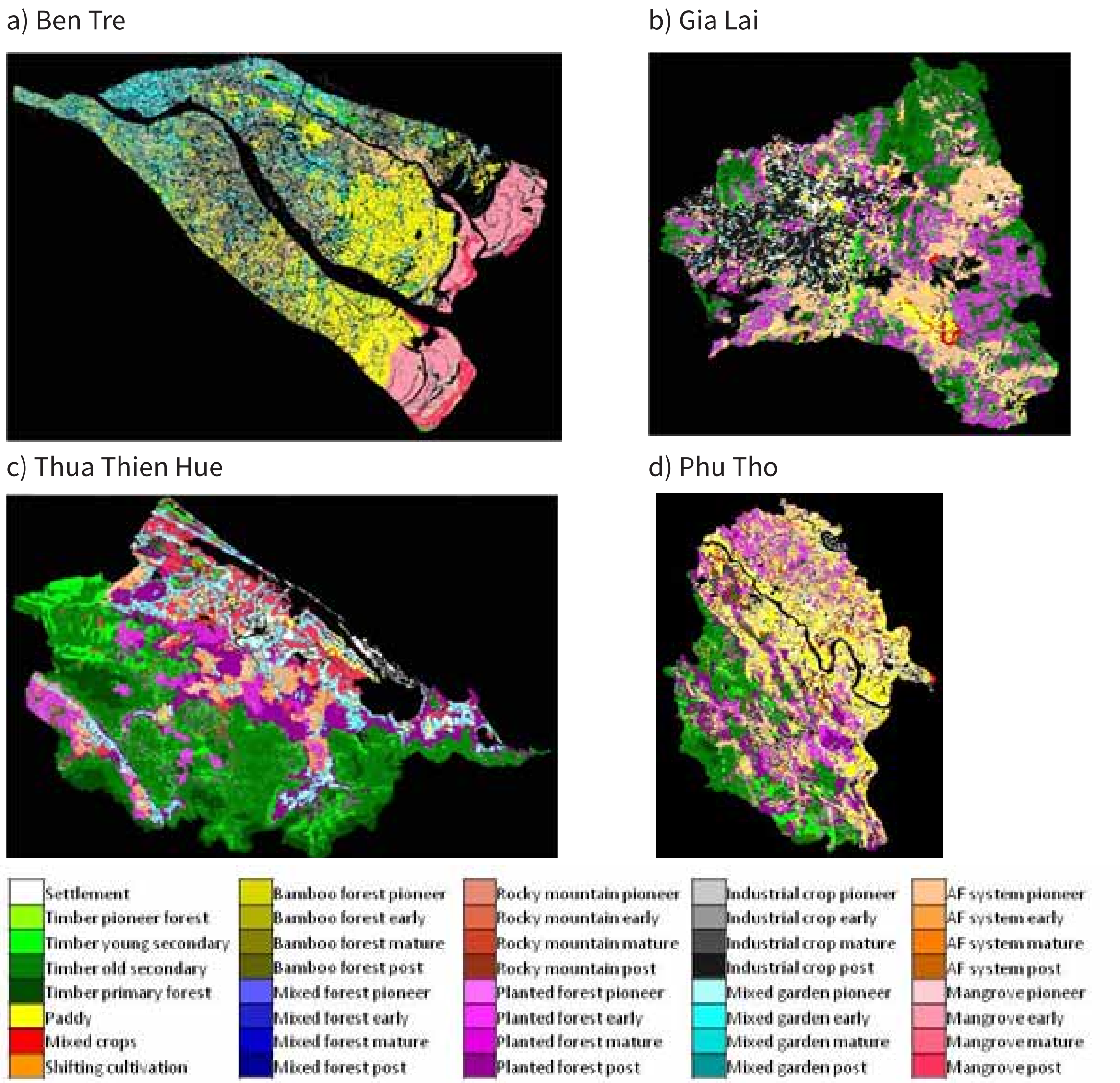
**Restored protection and special-use forest land*

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**	**REALU**	**BAU**	**AFPE**	**REALU**	**BAU**	**AFPE**	**REALU**	**BAU**	**AFPE**	**REALU**
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 income 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 compared 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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Ngan Sau river during dry season, Ha Tinh province, Northcentral Coast of Viet Nam (Photo: World Agroforestry/Ha My Tran)

CHAPTER 6

Hydrological assessment of forest-cover change and intensification strategies in Ho Ho sub-watershed, Northcentral Coast Viet Nam

Van Thanh Pham, Rachmat Mulia, Bac Viet Dam

Summary

To enhance the contribution of forest land to local livelihoods and environmental functions, the Government of Viet Nam formulated Forest Development Strategies 2006–2020. Long-term timber plantations were planned to be developed on production forest land across the country, combined with forest protection efforts, especially within watersheds to improve watershed services. In this chapter, we present the impact on hydrological functions of three forest-intensification scenarios in Ho Ho sub-watershed, Northcentral Viet Nam. The scenarios represent government planning as well as local expectations. The Generic River model was used to assess the impact on river flow of various forest scenarios.

Compared to scenarios with higher tree-canopy density, the conversion of degraded forests into short-term acacia plantations would lead to higher river flow and higher surface run-off with accompanying risk of severe soil erosion because most of the forest area is sloping land. In contrast, expansion of long-term timber plantations in the forest-restoration scenario would result in less river flow compared to an expansion of acacia plantations and less surface run-off with higher groundwater storage. The lowest surface run-off was found in the forest-restoration scenario. Owing to the projected unfavourable impact on river flow of higher tree-canopy cover and density, we recommend that local authorities carry out a trade-off analysis between environmental benefits that forest-intensification strategies can provide—such as carbon sequestration and biodiversity protection—and water provision. We also highlight the need to develop innovative forest-plantation models that can minimize soil loss, especially on sloping land, for example, by adopting agroforestry, which optimises the spatial and temporal aspects of systems. Finally, we emphasize the urgency in accomodating additional ecosystem services other than only water provision in the current Payment for Forest Ecosystem Services decree, to encourge smallholder forest owners to participate in forest-protection and -restoration efforts.

1. Introduction

Viet Nam has relatively successful forestry programs that have brought the country from extensive and severely degraded forests in the 1960–1980s to the present stage of reforestation and net forest increase. This achievement is mainly due to the government's effort in allocating forest land and devolving rights to households and communities since the 1990s, coupled with massive afforestation programs, such as Greening the Barren Hills (aka Programme 327) and Five Million Hectare Reforestation Programme (5MHRP). The latter replaced the first in 1998 and was implemented until 2010 (Clement and Amezaga 2009, To et al 2013).

The afforestation programs introduced exotic tree species, such as eucalyptus and acacia. The latter has been promoted as a fast-growing timber tree species that can restore soil fertility. Nowadays, the short-rotation acacia system for pulp and paper is the most popular forest-plantation system in Viet Nam. It dominates production forests (Tran et al 2014, Trieu et al 2016). The acacia system has improved the livelihoods of many smallholders and improved soil fertility in various regions but, despite this, recently several livelihoods and environmental issues have been observed (Chapter 4 of this volume). There is a tendency toward the acacia pulp and paper market becoming saturated, with a decline in log price over the last three years. Furthermore, farmers in different regions have reported cases of serious soil erosion in acacia plots mostly located on sloping uplands, particularly, between the clear felling and replanting stage. The slash-and-burn system practised in the short-rotation system is also a source of greenhouse-gas emission and not in line with the country's commitment to reduce emissions from the agricultural and forestry sectors.

To meet the national demand for timber—imports account for 80% of supply—the government has planned to gradually convert degraded production forests and short-term acacia plantations into long-term timber plantations. This plan has been translated by sub-national authorities into provincial or district targets for areas under long-term timber plantation and levels of production. In Viet Nam, production-forest land can belong to non-State groups, such as households, individuals, or communities, or State bodies, such as forest management boards (FMB) and State forest entreprises (SFE), currently known as forest companies (FC). The other forest types, that is, protection and special-use forests, are generally not allocated to communities or households but are fully managed by State bodies.

Short-rotation acacia plantations are popular in Northcentral Viet Nam, especially since the 2000s, thanks to government extension and subsidies. This region is known as one of the most vulnerable areas in the country to climate change and variability (Casse et al 2015, Nguyen et al 2014) owing to its massive area of degraded forest land (for example, see Nguyen et al 2016) as well as its geographical location on the coast, exposing it to different seasonal and cyclonal climatic hazards. For example, in September 2017 the strongest cyclonal storm in Viet Nam during the last decade hit the region, with Ha Tinh as one of the most affected provinces. In terms of the forestry sector, similar to other regions, the local authorities also formulated forest development strategies, including the development of long-rotation timber plantation on the land owned by smallholders as well land owned by the provincial FMBs and SFEs. The national guidance includes the Forest Development Strategy 2006–2020 that was built upon the previous 2001–2010 strategy and approved by the Ministry of Agriculture and Rural Development (MARD) and the Forest Sector Support Program (VAFS 2007). The Strategy aims to augment the contribution of the forestry sector to the livelihoods of local people and to the provision of environmental functions, such as biodiversity and soil protection, which should be associated with the protection of watersheds across the region.

The existing literature mainly focuses on the impact on local livelihoods of forest-cover change or carbon sequestration for climate-change mitigation and rarely addresses the hydrology of watersheds. However, the same attention should be paid to the impact on water and river flow since forests and trees are ones of prime regulators of water cycle (Ellison et al 2017, van Noordwijk et al 2014). A comprehensive literature review has also indicated that interaction between forest, water and energy plays an important role in storing carbon, cooling terrestrial surfaces, and distributing water resources (Ellison et al 2017). Particularly in the context of watersheds, land-use and forest-cover change will influence the daily water balance and determine the fresh water supply for local livelihoods. Moreover, National Decrees 99 and 147 on PFES have formulated payments mainly for forest functions as watershed services, where the single indicator for calculating payments for service buyers is the quantity of water from the watershed that they use for different purposes, such as production of hydroelectric power or potable drinking water, eco-tourism activities or other commercial purposes. Payments for other forest ecosystem services, such as carbon sequestration or biodiversity protection, have not yet been formulated in a detailed regulation.

In this chapter, we present the results of a hydrological assessment of forest-cover change and intensification strategies in Ho Ho sub-watershed, Ha Tinh Province, Northcentral Viet Nam. The hydrological assessment used the Generic River (GenRiver) flow model (van Noordwijk et al 2011) that can link land-use change in a landscape to water balance in a watershed, including projection of water flow from each sub-catchment to the main river or basin. Our study investigated the impact of three different forest land-cover scenarios: 1) expansion of short-term acacia plantations; 2) forest protection and restoration; and 3) expansion of long-term timber plantations according to the strategy formulated by local authorities. There were two specific research questions to answer: 1) What might be the impact of each of the three forest land-cover scenarios on the hydrological functions in the sub-watershed reflected by the amount of water flow to the main river and to the Ho Ho river basin and hydropower plant as the final outlet? 2) What might be the impact of the each scenario on the current level of PFES received by the smallholders in the sub-watershed? We also compared the results of the assessment with the expectations of local stakeholders that forest land intensification would mitigate the intensity of droughts and flooding and, overall, increase the total annual river flow in the sub-watershed.

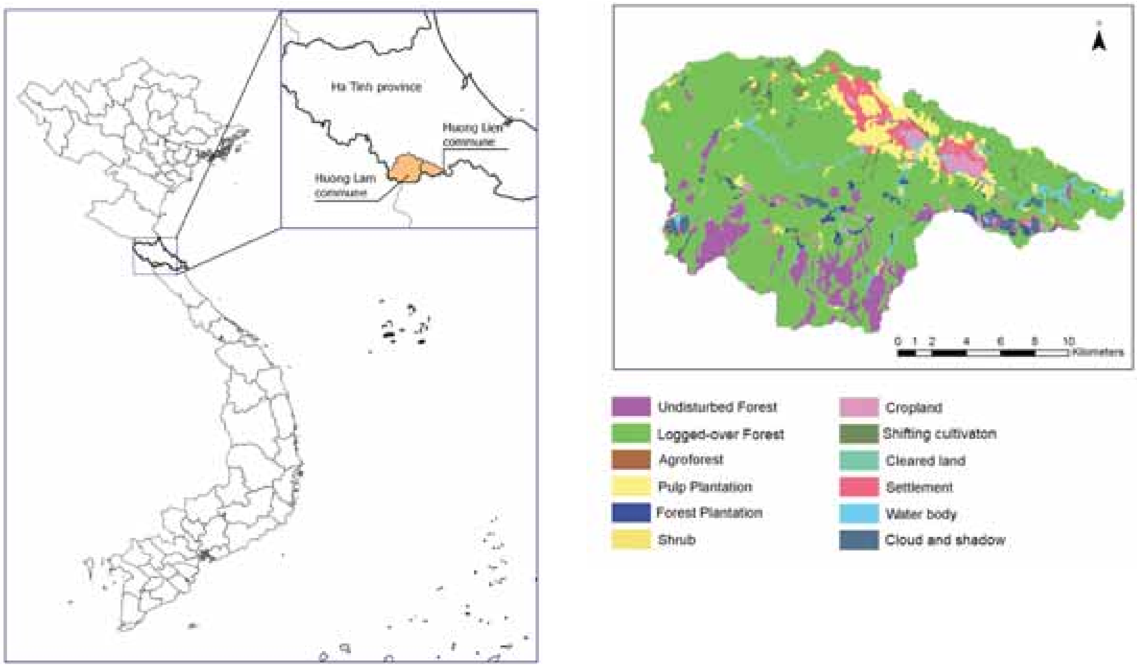
2. Materials and methods

Study site

Ho Ho sub-watershed is located in Ha Tinh province, Northcentral Coast, Viet Nam and mainly covers two communes of Huong Khe District: Huong Lam and Huong Lien (Figure 27a). It has the Ho Ho river basin and hydropower plant at the border of Huong Lien Commune (105° 50’ E, 18° 2’ N) operated since 2013. The sub-watershed has a total population of 3500 households (10,400 people) according to the 2014 census and covers an area of 27,600 hectares with 70% being logged-over forest (that is, degraded natural forest) and 7.5% being short-term acacia plantations (Figure 27b). Scattered, undisturbed natural forests still exist in the southern part of the sub-watershed thanks to difficult access owing to steep slopes and rugged terrain while the acacia plantations and farms mainly occur in the northern part of the sub-watershed closer to settlements.

The sub-watershed consists of tributaries that all feed into the Ngan Sau River, which drains into the reservoir of the Ho Ho hydroelectric plant (HEP). The reservoir is used by downwstream beneficiaries as a source of potable water and irrigation.

The sub-watershed experiences a tropical monsoonal Summer and Winter. The Summer extends from April to August with dry and hot climatic conditions. In particular, the area is severely affected by southwest winds between June and July. The cold season starts in November and ends in March with the northeast monsoon. The average annual temperature in the area is 24.5 °C, with 29.5 °C as maximum, usually observed in June and July, and 18 °C as minimum between December and January. The annual rainfall ranges 1,590–2,400 mm, with an average rainfall of around 390 mm in the wet season between August and September and 40 mm in the dry season between January and February. Agriculture is the main source of local livelihoods, with annual crops such as peanut, rice, maize, sweet potato, green bean and cassava. Livestock includes pig, cow, buffalo and chicken. Local people usually cultivate fruit trees in homegardens, such as orange or pomelo, with timber trees, such as *Aquilaria crassna* and *Dalbergia tonkinensis*, used as windbreaks or borders. On forest land, the common system is short-term acacia of 4–5 years rotation for pulp and paper. Some farmers also earn income from non-farm jobs, such as construction labour, as well as from public and private employment.



a) b)

Figure 27. (a) Location of Ho Ho sub-watershed as the study site; (b) 2014 land-cover distribution in the sub-watershed

Hydrology issues

In the sub-watershed, the local people use water from different sources, such as dug wells, artesian wells, streams, rivers, dams, pond/rain, and channel (Dam et al. 2015). The water from wells is for daily and domestic uses, such as cooking, drinking, washing clothes and bathing. River, stream and dam water is more commonly used for animals and for irrigating annual crops. In recent years, the water from these sources has been reported as being smelly, containing alum, contaminated by rubbish and muddy. The causes of the problems were claimed to come from household waste, defoliation, remaining branches after forest exploitation, and animal corpses after heavy flooding. After logging, defoliation and small branches of trees are carried in surface run-off to rivers and streams and even as far as the dam.

Key informant interviews revealed that the level of water flow in Ngan Sau River had been very low at times in the past decade. In 2003, the Ho Ho hydropower plant officially reported that river flow was about 19 $m^3 s^{-1}$ but the average between 2013 and 2015 was only 8 $m^3 s^{-1}$. It was also reported that rainfall patterns in the sub-watershed had changed in the last ten years. Nowadays, a stronger rainfall gradient was apparent between dry and wet seasons. The dry season restricted a second cropping season in many villages while flash floods in the wet season had become more intense. As a consequence, the Ho Ho hydropower plant has also had to operate below the minimum water level in the dry season and far above the maximum in the wet season.

PFES in the sub-watershed

Although globally the impact of forest-cover change to hydrology of watersheds is rarely addressed, Viet Nam is the first country in Southeast Asia that integrates PFES into national strategies and policies (McElwee 2012), formulating the payment rate for forest water service beneficiaries. In 2008, the Government of Viet Nam promulgated Decision No. 380/2008/QD-TTg to pilot the implementation of PFES in Son La (Northwest) and Lam Dong (Central Highlands) provinces for a two-year period (2008–2010). Learning from this pilot, in 2010 the government issued Decree No. 99/2010/ND/CP to mandate and apply PFES nationwide and issued revised Decree 147/2016/ND/CP in 2016. According to the new Decree, hydropower companies must pay VND 36 (USD 1 ≈ VND 22,000) per kWh of generated electricity, while the payment rate for water-supply companies is VND 52 per m^3 water used, and for organizations or individuals engaged in tourism businesses is 1–2% of their annual income. Based on this regulation, the smallholder forest owners in the sub-watershed receive about VND 30,000 (≈ USD 1.5) per hectare per year. To increase the amount of PFES, local stakeholders in the sub-watershed expressed the need for forest restoration, especially, in the upstream part of the sub-watershed.

GenRiver hydrological model

Hydrological models have been used to make projections of river flow through a water-balance process. They can also be described as watershed models. The water-balance process usually takes into account rainfall as input distributed to different river-flow components, such as surface, sub-surface and ground flows. Compared to other hydrological models, such as MIKE-SHE (https://www.mikepoweredbydhi.com/products/mike-she) or SWAT (http://swat.tamu.edu/), we chose GenRiver because it required less parametes but could still be used to make projections of the impact on river flow of land-cover changes in a

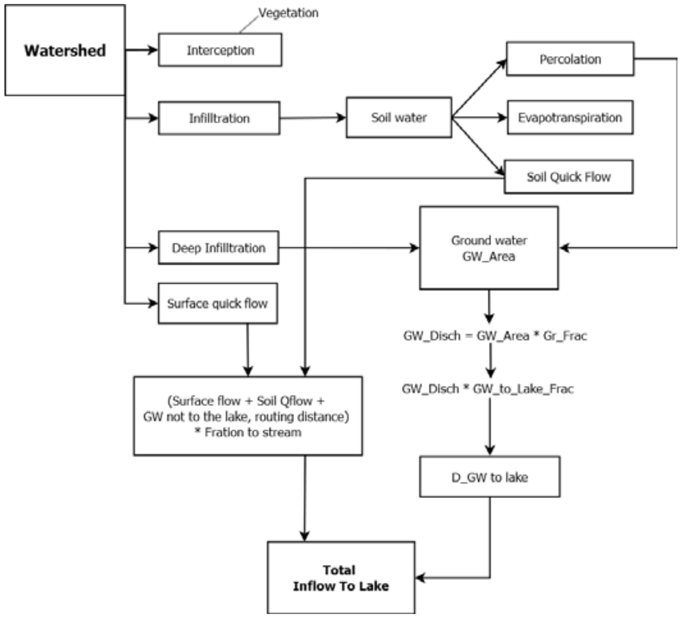


Figure 28. Water-balance process in the GenRiver model

watershed. The model was designed with the Stella platform and runs in daily time-steps.

In the model, rainfall as input is divided into four basic components: 1) canopy interception; 2) infiltration; 3) deep infiltration; and 4) surface quick flow (Figure 28). The interception rate varies depending on the land-use or vegetation type. A part of the sub-surface infiltration will evaporate. The rate depends on vegetation transpiration and soil evaporation. The rest will be stored as sub-surface or ground water. The simulated watershed can be divided into a maximum of 20 sub-catchments and the total amount of water flows from each sub-catchment will be the sum of surface run-off, sub-surface and ground flows.

Input maps and parameter values

The model simulations require maps and parameter values for input. A land-cover map was produced by interpreting LANDSAT imagery and a land-use map from MONRE as reference (Nguyen et al 2015). A soil map was provided by the Viet Nam National Institute of Agricultural Planning and Projection. Other maps, including administrative and river networks, were obtained from MONRE (Table 24). Climate data (that is, daily rainfall and air temperature) were obtained from the Viet Nam Institute of Meteorology, Hydrology and Climate Change recorded at Huong Khe weather station (18°11’N, 105°43’E), 19.5 km to the northwest of Ho Ho dam. They constituted more than 30 years of rainfall and air-temperature data (1982–2014) and were used for model simulation as well as to investigate climate change and variability in Huong Khe District.

The sub-catchment boundary within the sub-watershed was delineated by the ArcHydro tool available as part of ArcGIS software. The procedure included the elimination of water traps in Digital Elevation Model, determining the formation of streams by the terrain, defining the flow direction and routes, defining the stream network, dividing the stream network into a given number of sub-catchments, and defining the area of the sub-watershed surrounding each sub-catchment. Based on this procedure, the Ho Ho sub-watershed with area of about 27,000 ha can be divided into 19 sub-catchments. From each sub-catchment, a routing distance to Ho Ho dam and the HEP was calculated as the nearest distance from the centre point of the sub-catchment to the river and the routing distance followed the river path to the Ho Ho dam and the HEP.

Table 24. Input maps and data for GenRiver simulation in the Ho Ho sub-watershed

Data	Source	Date range	Resolution
Daily maximum and minimum temperatures	Viet Nam Institute of Meteorology, Hydrology and Climate Change	1982–2014	Daily
Daily precipitation	Viet Nam Institute of Meteorology, Hydrology and Climate Change	1982–2014	Daily
Elevation (m)	ASTER	2010	30 x 30 m
Soil type (FAO standard)	Viet Nam National Institute of Agricultural Planning and Projection	2010	1:1,000,000
Land-use map	Nguyen et al (2015)	2010, 2014	1:100,000
Water level in reservoir	NEDI-1 JSC. (owner of Ho Ho HEP)	2013–2014	Daily
Base map (boundaries, roads, river system)	National Administration Map		
Provincial agricultural planning map	Ha Tinh Provincial People's Committee	2011	

Thirteen land-cover types were simulated (Appendix 1). Their properties—such as interception capacity and transpiration rate—were estimated from the default values in the model's land–cover library that included different types of forest land-cover, annual crops and perennial systems, such as agroforestry. A detailed description of input-parameter values and the modelling concept can be found in van Noordwijk et al (2011).

Model validation

For validating the model, we estimated the historical river-flow based on the levels of water recorded in the Ho Ho dam during the period 2013–2014. There was no hydrological station close to the sub-watershed that had ever recorded the river's flow rate. The data from the Ho Ho company included the daily water levels in the reservoir, hours of turbine operation and electricity production. The river-flow estimation was based on the standard table and conversion method suggested by the company that defines the relationship between water level and water volume in the reservoir, and the relationship between electricity production and outflow rate. The estimated historical river flow was compared to the model projection for 2013–2014 using land-cover maps for 1990, 2000 and 2014 and the rainfall and air temperature data from 1990–2014. The model allowed four transition periods in the simulation, with different input land-cover maps, to capture changes in land cover during the assessment period.

Forest intensification scenarios

We assessed the impact of three forest-land intensification scenarios, that is, the expansion of short-term acacia plantations (AE); enrichment of degraded forest land with native tree species (FE); and expansion of long-term timber plantations (TP). The latter was based on the 2011–2020 Provincial Forest Protection and Development Plan formulated by the Ngan Sau Forest Management Board and Chuc A State Forest Enterprise while the former two were based on local stakeholders' expectations, providing the worst and the best cases from the perspective of forest tree-cover in the sub-watershed.

Short-term acacia plantations were still of high interest to local people in the sub-watershed owing to easy maintenance and a relatively stable market. The AE scenario simulated a case in which areas within 3 km of a main road and 1 km from the river—that is, the areas confirmed by local knowledge as potential sites for conversion into acacia plantations, constituting 38% of the total area of the sub-watershed—were completely converted from degraded forest land into short-term acacia plantations with a 5-year rotation cycle (Figure 29a). The FE scenario simulated a case in which areas were protected for forest restoration and enriched by planting native tree species (Figure 29b). This reflected the most extensive form of forest restoration and represented local expectations of restoring natural forest land to increase the level of river flow. Local people mentioned native tree species, such as *Erythrophleum fordii* and *Dalbergia tonkinensis*, were suitable for forest restoration. In the TP scenario, the production forests managed by FMB and SFE would be converted into long-term timber plantations (Figure 29c). The total area of the production forest land constituted 43% of the total area of the sub-watershed. The suitable tree species for this type of plantation, according to the authority's plans, were acacia, *Michelia mediocris* Dandy or *Erythrophleum fordii*. The two latter species usually have a rotation cycle of 15 years or more while acacia plantations for timber purposes usually have a shorter period, such as 8–12 years. For the model simulation, we assumed the rotation cycle for long-term timber plantations was 15 years. All scenarios were assessed over a 30-year period to allow the forest land in the FE scenario to reach a higher stage of development. The model assumed that the current degraded natural forests had a timber volume of 100 m^3 ha^{-1} and, with a forest protection and enrichment strategy as formulated in the FE scenario, the forest land would develop into enriched medium forests with a timber volume or more than 150 m^3 ha^{-1} in 30 years' time. This projection was based on a study by Vu (2010) of forest development in Viet Nam.

All scenarios used the 2014 land-cover map for initial land-cover distribution. For climatic conditions, the rainfall and air temperature in 2014 were based on empirical data whereas from 2015 onwards the daily rainfall and air temperature were the average from the last 10 years (that is, 2005–2014). To capture climate variability, all scenarios were also assessed under three different rainfall regimes: 1) with annual rainfall of 2,600 mm, constituting average annual rainfall for the last 10 years; 2) 1,300 mm per year or half of the average; and 3) 3,900 mm year per year or 1.5 times the average.

3. Results

Historical water debit and model validation

The estimated time-averaged historical water debit based on the observed height of water levels in the dam was 8 m^3 s^{-1} in 2013 and 3.5 m^3 s^{-1} in 2014. The latter is much lower than the first because the 2014 rainfall was lower than 2013. Compared to the rate of 19 m^3 s^{-1} in 2002, as reported in PECC (2002), the level of water flow in Ngan Sau River has decreased significantly. The estimated historical water debits capture the variation in rainfall (Figure 30a) and the values are close to the projected water debits by the GenRiver model (Figure 30b).

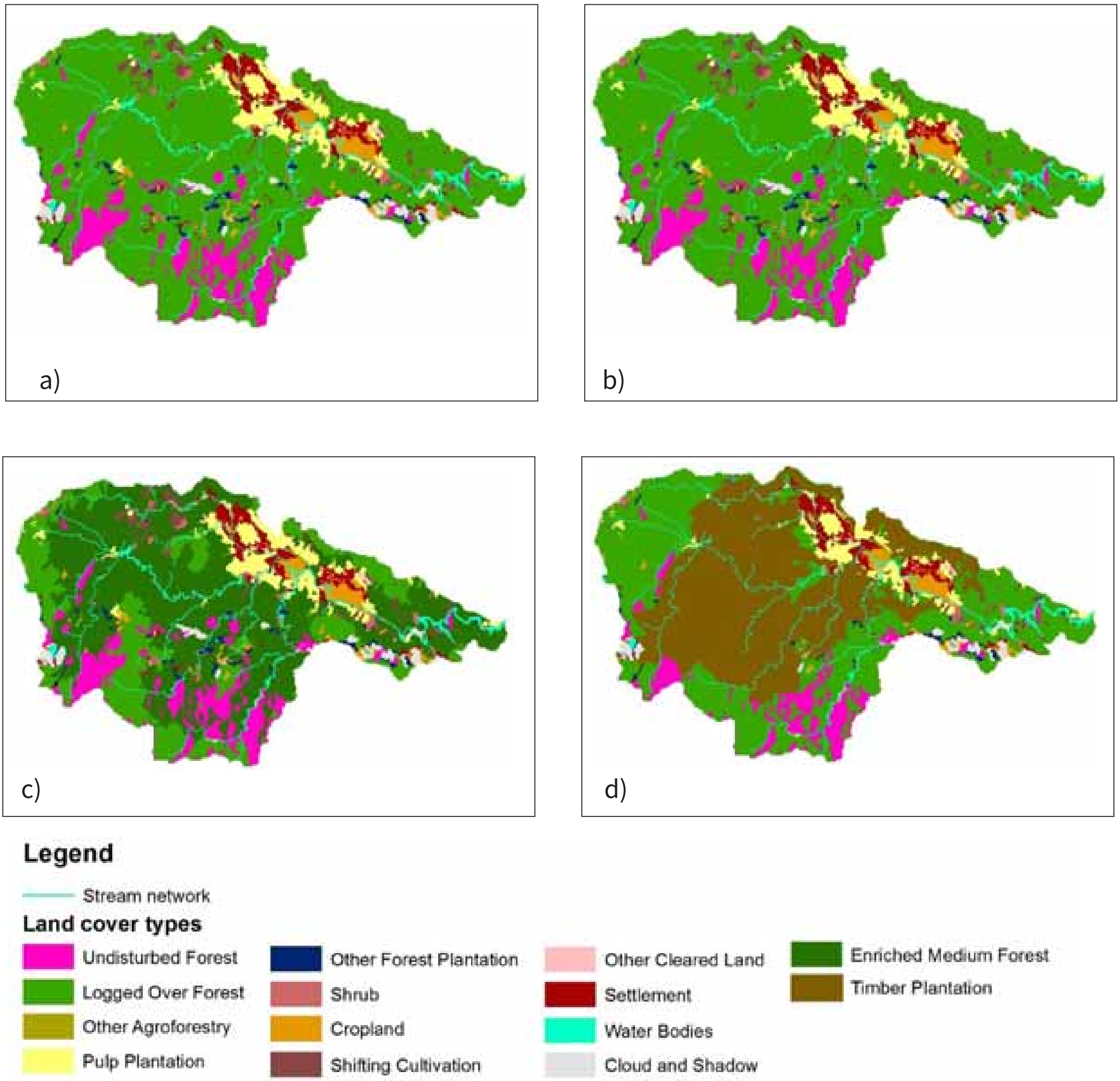
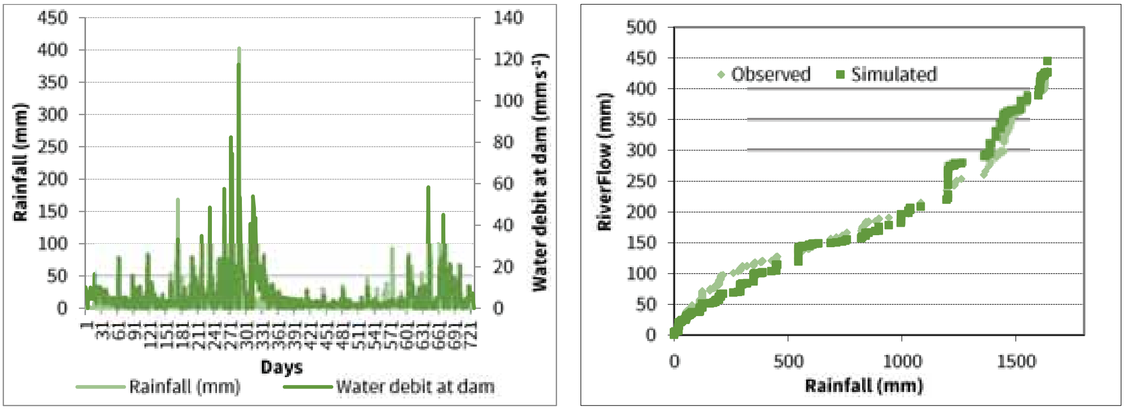


Figure 29. Land-cover distribution in Ho Ho sub-watershed according to (a) 2014 land-cover situation; (b) acacia expansion scenario (AE); (c) forest enrichment scenario (FE); and (d) long-term timber plantation scenario (TP)

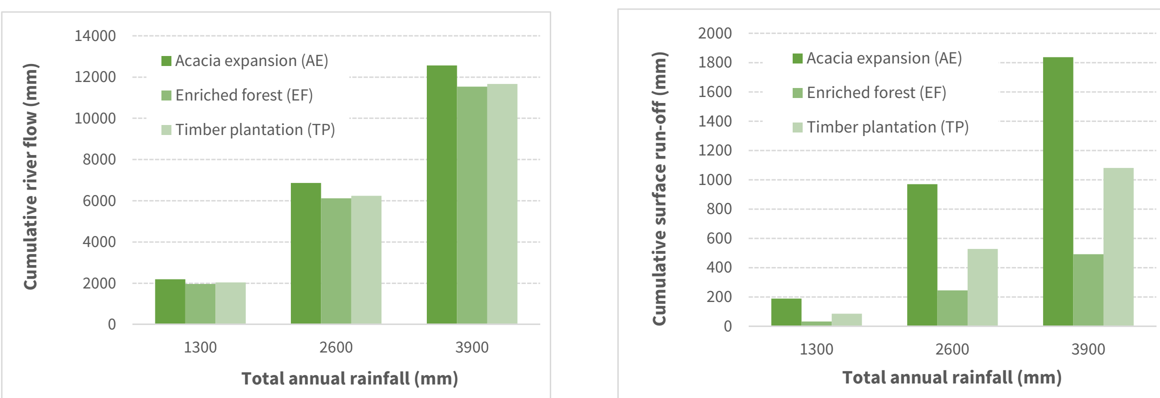


a) b)

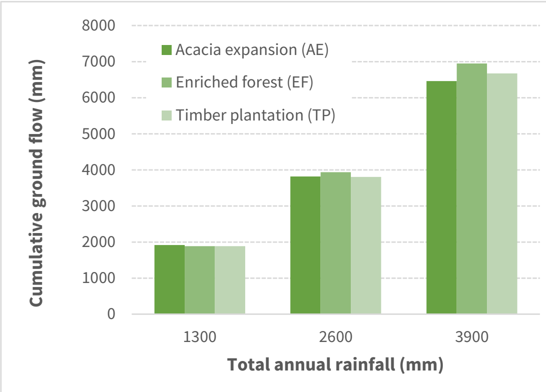
Figure 30. (a) Rainfall and historical water debit at Ho Ho dam, 2013–2014; (b) Observed and simulated water debits for 2013–2014

River flow to the dam

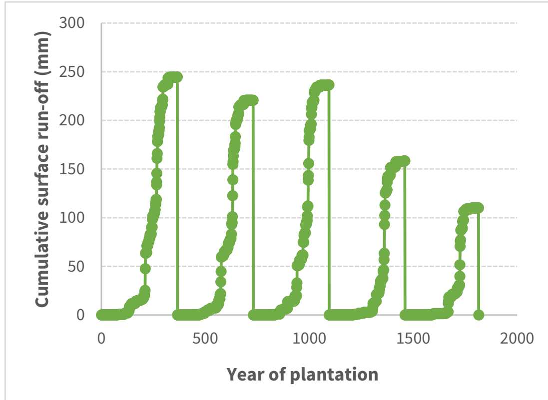
Under all rainfall conditions, the projected river flow was higher in AE than in the two other scenarios (Figure 31a). Under average annual rainfall (that is, 2,600 mm), the cumulative river flow in the scenario with short-term acacia plantations over five years—the complete rotation cycle—was 6,861 mm compared to 6,123 mm for EF and 6,242 mm for TP. The latter two, respectively, reflect 1) cumulative river flow over five years under enriched medium forest, namely, 25–30 years after degraded forest land was enriched by native tree species; and 2) the scenario with long-term timber plantations, namely, 10–15 years after planting. The difference in cumulative river flow in the scenarios is largest with higher annual rainfall (Figure 31a). For example, with 3,900 mm annual rainfall the difference in cumulative river flow between AE and the two other scenarios is 900–1,000 mm whereas with 1,300 mm and 2,600 mm annual rainfall the differences are 100–200 mm and 600–700 mm, respectively. No substantial difference in cumulative river flow was found between EF and TP for all rainfall regimes, which was most likely owing to comparable levels of tree cover in the two scenarios.



a) b)



c)



d)

Figure 31. Five-year cumulative river flow (a), surface run-off (b), and ground flow (c) in the three forest intensification scenarios under three rainfall regimes, and surface run-off by plantation year (d) in the acacia expansion scenario

More contrasting differences among scenarios were found related to surface run-off (Figure 31b). Under all rainfall regimes, the 5-year cumulative surface run-off in AE was much higher than in the two other scenarios. This is likely because of less canopy cover in short-term acacia plantations than in enriched medium forests or long-term timber plantations, which leads to lower canopy interception and higher rainsplash. For example, with average annual rainfall the cumulative surface run-off in AE was 970 mm compared to 244 mm in EF and 527 mm in TP. Owing to less canopy cover, the surface run-off in TP was also much higher than in EF: more than double than under average annual rainfall. Since surface run-off is related to the erosion/sedimentation rate, even though AE has a higher total river flow the level of water turbidity from short-term acacia plantation was higher than from the two other land-use types. Lowest turbidity pertains to the enriched medium forest.

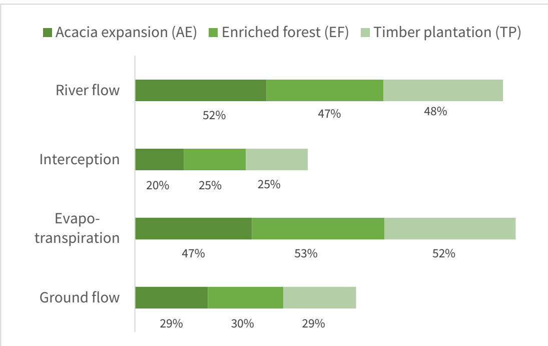
An opposite trend was found related to groundwater flow, where the 5-year cumulative flow in AE was lower than in the two other scenarios, particularly, under the highest rainfall regime (3,900 mm) (Figure 31c). Ground flow is part of deep infiltration and percolation and it is likely that these two water-balance components were lower in AE owing to higher surface run-off. On the other hand, the low surface run-off makes the enriched medium forest have higher groundwater storage and ground flow to the river. With the 3,900 mm rainfall, cumulative ground flow in EF was 6,950 mm whereas in AE and TP were 6,457 mm and 6,676 mm, respectively.

Surface run-off from acacia-plantation

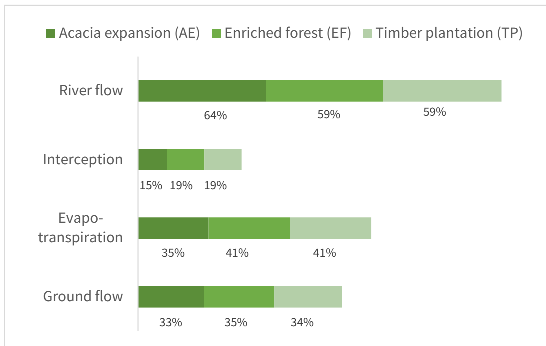
A high erosion rate in plots of acacia between clear felling and replanting and during the early plantation stage was reported by local people during key informant interviews. This risk of soil loss was also reflected by the model's projection of surface run-off during the 5-year acacia plantation cycle (Figure 31d). The annual surface run-off in the first year of a plantation reached about 250 mm, with a decreasing trend by plantation year, and about 110 mm at the end of the rotation cycle. In the long-term timber plantations, high erosion rates likely still occured between two rotation cycles but were not as frequent as in the short-term acacia plantations.

Water flows relative to rainfall

Under average annual rainfall of 2,600 mm, the cumulative river flow in the AE scenario constitutes 52% of total rainfall, with less proportion in the two other scenarios, namely, 47% in EF and 48% in TP (Figure 32a). The lower proportions were partly driven by a higher canopy interception rate in the EF and TP scenarios, which reached 25% of total rainfall, compared to 20% in AE. Another factor affecting the lower proportions to river flow was the evapotranspiration rate, which constituted 47% in AE and was 5–6% higher in the EF and TP scenarios. Related to ground flow, there was not much difference between the three scenarios, as is reflected in Figure 31c above. With higher annual rainfall (3,900 mm), a similar pattern was found when comparing the proportions of river flow, canopy interception, evapotranspiration, and ground flow between the three scenarios (Figure 32b). In the latter (that is, ground flow), the proportion between scenarios was slightly different, as reflected in Figure 31c.



a)



b)

Figure 32. Proportion of water flows relative to total rainfall in the three scenarios, under (a) average annual rainfall (2,600 mm); and (b) higher rainfall (3,900 mm)

PFES after forest restoration

The lower cumulative river flow in EF compared to the two other scenarios indicates that forest restoration would not necessarily lead to higher water levels in Ngan Sau River and Ho Ho dam, as expected by local stakeholders in the sub-watershed. Since PFES from hydropower companies as regulated in the national decree is solely based on water input and generated electricity, the local people would not receive higher PFES payments from forest restoration under the current PFES decree. Conversely, the low cumulative river flow in the forest restoration scenario would lead to lower PFES payments than the USD 1.5 per hectare per year received by smallholder forest owners in the sub-watershed at the time of writing.

4. Discussion

Our assessment of the impact of forest-cover change and intensification in Ho Ho sub-watershed showed that increasing tree-canopy cover and density leads to lower cumulative river flow. Higher transpiration was likely the most determining aboveground factor and better infiltration was the belowground factor. IIED (2002) claimed that most of the studies on watershed services reported a decrease in river flow with higher forest cover in a watershed. For example, in Viet Nam, river flow with forest cover has been found to be 2.5–2.7 times less than flow under agricultural crops (Do et al 2002). They (IIED 2002) also mentioned that a number of studies in Viet Nam have shown that natural forest is more effective than plantations in reducing river flow owing to higher quantities of litterfall and humus in soils and because some tree plantations use heavy machinery that compact the soil. Observation of the impact of tree cover on river flow in Dong Cao Catchment, Northern Viet Nam by Lacombe et al (2015) also found that land with annual crops and herbaceous plants provided higher flow to rivers than land with trees, such as mixed-tree plantations or forests. Their results are in line with an earlier study by Podwojewski et al (2008) that found that the annual surface run-off from annual crops, fodder and fallow land was higher than from eucalyptus and other tree-based plantations. They also found that in acacia plantations, soil surface cover by acacia litterfall can decrease surface run-off by 50%. A kind of forest type that can provide an opposite effect, namely, higher river flow, is presumably only cloud forests at high altitudes because the canopy has a rougher surface that increases the quantity of intercepted water directly from the clouds (IIED 2002).

On the other hand, the majority of local people worldwide still believe that the presence of forests can help provide more water in a river. Rather than claiming that this local knowledge is not correct, we acknowledge that the water-balance process is complex and variations in the impact of reforestation on river flow might exist owing to influences from local and large-scale atmospheric conditions as well. For example, owing to wind patterns, atmospheric moisture from forest evapotranspiration might not remain within the watershed boundary but could be transported across much larger scales, such as a continent (Ellison et al 2017). The opposite can also be true, in that atmospheric moisture from other areas can be brought in by prevailing winds across a watershed boundary. It has also been reported that trees are able to trigger rainfall owing to their microbial flora and biogenic volatile organic compounds (Ellison et al 2017). They can also generate additional moisture through fog and cloud interception. This indicates that tree and forest cover can also modify rainfall patterns. The large spatial and temporal variations of atmospheric conditions might help to explain the divergent impact of forest cover on river flow reported from different study areas. The projection of the impact of generated atmospheric moisture by forests on changes in rainfall pattern is, however, beyond the scope of most (if not all) watershed models owing to the larger scale of atmospheric conditions involved.

The claim that forests usually reduce river flow implies that they to some extent can control flooding as long as water input does not exceed their storage capacity. For example, Lacombe et al (2015) noted that while in the dry season the presence of tree-based systems and forests that reduce total river flow might have a negative impact on irrigation of annual crops, the higher capacity to store water owing to better soil porosity and inflitation might help to reduce flood intensity in the wet season. Tan-soo et al (2014) investigated the impact of deforestation on flood occurences in Peninsular Malaysia during 1984–2000—drawing on a large dataset on flood events and land-use changes in 31 river basins—and found that the conversion of inland tropical forests to tree plantations, such as oil palm and rubber, substantially increased the number of flood days during the wettest months of the year. They also suspected that the uncertainty about the role of forests in flood control was owing to the problem of defining variables to measure, making previous studies not able to be analysed for the impact of deforestation on the number of flood days. They also highlighted, however, that the link between deforestation and flood mitigation depended on the land use to which forests were converted and on the type of converted forest land.

Local people in the sub-watershed expected the problem both of water quantity and quality could be solved by restoring degraded forest land. While the impact of forest restoration on water quantity is not promising, low surface run-off most likely would reduce the problem of water quality, at least reducing the level of water turbidity. The low erosion rate associated with less surface run-off would also avoid serious sedimentation in Ho Ho dam. This is very important for the long term, ensuring that the dam can store water according to its capacity.

On the other hand, an increase in PFES payments is considered by local people in the sub-watershed as a co-benefit of forest restoration. However, this cannot be expected under the current PFES decree that only regulates payments related to water provision not other forest ecosystem functions, such as carbon and biodiversity protection. Because of this, there is a need to amend Decree 99/147 to formulate payments related to other forest ecosystem services or to provide guidance for smallholder forest owners as service providers on how to develop a voluntary PFES scheme. Under the current decree, voluntary schemes are encouraged but no guidance is provided. Indeed, more economic benefit from restored forests could be generated through several means, for example, developing and marketing non-timber forest products (NTFPs) or developing eco-tourism that involves the surrounding communities. Local people in the sub-watershed are able to extract some honey or rattan from the natural forests although these forests are quite distant from their settlement. Further study should investigate if the NTFPs contribute to family income. To our knowledge, a plan to develop eco-tourism with restored forests is still absent in the local authority's strategies. However, regionally, eco-tourism has the potential to develop in Northcentral Viet Nam because there are several national parks, such as Pu Mat, Vu Quang, Ben En, Bach Ma and Phong Nha–Ke Bang.

The 2006–2020 Forest Development Strategies try to pursue both livelihoods' and environmental benefits from forest land in Northcentral Viet Nam through 'focusing on establishment and consolidation of protection forests for watersheds', 'protecting the high biodiversity of the region in association with watershed protection', 'establishing and developing timber and NTFP material supply areas', and 'strengthening community-based forest management modality, especially for protection forests in scattered watersheds'. Because of the projected unfavourable impact of forest canopy cover and density on river flow in the sub-watershed, however, we recommend that local authorities analyse the trade-offs between forest ecosystem services, such as carbon sequestration and biodiversity protection on one hand and water provision services on the other. Furthermore, another trade-off analysis should be conducted of the benefit to local livelihoods and ecosystem services at landscape level from land-use strategies planned for the sub-watershed. We also recommend that the local authorities clearly identify which land is highly exposed to environmental hazards, such as soil erosion, and which land is less exposed, and develop more sustainable land-use systems for the critical land, for example, through novel, short-term acacia plantation models on sloping land that integrates grass strips and which still maintain convenience of harvest. In general, it has been shown that mixed systems, such as agroforestry, are effective in reducing soil erosion on sloping land compared to tree or crop monocultures. For example, in the Northwest region of Viet Nam where land is hilly with steep slopes, La et al (2016) reported that soil loss in agroforestry systems was an average 43% lower compared to monocultural systems. The reduced soil loss was valued at USD 250 per hectare, which is the cost of replacing the NPK lost through erosion by purchasing fertilizer. Furthermore, although not specifically mentioned in the case of the Northcentral region, the 2006–2020 Forest Development Strategies emphasize the need for developing agroforestry systems for the uplands in the northern mountainous region of Viet Nam.

5. Conclusions

Amongst the three forest-land intensification scenarios, enrichment of degraded forest land with native tree species would have a reduced river flow but, at the same time, would reduce the risk of severe soil erosion through minimizing surface run-off. The other two scenarios namely expansion of short-term and long-term tree plantations could provide higher levels of river water but also carry a higher risk of soil erosion, especially, related to the short-term plantation system.

In line with the results of hydrology assessment in the sub-watershed, the literature features many cases of how the presence of forests reduce river flow. However, rather than taking this as a general conclusion applicable in all situations, we acknowledge that the water-balance process within a given watershed is complex and that larger-scale atmospheric conditions might affect it. This is likely a factor that could explain variations in the impact of forests on river flow.

Because of the projected negative impact of higher tree canopy cover and density on river flow, there is a need for local authorities in the sub-watershed to conduct a trade-off analysis between the various environmental benefits of forests, for example, between carbon sequestration or biodiversity protection, and water provision. Such an analysis could inform the development of sustainable land-use strategies in the sub-watershed.

Balancing the total area of short-term and long-term tree plantations and the area of protected forests in the sub-watershed based on a trade-off analysis and on the identification of which land is more exposed to environmental hazards, such as soil erosion than another, would be the first step in developing a more approriate land-use strategy but there is also a need to innovate the current monocultural models of tree plantations through adopting the principle of mixed systems, such as agroforestry, which has been proven to reduce soil erosion on sloping land. Another option is to avoid large-scale clearfelling by introducing a gradual transition model of short-term to long-term tree plantations.

The projected unfavourable effect of forest restoration on river flow also indicates that the current PFES decree that only accomodates the water-provision functions of forests as the basis for calculating payments cannot be used to encourage smallholder forest owners to participate in forest protection and restoration efforts. The decree should accomodate other forest environmental functions as well, such as carbon sequestration or biodiversity protection, or provide clear guidance for the 'providers' and 'buyers' of forest ecosystem services on how to develop voluntary PFES mechanisms.

Appendix 1 Properties of simulated landcover types in Ho Ho sub-watershed by GenRiver model

Land cover types	PI* (mm day^{-1})	RDT+	BD/ BDref	Multiplier of Daily Potential Evapotranspiration											
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Undis-turbed Forest	4	0.7	0.8	0.6	0.6	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.7	0.6	0.6
Logged-Over Forest	3	0.5	1	0.5	0.5	0.6	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.5	0.5
Agroforest	2.5	0.4	1	0.5	0.5	0.6	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.5	0.5
Pulp Plantation (acacia)	2.5	0.4	1	0.5	0.5	0.6	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.5	0.5
Forest Plantation	2.5	0.4	1	0.5	0.5	0.6	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.5	0.5
Shrub	2	0.2	1.2	0.4	0.4	0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.5	0.4	0.4
Cropland	1	0.2	1.2	0.4	0.4	0.5	0.6	0.6	0.6	0.6	0.6	0.2	0.2	0.2	0.2
Shifting Cultivation	1	0.2	1.2	0.4	0.4	0.5	0.6	0.6	0.6	0.6	0.6	0.2	0.2	0.2	0.2
Cleared Land	1	0.2	1.2	0.4	0.4	0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.5	0.4	0.4
Water body	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1
Enriched Medium Forest	3.63	0.63	0.88	0.56	0.56	0.66	0.76	0.76	0.76	0.76	0.76	0.76	0.66	0.56	0.56
Long-term Timber Plantation	3.38	0.58	0.93	0.54	0.54	0.64	0.74	0.74	0.74	0.74	0.74	0.74	0.64	0.54	0.54

**Potential interception. +Relative drought threshold*

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Focus Group Discussion in My Loi, Ha Tinh province, Northcentral Coast of Viet Nam (Photo: World Agroforestry/Ha My Tran)

CHAPTER 7

Developing participatory agro-climate advisories for integrated and agroforestry systems

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Summary

Southeast Asian farmers face numerous slow and fast-onset natural hazards that have negative impacts on their livelihoods, and consequently risk slowing their ability to adapt to changing climate patterns. Meanwhile they are also tasked to implement farming practices that help mitigating climate change. One key activity could help farmers' decisions in addressing both challenges: better tailored seasonal weather forecasts combined with participatory development of climate-smart agricultural advice.

The Agro-Climate Information Services for Women and Ethnic Minority Farmers in Southeast Asia project (ACIS) addresses farmers' demand for more actionable climate services in Viet Nam, Lao PDR and Cambodia. Although generally perceived as climate-smart practices, integrated and agroforestry systems are rare in advisories, nor as a strategy to adapt to natural disasters and climate variability. To address this gap, we demonstrate how farmers are involved in co-producing such information, using the example of My Loi, a 'climate-smart village' in Northcentral Viet Nam. The documentation consists of logbooks and notes from three participatory scenario planning meetings, the development of advisories, and in-depth interviews conducted between 2016 and 2018. In short, the timing and content of forecasts and advisories need to be decided with farmers. Regularly updated forecasts over various periods were important for agroforestry systems. Farmers needed information about limiting weather conditions, not the average. When forecasts were uncertain, diversification of species often also meant diversification of risk. Social learning helped farmers observe and document recommendations to build checklists for how to combine trees and crops to minimize negative weather-related impacts.

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1. Introduction

"When ants build up mounds, a storm is coming. When dragon flies fly low, rain is coming"

For thousands of years, farmers' only means for forecasting weather was to observe the sky and interpret natural phenomena, like flowers, birds and seeds. As climate variability becomes more pronounced and farmers move away from traditional crop varieties, many report that their forecasting skills are no longer valid.

Over the past decade, the technologies for producing and distributing advanced climate information with higher accuracy and at higher spatial resolution has increased rapidly. Such advances remain largely underused, especially among farmers in developing countries, even though climate services for agricultural decision-making can reduce the risk of crop failure and contribute to national food security (Tall et al 2012). As farmers rarely are included in the design of agro-climate information products, their knowledge and needs are poorly addressed. Private companies and public institutions are now trying to fill these gaps (Dorward et al. 2015).

Some farmers obtain weather forecasts, management recommendations and price information via short message services or smartphone apps. Information communication technology also allows them to communicate with suppliers, provide commentary on field observations or correlate satellite data as access insurance (IWMI 2017). There are two short-comings with those approaches. Whereas existing advisories predominantly have been designed for monocultured grain crops and may help farmers plan the more laborious farm work, the main share farmers' income is from other products, such as cash crops, fruit trees and livestock. Secondly, it misses the tree-crop or crop-crop interaction benefits that could reduce climatic stress in a longer-term time perspective.

Agroforestry, one of a suite of climate-smart agricultural practices (FAO 2013; Rosenstock et al. 2015), has a demonstrated capacity to contribute to adaptation, food security and resilient livelihoods (Simelton et al. 2015) as well as mitigation objectives (Zomer et al. 2016). Agroforestry is mentioned in national adaptation policies and strategies, such as in Viet Nam's Decision by Ministry of Agriculture and Rural Development QD819/2016/BNN-KHCN on action plan on climate change response and in the Forestry Law of 2017 16/2017/QH14. However, the buffering provided by the interaction of trees and crops does not mean that agroforestry is immune to extreme weather events nor that weather forecasts are less important for such integrated systems.

Funded by the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), the Agro-Climate Information Services for Women and Ethnic Minority Farmers in Southeast Asia (ACIS) project has been testing approaches that improve the use of climate services, specifically, so that women and men farmers of different ethnic groups can *access* (available in a variety of designs and formats), *understand* (appropriate language and content) and *use* (appropriate advice, on time) agro-climatic information. This, in turn, is expected to reduce climate-induced crop failures. The project is being implemented together with CARE in five sites in three countries—Ha Tinh and Dien Bien provinces in Viet Nam (2015-2018), Ekxang and Phongsaly province in Lao PDR and Rathanakiri province in Cambodia (2016-2018). It is designed in two main sections, which can be adapted for expansion in different contexts: 1) seasonal weather forecasts; and 2) participatory advisories that incorporate farmers' knowledge and feedback.

While annual crops typically receive more attention in advisories, in this chapter we draw specifically on the work in My Loi, a CCAFS 'climate-smart village' in Northcentral Viet Nam that was led by ICRAF in collaboration the provincial Farmer's Union. Given the diversity of crops, ACIS was developed for integrated crop and agroforestry systems.

2. The ACIS process and study sites

The ACIS process follows a chronological cycle from developing forecasts and advisories to farmers' learning and feedback. The country and level at which the process is implemented features differing elements.

- *Provincial level:* The process for developing forecasts is different in the three countries. In Viet Nam, a seasonal (updated) forecast is developed by the provincial meteorological bureau, initially with support from national staff. The forecast is forwarded to the provincial agricultural department. The initial dialogues involve representatives from provincial and district Department of Agriculture and Rural Development (DARD) and Department of Natural Resources and Environment (DONRE) offices and farmers to ensure mutual understanding of needs and adjustment of the forecast products.
- *Agro-climatic zone*: The seasonal forecasts and agricultural risks are interpreted in participatory scenario planning (PSP) workshops. The PSP process was developed in Africa (CARE 2015) and adapted for Southeast Asia under ACIS. In Viet Nam, PSP workshops are run with leading farmers and facilitated by a local resource person, for example, a representative of the Farmer's Union (as in Ha Tinh Province), district extension office (as in Dien Bien Province and Ekxang village) or civil society organisation (as in Phongsaly and Rathanakiri), initially with support from project staff. During the workshop, the group examines the seasonal forecast and discusses the probabilities of different outcomes, which results in localized recommendations that incorporate farmers' knowledge. Farmers are encouraged to add their local knowledge to the process of making weather forecasts. The PSPs are done before, during and after the main crop season (usually following the rice calendar). Farmers and facilitators document the process in logbooks and provide reports on forecasting skills and the suitability of agricultural advice to extension and meteorology offices. The local resource person then develops an advisory based on the information. Resource persons can be called in as necessary, for example, from the plant protection department or provincial meteorological bureau.
- *Village level:* Leading farmers and village leaders share advisories to their neighbours, for example, through printed bulletins and public announcements made through village loudspeakers (common throughout Viet Nam). In Ha Tinh Province, the meetings are carried out concomitantly with the four-monthly Community Innovation Fund meetings. In Dien Bien, Rathanakiri and Phongsaly, the Village Savings and Loan Association leader shares the printed bulletins at bi-weekly meetings. The village leaders also share the printed bulletins at village meetings that are organized around events, not on a regular basis.

3. Study site: My Loi Village

My Loi is in the uplands of Ky Son Commune, Ky Anh District, Ha Tinh Province. The annual average temperature is 25°C and average annual rainfall is 2,800 mm, the majority of which falls between August and December, peaking in October. The major threats to food security are periodical flooding and typhoons. During the two most-recent episodes of food insecurity, in 2007 and 2011, villagers depended on food aid.

My Loi has about 820 inhabitants of the approximately 6,000 in the commune. In 2016[1], total village area was 195 ha of 9,036 ha in the commune, of which 140 ha of 6,973 ha was forest and 55 ha of 1,283 ha was agricultural land, primarily, rain-fed. More than half of the commune's agricultural land (895 ha, an increase from 545 ha in 2011 owing to conversion from annual-crop production) was perennial plantations, for example, tea, orange and rubber. Less than 8 ha of the commune's 153 ha of rice fields were irrigated; the remainder were upland or terraced fields.

Forestry, predominantly acacia, eucalyptus and cajaput (*Melaleuca* spp) monocultural plantations, generates about half of the household incomes in My Loi while the other 50% comes from agriculture and other activities (Le et al. 2015). Only a minor portion of the rice fields is used for two crops annually. The main challenges are water shortages (in Spring) and cold spells. The lowlands are used for peanut monoculture (Spring) and mung bean (green bean) or white radish monoculture (Summer) and maize monoculture or maize intercropped with sweet potato (Autumn) and vegetables (Winter). The planting sequence is adjusted to avoid soil evaporation in between the Spring and Summer crops; each season is short and flexible. In terraced fields, cassava is intercropped with solely peanut or peanut with maize. In upland fields,

Figure 33. Location of ACIS project sites in Viet Nam (My Loi climate-smart village in Ha Tinh and Dien Bien provinces), Cambodia (Rathanakiri) and Lao PDR (Ekxang climate-smart village and Phongsaly)

[1] Scheme on restructuring the agricultural sector towards enhancing added value and sustainable development associated with NRD for the period 2016–2020 in Ky Son Commune (Đề án tái cơ cấu ngành theo hướng nâng cao giá trị gia tăng và phát triển bền vững, gắn với xây dựng NTM giai đoạn 2016–2020)

cassava monoculture (Spring to late Autumn/Winter) or intercropped acacia and cassava are grown in the first year or acacia monoculture. Home-gardens are mixed, predominantly with fruit trees (banana, jackfruit, mango, orange, pomelo and lime) and black pepper. My Loi (and Ekxang in Laos) has been a CCAFS climate-smart village project site since 2015, hence differing opportunities to integrate ACIS with CSA.

4. Data

A baseline survey was conducted at the start of the ACIS-project to map and understand farmers' access to weather forecasts and advisories. The survey was done in all sites (Figure 33) during 2016, including 1,333 households. Here we extract questionnaire results from the two sites in Viet Nam, to better highlight within-country similarities and differences (in total n=595 households were interviewed in Ha Tinh and Dien Bien provinces, of which in Ha Tinh 134 women and 142 men (CARE and ICRAF 2016).

The PSP groups in My Loi consist of 43 households (the gender distribution varies 19–25 women and 18–24 men because husbands and wives participate interchangeably), as representatives of four interest groups: home-garden, forestry, intercropping, and livestock, where the former two include integrated tree-crop systems, and the third mainly integrated annual crops. Three advisories evaluated in My Loi were prepared for the summer-autumn season (June–October 2017), during three PSP meetings (June, August and November). The first seasonal forecast was provided as an average for the whole season and distributed prior to the season (pre-PSP). From the second PSP and onwards, monthly updates were provided. Hazards, risks and solutions were participatory made by combining local knowledge and scientific knowledge (from farmers, extension officer, met officer and representative of social organisation) based on different climate scenarios which were built on seasonal forecast information. Findings related to integrated systems were extracted from qualitative documentation from farmers' and facilitator's logbooks, which were evaluated in November 2017. Additional, in-depth, focus-group discussions were held during the PSPs in 2017. The selection process is described in Duong et al. (2016). Gendered similarities and differences in farmers' preferences, understanding of, and benefits from the advisory information were teased out and presented in Duong et al. (2017). Work on evaluating forecast skills is covered elsewhere, for example, Roy et al. (2017). For participatory tools for discussing what trees and crops are suitable for particular extreme events, see Simelton et al. (2013a).

5. Results

Baseline actionability of climate services

At the start of the project there was a one-directional flow of agro-climatic information, biased towards rice. Typically, farmers followed the instructions and did not discuss their interpretations of the information amongst themselves or how to turn the information into farming plans. Neither was farmers' knowledge or feedback incorporated into the design of the advisories. The baseline survey (n=595) for Viet Nam showed the following general and site-specific results:

Availability and accessibility: Seasonal forecasts were prepared at the provincial level, did not reach communes or farmers and were not updated. Daily or 3-day weather forecasts and early warning alerts for storms and floods were disseminated via television and village loudspeakers (over 90% of the interviewed households in both Ha Tinh and Dien Bien said they had access to such forecasts). Advisories were distributed via loudspeaker, extension services and radio and timed for the rice season (between 80–90% of the farmers had access to these). For comparison, in Laos and Cambodia, only half of the respondents had access to forecasts while nearly all received some advice for crops, often via extension, NGOs or village leaders.

Usefulness: Although farmers said the forecasts were useful, the main complaint was that the information was at too low resolution for farm decisions. They depended on seasonal forecasts and advisories that were based on long-term climate averages without seasonal updates or taking into consideration agro-ecological diversity.

Timeliness: Weather forecasts were perceived more-timely than the advisories. This indicates a delay in the translation and distribution, as the information passes between two ministries[2]. Furthermore, the timings of the advisories were primarily determined by the rice season (in some locations the advisories included peanut and livestock), which does not apply to agroforestry or other integrated systems.

Understandable: Women understood the forecasts and advisories equally well (67%) while more men said the forecasts were easier to understand than the advisories (73% versus 64%). Literacy also relates, not only to technical terminology, but also to ethnic languages (three of the five project sites have high shares of peoples whose first language is another than the national language), literacy levels for text and visuals. For example, interpreting information in 'conventional' weather symbols can be cultural, and in Cambodia farmers designed their own icons (Smytzek and Simelton 2018).

Towards a two-directional flow of agro-climate information

Through the ACIS project, more frequent forecasts have been put in place and approaches to provide more spatially relevant forecasts are being tested. One main objective has been to ensure that farmers' needs and knowledge are understood by climate service providers.

First, the relevance of using seasonal weather forecasts in agricultural planning was evident simply by the fact that each average monthly observed temperature in 2016 was at least 0.5 °C higher than the long-term climatological average. Second, after it was emphasised to the authorities that farmers intercropped and used seasonal forecasts to phase crops continuously, they quickly changed the timing of the seasonal forecast for one specific crop (rice) to monthly, updated, 3-monthly forecasts. Also, the range of exposure and uncertainty in forecasts (Roy et al. 2017) helped demonstrate the need for updated, short-term forecasts to provide more details for management that could help farmers adjust their plans. Third, meetings between meteorologists, extension officers and leading farmer allowed farmers to ask questions and request forecast indicators relevant for their agricultural systems. The seasonal forecast was then discussed and interpreted in the PSP groups, where farmers and extension workers combined local and scientific knowledge to prepare advisories for various land uses in particular agro-climatic zones. Daily messages and updates were developed for loudspeakers. After the season, the results of the forecast and advisories were shared with provincial and district forecasters and agricultural officers.

Developing participatory advisories for agroforestry

Discussions with farmers about rating the risk of certain crops against the main hazards during Spring and Autumn resulted in diagrams as shown in Figure 34. The diagram helps better understanding farmers' knowledge and rationalization of

[2]As is common in many countries, meteorological data is produced by the Ministry of Environment and the agricultural advice by the Ministry of Agriculture. In Viet Nam and Laos, these correspond to the Ministry of Natural Resources and Environment (MONRE) and Ministry of Agriculture and Rural Development (MARD).

their tree and crop selection. This is further documented in Table 25. The process of creating Figure 34 also helps reveal potential adaptation gaps that need to be addressed. In particular, it can highlight underuse of the protective functions of multi-strata systems.

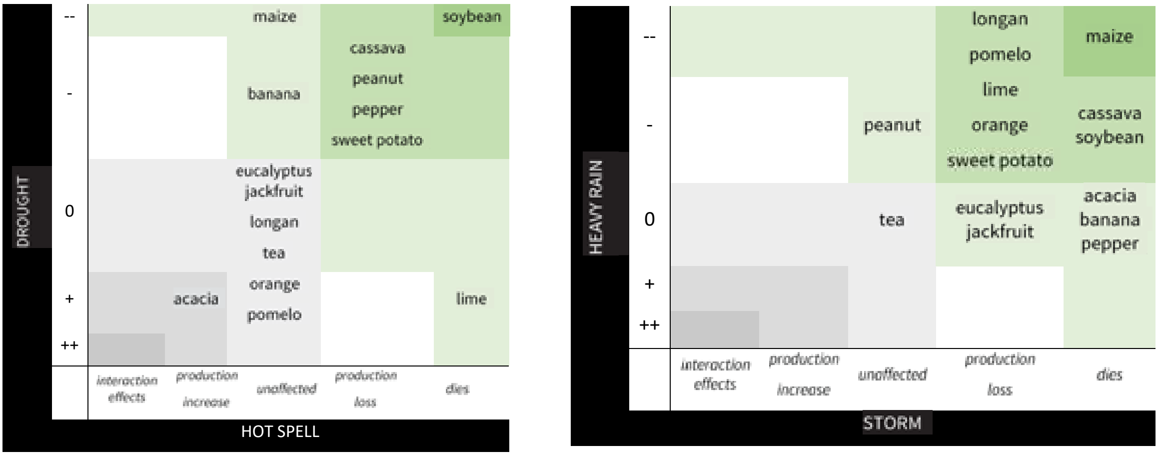

Figure 34. Suitability of, and risk associated with, agroforestry crops and trees during droughts and hot spells in Spring-Summer (top) and heavy rains and storms during Autumn (bottom). (the signs – to ++ on the y-axis correspond to the impacts on the x-axis). Source: focus-group discussions in My Loi, 2011.

Farmers' checklist

In preparing and disseminating the advisories, there was a trade-off between the level of detail and amount of information that farmers could absorb, both text and visual elements (Duong et al. 2017). One remaining step towards incorporating climate-smart advice is acknowledging the role of poly-cultural systems as adaptation options. Considering the potential information overload in agroforestry advisories, farmers in My Loi suggested assembling their observations and experience from past years into a checklist. After one year of testing they had a draft with actions that they could revise according to the forecasts (Table 25).

The farmers' checklist was created through facilitated discussions, focusing around farmers' observations of tree and crop interactions (Table 26). In the PSP workshops, farmers were encouraged to talk about how they adapted the farming calendar with annual crops and how they paired crops and trees to reduce risks (in effect, this meant detailing the benefit of ecosystem functions). Farmers related adaptation functions to the shape of canopy and root systems, flexibility of trunk and branches, quality and amount of leaves, and nitrogen-fixing species (acacia, legumes) on poor soils. A range of local strategies, especially for drought management, were collected. To minimize soil evaporation and soil erosion, some intercropped peanut and/or bean with cassava. The benefits of compost and mulching with rice straw and palm leaves were applicable for many plants, for example, orange, ginger and pepper, and made it easy to introduce new species and practices that can be components of agroforestry systems (for example, vermiculture, Guinea grass, *Arachis pintoi*, seasonal vegetables).

BOX. EXTREME EVENTS AND FARMERS' OBSERVATIONS OF TREE-CROP BENEFITS

The impacts of recent extreme weather events served for demonstrating opportunities for intercropping and timing.

- April 2015: The first tornado hits My Loi. Acacia trees were among the worst affected (Le and Simelton 2015).
- May 2015: Three rainy days totaling 13 mm (compared to the long-term average of 164 mm), and five days with temperatures above 38 ˚C. This greatly reduced monocultural peanut and cassava yields while intercropped fields had lesser losses.
- February 2016: Temperatures dipped to 10 ˚C. The highest observed temperature in the same month was 34 ˚C.
- October 2016: On the 14^{th} and 15^{th}, 474 mm and 207 mm of rainfall, respectively, and another 330 mm on the 30^{th}.
- September 2017: On the 15^{th}, typhoon Doksuri hits Ky Son Commune. Among the most damaged were 3-year-old acacia monocultural plantations and older, unpruned fruit trees.

Harvesting before rain fell reduced damage and, although fields were flooded, saved Autumn crop failures both in 2016 and 2017. A limited area of Autumn-Winter crops (sweet potato, maize) near flood plains were lost in 2016. While monocultural maize near a river were swept away, intercropped maize and sweet potato in adjacent fields were less affected. Here, the sweet potato stabilized the soil into micro-terraces that supported the maize. Yields from agroforestry systems were less affected by heavy rain and drought, as the canopy protected sub-canopy crops from rainfall and reduced wind speeds. The 'mac' trees reduced storm and rainfall impact on recently planted pepper seedlings compared to pepper grown on cement poles (September 2017).

The discussions contextualized why 'farmers' practice' may go against 'extension recommendations'. While short-rotation annual crops are recommended as an adaptation strategy, from a farmers' perspective the same may be said for some perennials. For example, by following the recommended spacing for acacia timber trees (2 x 2 m for 8 years) trees are exposed to longer and higher risk than by spacing for pulp (1 x 1 m for 4 years). In the two most-recent storm events, monocultural acacias were badly damaged.

In some cases, facilitators (extension workers or project staff) helped with recommendations or explained why some methods might have worked and others did not.

Table 25. Extract from farmers' checklist of preventive measures for agroforestry systems and recommendations for advisories in Autumn 2016; inconclusive examples from My Loi

<table>
<tr><th rowspan="3">Applies mainly to
FORECAST PERIOD</th><th colspan="4">In the case of…</th></tr>
<tr><th>Drought</th><th>Hot spell</th><th>Heavy rain, flooding</th><th>Cold spell</th></tr>
<tr><th>SPRING–SUMMER</th><th>SPRING–SUMMER</th><th>AUTUMN</th><th>WINTER</th></tr>
<tr><td>Things to think about

What can I do?

What can I plant?

What tree-crop interactions can I make better use of?</td><td colspan="4">Do I have enough information?
• How does this season's/year's forecast compare with the same time in the previous year? (Important for making annual planting selection)
• How does this year's forecast compare to the inter-annual variability of many years? (For selecting perennials, the extreme inter-annual ranges are good indications for what microclimatic situations trees are intended to ameliorate, for example, shade, heavy rain, soil evaporation)

How can I use annual crops to reduce the risk of crop failure?
• Are seedlings at risk?
• Does the weather event interfere with the time for planting, flowering, harvesting or the following crop? Can I change the planting dates? Can I change the annual crop variety or species?
• How can I best avoid wasting time and money on replanting and agro-inputs?

How can I use (existing or add) perennial crops/trees to reduce the risk of crop failure?
• When (what growth stage) are fruit trees particularly sensitive to which weather stress?
• Where should I introduce what types of trees? What combinations of trees (canopy shape, root system, natural pest and disease control) and crops go well together?
• How can I select different trees or varieties to spread harvest times?

How can I use natural resources and inputs more efficiently?
• Use biological pest/disease control.
• Time with weather (forecast): spray pesticide on a cloudy day (not in direct sunshine or before rainfall); irrigate early in the morning or late afternoon (avails stressing plants with rapid change in soil temperature).</td></tr>
<tr><td rowspan="2">General</td><td colspan="2">Increase soil water-use efficiency:
add (vermi-)compost before planting crops/trees; mulch with rice straw or leaves; plant cover crops; no minimum tillage</td><td rowspan="2">Keep seeds dry
Clear ditches
Reduce damage from falling objects: prune, cut damaged branches, thin-out leaves
stabilize plants: cover tree bases/ roots with soil; use supporting trees or pillars to firm up sensitive plants (e.g. sugarcane); plant wind breaks (e.g. bamboo).</td><td rowspan="2">Monitor minimum temperatures to take action (especially for seedlings and livestock)</td></tr>
<tr><td>Avoid planting trees during extended droughts</td><td>Regulate micro-climate (reduce temperature difference):
plant shade trees;
grow ginger in bags under shade;
monitor maximum temperatures to take action</td></tr>
</table>

Bean or cassava intercropped with peanut-bean and/or maize in rotation	After the peanut harvest, plant bean while soil remains moist from previous crop	Plant beans in time to harvest before the heavy rains start Prevent rotting disease e.g. rhizoctonia solani in peanut: add lime before rains and on a sunny day after 3-4 days of continuous light rain. Hill up plants and provide good drainage Remove infected plants, add lime on the soil to kill fungus	Add ash or mulch with rice husk and cover topsoil, to maintain soil temperature	
Maize intercropped with sweet potato	Avoid planting when soil is crust and temperature is too high (38-40°C for 3 days continuously) Irrigate	Adjust farming calendar to avoid planting during heavy rain, flooding and storm conditions Clear ditches to ensure drainage	Add ash or mulch with rice husk to maintain soil temperature	
Black pepper with Mac tree *(Wrightia annamensis)*	Mulch with rice straw, palm leaves or another crop residue Drip irrigation	Cover the soil around young pepper seedlings (1-2 year-old) with palm leaves Use live supporting trees (e.g., Mac tree) for pepper instead of cement pillars to create micro-climate temperature under trees and reduce heat during hot spells period. Cementitious materials absorb heat and drain quickly, making the column hot and dry (up to 45°C during the dry season)	Prevent rotting diseases: prune branches, runner shoots, and leaves near the soil, branches should be at 10-15 cm from topsoil; remove dead and sickplants; add lime (see cassava-peanut) to avoid Phytophthora fungus and nematodes, which may cause root- rot, and quick or slow wilt diseases on pepper	Irrigate in the morning to avoid frost damage, if possible Plant wind shield trees, e.g., bamboo and jackfruit trees can minimize cold humid wind directly on the pepper plant

Orange and pomelo-based systems	Suitable cover crops: legumes, vegetables, *Arachis pintoi* Mulch with straw or palm leaves Drip irrigation Water harvesting pond	Cover the soil around young trees and seedlings with palm leaves as mulch	Ensure well-drained soil Remove broken and shooting branches Prepare terraces for fruit crops (e.g., citrus, guava, and banana) on steep slopes to prevent nutrient and top soil losses due to heavy rain Plant strips of grass or pineapple to prevent soil loss	Irrigate in the morning to avoid frost damage Spray flower stimulants to stimulate timing of orange flower (ask extension for advice)
Tea	Plant shade tree *(Senna siamia)* Intercrop tea with maize in the first year Mulch with rice straw and leguminous residue		Drain well Prune trees before	Irrigate in the morning to avoid frost damage, if possible

Farmers' general recommendations for agroforestry advisories

When preparing advisories for agroforestry systems we observed a few differences with respect to annual crops, which need to be taken into consideration.

For reference climate (weather): For annual crops, farmers preferred to compare the current year's forecast with the previous year's weather. However, for planting new perennials, the range of historical inter-annual variability is important (frequency and intensity) and to avoid planting during the most intense drought. Knowing the phase of the El Niño–Southern Oscillation is a good first indicator.

For the forecast: First, to time the advisory for monocultural rice makes little sense for upland farming systems. Farmers preferred receiving continuously updated forecasts. Second, similarly for annual crops, farmers need to know the limiting factors not monthly or seasonal averages, for example, minimum (Winter) and maximum (Summer) temperatures and risk of drought (dry days) and floods.

During the Participatory Scenario Planning: In the original PSP approach, farmers prepared for all forecast scenarios except those with low probabilities. Especially for agroforestry systems, farmers often noted that different scenarios meant the same risk or they prepared the same way, regardless of the risk level. So, 1) they preferred only the scenario with highest probability and focused on different 'what if' scenarios of the exposure, for example, depending on the timing and intensity of the event, how might certain crops be affected and how to avoid this; and 2) instead of repeating, the farmers assembled a list of general actions (Table 25). The PSP workshops provided opportunities to learn adaptation strategies from natural disasters (Box, Table 26).

For the advisories: Many general recommendations are the same for agroforestry as other types of advisories: the information needs to be clear, detailed (what treatment, how much, when) and avoid complicated terms and abbreviations as this creates barriers to farmers who are not part of developing the advisory. Specific climate-smart practices should be added and, for agroforestry in particular, farmers appreciated icons to illustrate plant growth and tree-crop canopy/root interaction effects and for complementing technical terms. However, icons should complement rather than replace words. The advisories should be tested with female and male farmers outside the PSP groups before using widely. Figure 35 exemplifies a modified agroforestry advisory based on two years of testing.

Table 26. Extracts of adaptation measures and farmers' observations discussed in the Participatory Scenario Planning (PSP) meetings for the Autumn season 2017

Pre-PSP in May 2017	Mid-PSP in August 2017	Post-PSP in November 2017
Forecast for the season: • dry in June (less rain in 2017 compared to 2016) • days with heavy rain (>50 mm) in August to October (2-4 days per month) • heavy rain and storm possible in September and October **Drought and storm preparedness recommendations:** avoid planting during the dry period; harvesting of annual crops should be done before the storm; strengthen and prune long-term trees; ensure good drainage and prevent root diseases. • crops: after the peanut harvest, plant bean while soil remains moist from previous crop; choose short-term and short crop or varieties; intercrop peanut and cassava • mulch orange, ginger, pepper with rice straw and palm leaves • plant or make use of shade trees and cover crops (Guinea grass, arachis pintoi, seasonal vegetables) • add compost to improve soil water-holding capacity and soften the soil • clear ditches to ensure good drainage • prevent rotting diseases and reduce damage from falling tree parts: prune branches, runner shoots, and leaves near the soil. Branches should be at 10-15 cm from topsoil; remove dead and damaged plants; add lime to avoid fungus and nematodes, which may cause root diseases. • Keep updating weather forecast to take action.	**Farmers' actions:** • update weather forecast • used short-term crops/ varieties • used various types of compost: pig, chicken and cattle manure, vermicompost, green manure (peanut leaves) • used drip irrigation for orange and pepper • mulched • planted cover crops under orange • add lime into the soil before planting **Farmers' observations:** Households who had established drip irrigation for pepper and orange said it saved water, compared to sprinkler irrigation and tubes, and reduced pests spreading via sprinkled water between canopies. **Forecast for next phase:** Actively follow weather forecast, prepare for rain. Extension workers advised on nitrogen and lime application for acid soils to minimize nitrogen overuse. Postpone planting maize and sweet potato (Autumn – Winter season) if high probability of heavy rain and storm.	**Farmers' views on the comparatively low impact of a flood in October:** • prune trees to cut damaged branches, and thin out leaves • deep-root trees were largely unaffected (Mac trees, jackfruit) • tea was less affected by the storm • most lowland crops had already been harvested • unharvested crops were planted at higher elevations (e.g. ginger, cassava) • Intercropped maize and sweet potato were less damaged than monocultures. Maize and sweet potato has supporting benefits to storms • Farmers who used compost that decomposed more than previously, noted more effective nutrient and pest control and reduced weeds. **Forecast for the following season:** Winter is forecasted to be colder than last year. Farmers planned to follow weather forecasts for planting vegetables and crops (planting date may be later than last year), add ash or mulch with rice husk on topsoil to maintain soil temperature.

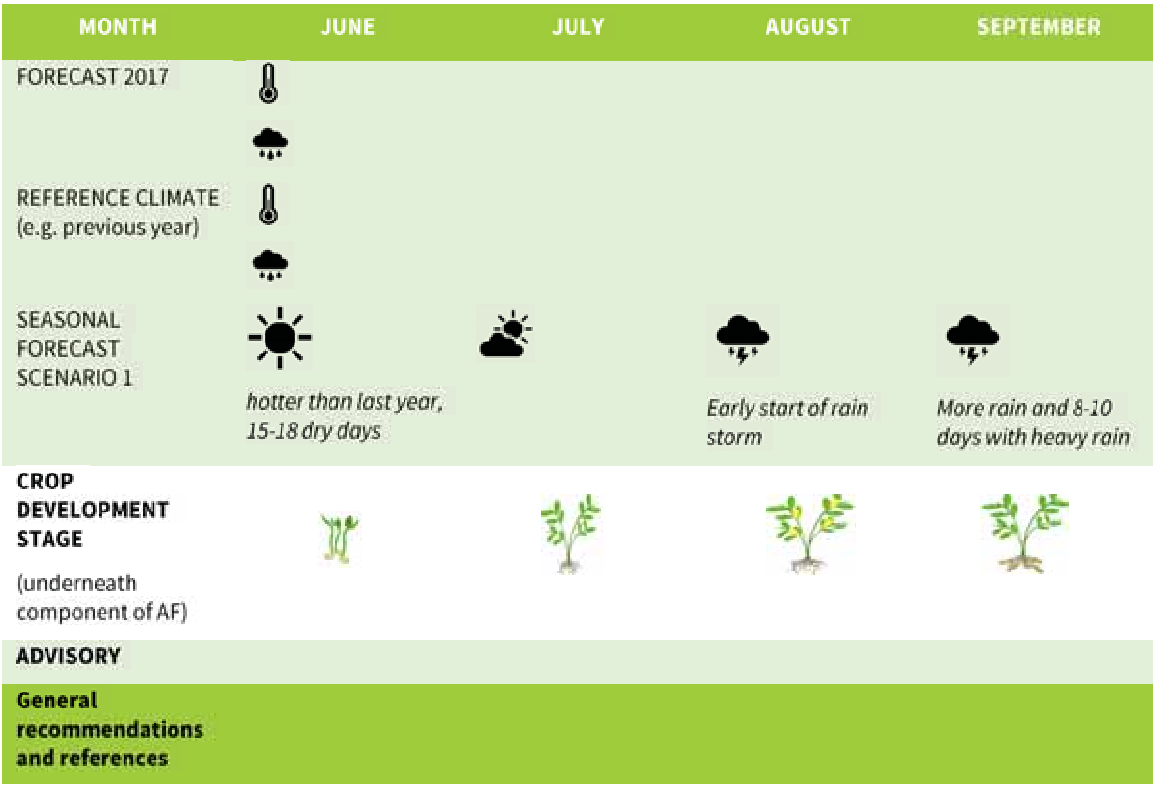

Figure 35. Example of advisory design

6. Discussion and recommendations

The ACIS project offers a unique opportunity to incorporate agroforestry in climate services and, thus, support the implementation of national adaptation strategies in local land-use plans. At farm level, preparedness and better planning frees labour and resources from recovery operations to invest in more productive work.

At local level, a regular and close dialogue between forecast suppliers (DONRE), agricultural planners (DARD) and farmers' representatives helps deliver actionable information. For example, farmers' feedback helped adjust the timing of forecasts to crop seasons and the type of information provided. The usefulness of two-way communication for disseminating forecasts to farmers, for example, by meeting extension workers or through farmers' climate field schools, has been proven to enable farmers to seek clarification on questions (Patt et al. 2005; Sala et al. 2016). The dialogues help clarify what meteorologists, extension workers and farmers mean, for example, when they talk about 'normal' weather, to better understand the different perspectives of meteorological, agronomic and technical droughts (Simelton et al. 2013b) or explaining probability and uncertainty to avoid raising false expectation that forecasts are 'predictions'. To meet farmers' expectations of which situations can be 'adapted' to meet both market- and weather-related challenges and what problems can be solved, the advisories can strive for 'no regret' options for short- and long-term solutions (farmers testing different options). Diversification can be considered a no-regret option because it spreads risk over the year, in contrast to 'not knowing what to do' even when there are strategies available.

The PSPs create enabling conditions for combining farmers' knowledge with scientific knowledge for climate services. Forecasts based on traditional knowledge should be respected; we cannot expect the same detail as from a meteorologist's forecast, however, both should be objectively scrutinized. For example, in August 2017, farmers had many indicators of an Autumn without major storm events—jackfruits grew on branches rather than trunks, bamboo expanded and grew straight, and 'vespa' bees were not hiding below ground—but then typhoon Doksuri hit. We point out that indigenous knowledge may vary and does not mean that all farmers agree. For example, in Dien Bien, only half of the PSP farmers believed that chestnut was a good indicator of rainfall while the other half had no opinion. It may also be that farmers believe that weather is decided by gods and, thus, adapting or planning makes no difference. Nevertheless, the PSPs help monitor indigenous knowledge, forecasting techniques and encourage better understanding rather than disqualifying farmers' indicators. Specifically, the process has helped farmers with planning (timing their farming calendars), receive updated information, and learning how to monitor and reflect on actions taken in response to information. Moreover, new opportunities arose to provide feedback to provincial authorities, such as the meteorological and agricultural departments.

Given the bottlenecks for agroforestry development in Viet Nam (Simelton et al. 2016), particularly related to institutional, human and technical capacity, there are challenges for expanding the use of better forecasting services as described here. One challenge with agroforestry compared to monocultural crops is that farmers may have diverse combinations of crops and trees, which would result in lengthy advisories.

There is certainly a trade-off involved in how much information to introduce in both the PSP and the advisory. We expect that when advisories can be accessed online, such 'information overload' can be more easily managed. Specifically, to fast-track actionable climate services specifically for agroforestry, the following is needed.

Capacity development

In all three countries, we encountered communication gaps between meteorology and agronomy.

- *Training*: Few agricultural extension officers were trained in integrated farming systems and agro-meteorology. As a result, extension workers were not familiar enough with weather forecasting to know what to ask for. Conversely, meteorological staff were not trained in agro-meteorology and were largely unaware of what farmers or extension workers needed to know and when they needed to know it.
- *Farmers' needs*: For the development of seasonal forecasts, it is important to first understand farmers' priority crops and avoid assuming that rice alone determines the timing of seasonal forecasts. Moreover, crop and variety selection depend not only on the weather to come but also on how it was in the previous season (delayed, early, dry, wet etc). Mutual understanding can be formed through farmers' field schools running over longer periods, for example, in the ACIS project sites in Cambodia rain gauges were used for school education that will create a new generation of young farmers with a basic understanding of weather monitoring.

Climate-smart advisories

- Advisories can be improved immediately by introducing climate-smart practices and practices with demonstrated benefits of making better use of existing perennials in, for example, upland fields, home-gardens or as windbreaks in neighbouring fields. However, what, when and how to plant needs to be specific to local contexts (Duong et al. 2016).

- *Adding value to standing trees*: Farmers alone typically rationalized what crops to add to standing trees usually by their provisioning services while in the PSP groups they discussed regulating functions to match the need for animal feed, mulch, compost or green manure, or natural pest control. The loan groups discussed 10-year business plans, reducing the risks associated with monocultures by adopting mixed species' stands with mixed ages and selective felling. This calls for clear guidelines and intentions from government support programs. To cover the establishment gap, additional income could be generated from bee hives and shade-tolerant species, such as medicinal plants, ginger and lemongrass.
- *Adding value by species selection*: Canopy and root structures need to be considered when prioritising multi-strata and sub-canopy species in relation to their regulating functions. For example, knowing the likely frequency of natural disasters can help when considering a light canopy to provide shade to Spring crops or a dense canopy to ameliorate rainfall intensity for Autumn crops.
- *Land-use planning*: When deciding which perennials to plant where, planners need to consider a range of climate risks over several years and the frequency and intensity of such events (hazard mapping and hazard history). For example, strong trees as windbreaks can be planted closer to houses and animals and trees that break more easily further away, for example, acacia. Learning can be facilitated by evaluating post-disaster damage. For example, after recent storm and flood events in in 2017 and 2018 the team joined the disaster evaluation teams to also point out 'good practices', where the damage was less.

Viet Nam's plan to join the Framework for Climate Services (GCFS) could lead to more practical and useful forecasts being of benefit to farmers throughout the nation. This would connect to the National Adaptation Strategy, which acknowledges the importance of climate-smart agriculture, and could support Nationally Determined Contributions to reduce greenhouse-gas emissions and mitigate climate change. We stress the importance of offering services that are feasible for smallholders with mixed farming systems in complex upland terrain.

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TOWARDS LOW-EMISSION LANDSCAPES IN VIET NAM

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