Viability assessment of jurisdictional Reduced Emissions from Deforestation and Forest Degradation (REDD+) implementation in Vietnam

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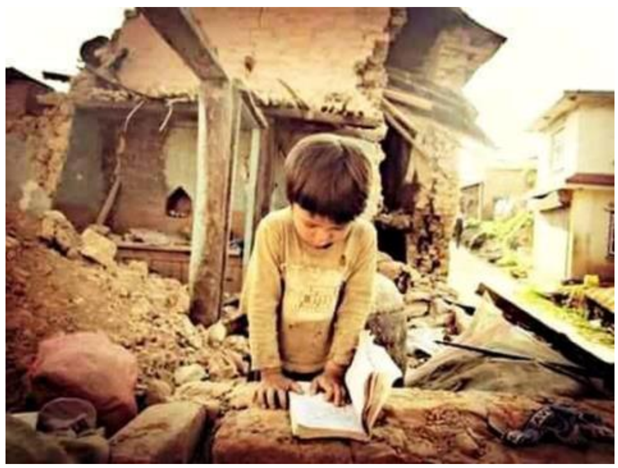

Dedicated to
all 2015 earthquake victims in Nepal

Declaration

I hereby declare, on oath, that I have written the present dissertation by my own and have not used other than the acknowledged resources and aids.

Hamburg, 16 July 2015 ………………………………………..

(Prem Raj Neupane)

I certify that the English of the dissertation "Viability assessment of jurisdictional Reduced Emissions from Deforestation and Forest Degradation (REDD+) implementation in Vietnam" written by Prem Raj Neupane from Department of Biology, Institute for World Forestry, University of Hamburg was reviewed and is correct.

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Summary

International climate negotiations under the United Nations Framework Convention on Climate Change (UNFCCC) conceive a nationwide approach of performance evaluation and national-level carbon accounting for REDD+. Decisions adopted in the 16th Conference of the Parties (COP16) to the UNFCCC in Cancún, 2010 acknowledged sub-national or jurisdictional approaches, as an interim measure, for REDD+ accounting and monitoring. A jurisdictional approach is the nation-wide approach under which a sub-national or provincial government implements and administers REDD+ ensuring compliance with nationally and internationally agreed-upon financial, fiduciary and reporting standards. The study is focusing on Vietnam which is working on multiple phases of REDD+ and is taking action at multiple scales. Vietnam is developing a national REDD+ strategy, building measurement, reporting and verification (MRV) capacity, establishing reference emission levels, and piloting benefit-distribution systems. The country is exploring nested approaches to integrate jurisdictional REDD+ activities into national REDD+ schemes. Jurisdictional REDD+ implementation (JRI) involves both state and non-state actors (local governments, non-profit/governmental organizations, indigenous peoples' organizations) and opens the door for private-sector engagement in REDD+. For the JRI, the government needs to identify potential jurisdictions and decide upon priority areas. In addition, whether realistic jurisdictional REDD+ implementation is achievable from technical, operational, financial and policy perspective, needs to be analyzed and evaluated before the decision for a specific jurisdiction is made. To inform such decision making, this study attempts to evaluate the viability of the jurisdictional REDD+ implementation in Dinh Hoa, Vietnam. Dinh Hoa is a mountainous district inhabited largely by ethnic minorities and is deeply poverty stricken. In the district, forestry is major land use and 70% of the total forest area is managed by households. Based on designated ecological function, forests are classified as Special use, Protection and Production forests in Vietnam. The district possesses all the forest types, and is rich in natural forest formations and biodiversity. The study provides an understanding of JRI feasibility in a jurisdiction (i.e. the Dinh Hoa district) and suggests potential REDD+ activities in household-based forestry - a major forest management regime in Vietnam. The research examined the viability of the jurisdictional REDD+ implementation as a combination of technical, operational, financial and political aspects using multiple methods and analytical techniques.

The study conducted ground-based forest inventories to estimate carbon stocks in forests. Besides biomass and carbon densities for the different forest types, the study provides data on soil organic carbon, litter and understorey carbon pools, which is currently scarce in Vietnam. Forest cover change was assessed using remote sensing and geographic information systems. Based on findings of the forest inventories and forest cover change analysis, technically feasible REDD+ activities were identified. The study used household surveys to assess the perception and attitude of local households towards forest management, forest land allocation and REDD+. Forest use-rights, tenure, and willingness and capacity of the forest owners to participate in REDD+ were assessed. Outcomes of the assessments were used to evaluate operational feasibility and local acceptability of the JRI. Net present value (NPV) and benefit-cost ratio (BCR) were used to measure financial viability of natural forests and planted forest management. A rigorous desk review of national legal and regulatory frameworks and institutional arrangements for REDD+ implementation was conducted to explore whether the frameworks and the arrangements are supportive for operationalizing jurisdictional REDD+.

In the household-based forest management (HBFM) regime, subsistence households were managing small and fragmented patches of forests with differing forest carbon stocks. From technical perspective, *conservation of forest carbon stocks through protection of existing forests* and *enhancement of forest carbon stocks- through restoration of degraded forest lands with assisted natural regeneration* would be promising REDD+ activities for Protection forests and Special use forests. A recent trend of conversion of degraded natural forests to planted forests indicates *sustainable management of forests through enrichment planting*, and *reducing emissions from deforestation through avoided planned deforestation* might be further activities to be considered. The study suggests estimation of emission factors and preparation of reference emission levels for each activity; and calculation of corresponding financial values for explicit determination of REDD+ activities.

Benefit-cost ratio of greater than one and NPV of benefits of US$25 per ha per year revealed household-based natural forest management is economically feasible in Vietnam. The NPV indicates opportunity costs of forest conservation under REDD+ to the household. This implies that carbon markets under a REDD+ mechanism may entail high opportunity costs compared with the current carbon price in international market. JRI might be financially attractive to the households, if it provides incomes additional to the current income from the forest management under the HBFM. Moreover, the HBFM enhanced small-holders' access to external finance, increased employment opportunities and promoted cross-sectoral linkage between forestry and agriculture, which are key for sustainable management of forests.

Jurisdictional REDD+ implementation is politically acceptable and compliant with requirements of national legal and regulatory frameworks, UNFCCC REDD+ process, and other relevant processes, such as Verified Carbon Standard. The Vietnamese multi-tiered and partially decentralized institutional arrangements for REDD+ implementation are in principle highly supportive to a jurisdictional REDD+ approach. The arrangement constitutes a network of institutions with substantial decentralization of fiscal, administrative and monitoring authorities from national level authorities to province and district level authorities of REDD+ implementation. However, low level of knowledge and understanding about REDD+ among local stakeholders is an impediment for the JRI. Capacity of all state and non-state actors, particularly of ethnic minority groups, and forest-adjacent/dependent households needs to be strengthened to enhance their complete and effective participation in program design and implementation, benefit sharing, as well as safeguards design and monitoring.

The small-holders showed positive perception towards the household-based forest management regime and positive attitudes to forest land allocation and REDD+ initiatives. Positive perceptions and attitudes on conservation initiatives are good indicators for the sustainability of a REDD+ mechanism and indicate the likelihood that the local residents will continue to be involved in the implementation of the regime. Participation of local stakeholders is considered as building block for efficiency of REDD+ and its success which depends on its legitimacy. The substantive participation of the households and state-actors in the forest management regime encouraged an inclusive and informed decision-making process. Long-term land tenure, secured and explicit forest-use rights, mutually understood and respected roles and responsibilities, and accessible institutions and processes ensured traditional, legal and local legitimacy.

Thus, jurisdictional REDD+ implementation is conceptually feasible and operational, provided that REDD+ activities are coherent to and embrace the concomitant policies, programs and practices. This is equally important for political adoption and local legitimacy of REDD+ at local level. The study suggested jurisdictional REDD+ implementation is technically feasible, operationally achievable, financially viable, and politically acceptable. However, to achieve fully operational JRI, REDD+ activities should be additional to and embedded into concomitant forest management and land use policies and programs at jurisdictional levels.

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Acronyms

A/R	Afforestation and Reforestation
ADB	Asian Development Bank
AGTB	Above ground tree biomass
AGTC	Above ground tree carbon
ANR	Assisted natural regeneration
ATK	Scheme on Forest Protection and Development in Dinh Hoa Safety Zone, Thai Nguyen Province
BCA	Benefit-cost analysis
BDS	Benefit distribution system
CBD	Convention on Biological Diversity
CF	Community forest
CMP	Conference of the Parties serving as the Meeting of the Parties
CO_2	Carbon-dioxide
COP	Conference of Parties
CPC	Commune Peoples' Committee
CPF	Collaborative Partnership on Forests
DARD	Department of Agriculture and Rural Development
dbh	Diameter at breast height
EBM	Evergreen - Broadleaf forest – Medium
EBP	Evergreen - Broadleaf forest – Poor
EBR	Evergreen - Broadleaf forest – Regrowth/Restored
ER Program	Emission Reductions Program
ER-PD	Emission Reduction Program Document
ER-PIN	Emission Reductions Program Idea Note
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FCPF	Forest Carbon Partnership Facility
FIPI	Forest Inventory and Planning Institute
FLA	Forest land allocation
FLEGT	Forest Law Enforcement Governance and Trade
FPDP	Forest Protection and Development Plan
FRL	Forest reference level
FSC	Forest Steward Council
GDLA	General Department of Land Administration
GHG	Greenhouse gas
GIS	Geographic information system
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
Gt	Gigatonnes
Ha	Hectare
HBFM	Household-based forest management
HHs	Households
ICRAF	World Agroforestry Centre
INDC	Intended nationally determined contribution
IntAct	International Action for Primary Forests
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
JNR	Jurisdictional and Nested REDD+
JRI	Jurisdictional REDD+ implementation

KfW	German Development Bank
LFPD	Law on Forest Protection and Development
LULC	Land use/land cover
MARD	Ministry of Agriculture and Rural Development
MONRE	Ministry of Natural Resources and Environment
MRV	Measurement, reporting and verification
NFDS	National Forestry Development Strategy 2006-2020
NGO	Non-governmental organization
NRAP	National REDD+ Action Plan
NTFP	Non-timber forest product
NTP-RCC	National Target Program to respond to climate change
NYDF	New York Declaration on Forests
PES	Payment for Environmental Services
PFES	Payment for Forest Environmental Services
ppm	parts per million
PV	Present value
QMD	Quadratic mean diameter
REDD+	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
REL	Reference emission level
REM	REDD Early Movers Program
R-PP	REDD+ Readiness Plan
SBSTA	Subsidiary Body for Scientific and Technological Advice
SFE	State forest enterprise
SFM	Sustainable forest management
SNV	Netherlands Development Organization
SOC	Soil organic carbon
TWG	REDD+ Technical Working Group
UNCED	United Nations Conference on Environment and Development
UNFCCC	United Nations Framework Convention on Climate Change
UNFF	United Nations Forum on Forests
UN-REDD	United Nations Programme on Reducing Emissions from Deforestation and Forest Degradation
UTM	Universal Transverse Mercator
VCS	Verified Carbon Standard
WBF	Mixed wood and Bamboo forests
WFREDD+	Warsaw Framework for REDD+
WWF	World Wide Fund for Nature
5MHRP	Five Million Hectare Reforestation Program

1 Introduction

1.1 Background

1.1.1 Role of tropical forests for global socio-economic and ecological prosperity

Tropical forests make multiple contributions to welfare of people across the tropics, throughout concerned nations and people all over the world (Myers, 1992). In addition to billions cubic meters of wood and wood products each year, tropical forests provide a wealth of ecosystem services that are indispensable for human wellbeing. The services include storage of a quarter of a trillion tons of carbon, reduction of carbon dioxide concentrations in the Earth's atmosphere through carbon sequestration, regulation of local, regional and global water and climate services, maintenance of a rich array of flora and fauna, soil formation and protection, and regulation of sediment outflows (ISU, 2015). Ecosystem services, benefits that humans obtain from ecosystems, are vital for rural livelihoods (Bhatta et al., 2015). Tropical forests are home to many thousands of indigenous and tribal peoples and to countless other flora and fauna lived in a symbiotic relationship for years. More than 1.6 billion people, nearly one fourth of global population, depend on forests for food, job, water, fuel, medicines, traditional cultures, security and livelihoods (UNEP, 2011a; IPCC, 2014a). Globally more than two billion people have no access to modern commercial energy services, for instance, electricity and gaseous and liquid fuels, leading to increased dependency on traditional biomass fuels (UNDP, 2004). Global Energy Assessment (2012) estimates have shown about three billion people rely entirely, or to a large degree, on traditional biomass or coal for cooking and heating (GEA, 2012).

Loss of tropical forests, consequently, results in decline of critical ecosystem services, at the same time interferes with regional hydrological cycle and climatic patterns. This in turn imposes serious knock-on effects on agriculture and imperils food security which increases vulnerability and livelihood insecurity of billions of rural inhabitants. Improved tropical forest management, on the other hand, can contribute to economic growth, poverty alleviation, rule of law, food security, climate resilience, and biodiversity conservation (United Nations, 2014b).

1.1.2 Extent and condition of tropical forests

Forests cover a total of 4.03 billion hectares (ha) land area worldwide, equivalent to 31% of the total world's land area (FAO, 2010b). Tropical land surface has undergone substantial changes in the last few decades as forests have been cleared to enable other forms of land use (Grace et al., 2014). Despite the enormous economic, ecological, and social benefits, forests are still being destroyed at an alarming rate – 13 million hectares annually – often for limited private and short-term gains (UNEP, 2011a). Every two seconds, across the world, an area of forest equivalent to size of a football field is clear-cut by illegal loggers (Goncalves et al., 2012). Notably, 250 million hectares of tropical forest have been cleared and converted, mostly for agriculture, since the 1992 Rio Summit (ISU, 2015). FAO (2010b) suggests rate of deforestation shows signs of decreasing: around 13 million hectares in the period of 2000-2010 compared with 16 million hectares per year in the period of 1990-2000. Globally, net change in forest area in the period of 2000-2010 is estimated at 5.2 million hectares decline per year (FAO, 2010b). Area of planted forests is a relatively small component, with perhaps 70 million hectares across the tropics, within a total of 260 million hectares globally (ISU, 2015).

Deforestation is rampant in the tropics. Tropical forests, once covered 3.6 billion hectares, almost a third of which have been lost as a result of deforestation. Of the remaining 2.6 billion hectares, 46% is fragmented, 30% is degraded, and only 24% (600 million hectares) is in a mature and relatively undisturbed state (ISU, 2015). Kim et al. (2015) reports a 62% acceleration in net deforestation in the humid tropics[1]. During the 1990-2000 period, annual net deforestation was about 4 million ha and during 2000-2010, it was 6.5 million ha. According to Hansen et al. (2013), annual tropical forest area loss is 8.5 million hectares, with the rate of loss increasing by 200 thousand hectares a year. Within forest estate, worsening condition of tropical forests remains a matter of profound concern.

1.1.3 Climate change and greenhouse gas concentration

Emerging body of science suggests increased concentration of greenhouse gas[2] (GHG), particularly of carbon-dioxide (CO_2), in the Earth's atmosphere has brought changes in the Earth systems: temperature, precipitation, sea level rise and extreme whether events. Number of climate related disasters- floods, storms, droughts and extreme temperature- has been ratcheting-up around the world. The world witnessed 3455 floods, 2689 storms, 470 droughts and 395 extreme temperature events between 1980 and 2011 (UNISDR, 2012). Number of flood occurrence increased from 39 in 1980 to 183 in 2010, and number of storms encountered increased from 43 to 91 for the same period (*ibid.*).

Concentration of atmospheric CO_2 has increased from a pre-industrial (1861-1880) value of about 280 parts per million (ppm) to 392.52 ppm in 2012. Combustion of fossil fuels and land use changes including deforestation and forest degradation are major sources of the rising atmospheric $CO_{2.}$ Le Quéré et al. (2014) estimates cumulative CO_2 emissions reach about 535 gigatonnes of carbon (GtC)[3] (emissions from fossil fuel combustion and cement production: 390 GtC and land use change emissions: 145 GtC) for 1870-2013. Net increase of CO_2 concentration in the atmosphere for the same period was 220 GtC. Last decade experienced a continued growing trend in the emissions. For 2003-2012, average global atmospheric CO_2 concentration growth rate was 4.3 GtC per year and for year 2012 the rate was 5.1 GtC per year (Le Quéré et al., 2014).

In 2013, Working Group I of the Intergovernmental Panel on Climate Change (IPCC) released a report, *Climate Change 2013: The Physical Science Basis* which unveiled, with 95% confidence, that climate change is occurring and humans are major contributors for this result (Adams-Schoen et al., 2015). Emissions of CO_2 is the main factor for anthropogenic climate change (Friedlingstein et al., 2010). Climate change caused by persistently increasing GHG concentration in the atmosphere emitted by anthropogenic activities, principally, by fossil fuel burning, deforestation, forest degradation and land use change presents severe, pervasive and irreversible consequences for the humanity and the planet (UNEP, 2011b). Climate change is a wager of our generation and comes down to matter of choice, as the former IPCC chair says:

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[1] 34 countries comprise over 80% of forest area in the tropics and dominate forest area of the humid tropics

[2] Carbon-dioxide ($CO_{2)}$, Methane (CH_4), Nitrous oxide (N_2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs) and Sulphur hexafluoride

[3] 1 gigatonne (Gt) = 1 billion tonnes = 1 Petagram (Pg)

"*We either continue the path we are on and possibly face the catastrophic consequences of climate change. We can choose to do nothing and face uncertain future, or, we listen to the voice of science and act accordingly and begin a deliberate revolution* (*sic*)".

Science of emissions suggests atmospheric concentration of CO_2 (equivalent) should remain between 450-500 ppm by 2100 in order to achieve the objective of the United Nations Framework Convention on Climate Change (UNFCCC): holding global temperature increase limits below 1.5^0C or 2^0C compared to pre-industrial levels. The world cannot emit more than 1410 additional Gt CO_2 (>33% probability of not exceeding 2^0C), 1120 additional Gt (>50% probability), or, 1010 additional Gt (>66% probability) for the period of 2012-2100 (IPCC, 2013; Adams-Schoen et al., 2015). To have a 'likely' (two-in-three) chance of not exceeding 2^0C, the world needs to reduce GHG emissions by at least 40-70% by 2050 and, to zero or below by 2100 (IPCC, 2014c).

1.1.4 Potentials of tropical forests to mitigating climate change

Forests, climate, climate change, and climate change mitigation are inextricably linked (Goodman and Herold, 2014). Forests store 45% of terrestrial carbon and tropical forests contain 25% of the carbon in terrestrial biosphere (Bonan, 2008). Forests loom large in the terrestrial carbon cycle, and they can and should be utilized as part of solution for immediate climate change mitigation action (Goodman and Herold, 2014). Friedlingstein et al. (2010) estimated average CO_2 emissions during 2000 to 2009 from deforestation and other land use changes (LUCs) to be 1.1±0.7 GtC per year, which was lower than the level estimated for 1990s (1.5±0.7 GtC per year). For the period of 2003-2012, average emissions per year was 0.9±0.7 GtC (Le Quéré et al., 2014).

Carbon budget of the tropics has been perturbed as a result of human influences (Grace et al., 2014). Tropical forests have the highest carbon densities in the world and store over 470 GtC, but are also subjected to the highest deforestation rate (Goodman and Herold, 2014). Tropical deforestation remains a major driver of global warming, emitting 0.8-0.9 GtC per year, equating to 8% of global carbon emissions, whilst less widely recognized, tropical forest degradation accounts for a further 0.6-1.5 GtC per annum, equating to a range of 6-14% of all anthropogenic carbon releases (ISU, 2015). In aggregate, the two sources may account for 14-21% of all carbon emissions, perhaps higher still when tropical peatlands and mangroves are included. Houghton (2013) suggested to attribute 2.28 GtC annual emissions to deforestation and forest degradation together for the period of 2000-2005.

On the other side of the tropical forest carbon ledger, tropical forests serve a vital role as a natural buffer to climate change capturing 2.2–2.7 Gt of carbon per year (Goodman and Herold, 2014). Houghton (2013) estimated emissions from avoiding deforestation (0.81 GtC), avoiding forest degradation (1.47 GtC) and safeguarding current sequestration (1.17 GtC) produces a combined tropical forest mitigation of the total of 3.45 GtC, which could amount as much as 28.63% of all anthropogenic carbon mitigation. Grace et al. (2014) suggested 3.86 GtC for the combined potential. According to Houghton (2013), the potential CO_2 mitigation could rise to 36% and as much as 1.55GtC can be additionally sequestered protecting tropical forest from further disturbances and increased afforestation. If deforestation were halted entirely, forests were allowed to regrow, and mature forests were left undisturbed, tropical forests alone would have captured 25–35% of all other anthropogenic carbon emissions (Goodman and

Herold, 2014). This underscores tropical forests have potential to be managed to reduce atmospheric concentration of CO_2 and thus mitigate climate change.

1.1.5 Drivers of tropical forests loss and damage

The need to protect tropical and sub-tropical forests from degradation and deforestation finds wide, societal agreement. It is now widely accepted that battle against climate change cannot be won unless deforestation is halted (Global Witeness, 2009). Drivers of tropical deforestation and forest degradation vary greatly through time and space and as a function of socio-economic and political factors (ISU, 2015). A formidable array of political economic interests, for example, state initiated colonization programs, enhanced opportunities for economic elites to cut down and sell valuable old growth trees, and reluctance of forest rich but poor tropical countries to address proximate causes of natural forest decline in their forest action plans, came together to support the destruction of tropical forests after World War II (Rudel, 2008).

Deforestation and forest degradation occur as a result of direct or proximate causes (human activities and actions) which are generally underpinned by several other indirect or underlying causes. The indirect causes are produced due to complex interactions among demographic, social, economic, institutional, political, and technological processes (Geist and Lambin, 2001, 2002). There is rarely a single (direct or indirect) cause of deforestation or forest degradation at a time and space, but causes are manyfold and inter-connected. The drivers are dynamic, for example, forest degradation often leads to deforestation.

An extensive literature exists discussing the causes of forest degradation and deforestation. Commonly referred direct causes include: global commodity supply chains-expert demand of palm oil, beef, leather, soy, pulp and paper, maize, rice, and sugarcane; oil and gas extraction and mining; development of transport and other infrastructures; subsistence agriculture; fuelwood and charcoal collection; forest fires; and logging (illegal, legal and informal or subsistence) (Geist and Lambin, 2001, 2002; Kissinger et al, 2012). The underlying causes include poverty; increase in population and consumption, and changing diets; migration; market growth and price trends; and urbanization and industrialization. Other factors such as drought, flood, fire, pest and earthquake; war, insurgency and revolution; as well as drug trafficking and arms smuggling also trigger forest degradation and deforestation (Geist and Lambin, 2001, 2002; Lawson and MacFaul, 2010; Kissinger et al, 2012; McSweeney et al., 2014; ISU, 2015). Policies on forest management and climate change, and abrupt policy shift (for instance, nationalization of forests) are also important drivers. Moreover, definitional challenges for deforestation and forest degradation- a cross-cutting issue and defaunation as a driver of degradation are mostly overlooked (ISU, 2015).

1.1.6 Global policy responses

Forests lie within national jurisdictions; within framework of its international obligations, each state has sovereign right to exploit its own forests according to its environmental and developmental policies (Glück, 1997). Forests are of national interests to accrue additional and sustainable revenue for economic development and poverty alleviation. However, the devastating and ubiquitous loss of natural forests across the tropics implies important and critical losses in biodiversity and decreasing forest ecosystem resilience against climate change (UNEP, 2011a)- problems that are global. To address the global nature of forest problems, an international response was envisioned in the form of a global forest convention. The convention was discussed in Houston Economic Declaration 1990 (Glück, 1997) and was proposed in Sào Paulo Declaration of the IPCC (Vanclay and Nichols, 2005) in the same year. Eventually, the global forest convention emerged as a priority on international political agenda in the UN Conference on Environment and Development (UNCED) in Rio de Janeiro in 1992. The UNCED could not articulate the convention, but adopted a Non-Legally Binding Authoritative Statement of Principles for a Global Consensus on the Management, Conservation and Sustainable Development of all Types of Forests, also known as "Forest Principles" by consensus. Although the run-up to the UNCED failed to adopt the convention, the negotiations and results of the UNCED initiated a change of paradigm towards sustainable development in general and sustainable forest management (SFM) in particular. Concomitantly, several other initiatives such as forest certification, boycott of tropical timber and definition of standards for SFM appeared. Outside the UNFCCC framework, instruments like forest law enforcement and governance and criteria and indicators for SFM were initiated in regional level.

The UNCED 1992 linked the tropical forest management to the sustainable development. Continuous policy shift from centralized state forest management to participatory forest management with a full spectrum of decentralization and devolution has been realized in the tropics, where *outright protection* is not a viable or desirable option. Several follow-up to the UNCED, such as the Intergovernmental Panel on Forests and the Intergovernmental Forum on Forests elaborated. Progressively, high level political priorities for forests are issued which relate to human well-being, such as the Millennium Development Goals.[4] Further efforts to sustainable forest management have been led by the UN Forum on Forests (UNFF) and the UN Food and Agriculture Organization (FAO). The 2007 adoption of a "Non-Legally Binding Authoritative Statement of Principles for a Global Consensus on the Management, Conservation and Sustainable Development of all Types of Forests" (Forest Principles) by the UN General Assembly and four Global Objectives[5] on forests are perhaps the most significant outcomes of the last decade at the international level. Other institutions and initiatives that have made notable contributions for the global policy processes include UNEP, the UNFCCC, the Convention on Biological Diversity (CBD), and the Collaborative Partnership on Forests (CPF).

Illegal logging has gained attention in international forest policy over the last 15 years, particularly after the G8 Forestry Action Program on Forests in 1998. During the last decade, enhancement of legal timber production and its associated trade has become one of the strategies used to promote SFM for sustainable development (van Dam and Savenije, 2011). Consequently, a large number of initiatives led by governments (unilateral or bilateral), private sectors and NGOs; and knowledge and capacity building

[4] Three MDGs related to forestry issues: Goal 1: Eradicate extreme poverty and hunger, Goal 7: Ensure environmental sustainability, and Goal 8: Develop a global partnership for development.

[5] The four (4) global objectives seek to: 1. Reverse the loss of forest cover worldwide through SFM, including protection, restoration, afforestation and reforestation, and increase efforts to prevent forest degradation; 2. Enhance forest-based economic, social and environmental benefits, including by improving the livelihoods of forest-dependent people; 3. Increase significantly the area of sustainably managed forests, including protected forests, and increase the proportion of forest products derived from sustainably managed forests; and 4. Reverse the decline in official development assistance for SFM and mobilize significantly-increased new and additional financial resources from all sources for the implementation of SFM.

initiatives working independently or together, to combat illegal logging and associated trades, and concomitantly, promoting trades in legal timber, enhancing forest law enforcement and governance across the world. Government initiatives include international agreements and processes (such as International Tropical Timber Agreement, Forest Law Enforcement, Governance and Trade (FLEGT)) and national government initiatives (national policies, for example, Australian Illegal Logging Prohibition Bill, EU Timber Regulation, US Lacey Act, Timber Legality Assurance System of Ghana, Cameroon, Indonesia etc.). Private sector initiatives comprise certification systems such as Forest Steward Council (FSC), Program for the Endorsement of Forest Certification (PEFC) and private and corporate procurement policies. NGO initiatives includes initiatives on advocacy (for instance, Forest Trends), legal timber production (such as, the wildlife monitoring network- TRAFFIC[6]) and independent forest monitoring (such as, Global Witness) initiatives. Knowledge and capacity building initiatives contains regional and country support initiatives (such as, EU-FLEGT Facility) and initiatives such as Forest Legality Alliance and Chatham House.

Within the UNFCCC negotiations, more than 150 nations adopted the Kyoto Protocol in 1997. For the first time, nations agreed to place legally binding limits to their emissions of the heat trapping GHGs. Thirty-eight industrial governments agreed to reduce their emissions of (six) GHGs to 5% below 1990 emission levels by the year 2012. In the 8th CMP (Conference of the Parties serving as the Meeting of the Parties) to the Kyoto Protocol in the UNFCCC Doha Conference (COP 18) in 2012, governments decided eight-yearlong (2013-2020) second commitment period.

The UNFCCC COP 16 in Cancun (2010) formally included 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+) into international climate regime (section 1.1.7). Under REDD+, forest conservation is seen as critical to limit global warming to two degrees Celsius - ambitious objective of the UNFCCC. REDD+ is referred as a part of international climate change mitigation efforts, in the context of the implementation of the UNFCCC, developing countries are encouraged to reduce GHG emissions from deforestation and forest degradation, conserve and sustainably manage their forests and enhance forest carbon stocks (Maniatis et al., 2013). Moreover, international and national negotiations of a REDD+ regime may be the best opportunity to protect forests and ensure their contribution to a green economy (UNEP, 2011b).

Concurrently, several other policy responses have taken place to combat the tropical forest problems. Most commendable responses are Bonn Challenge (2011), New York Declaration on Forests (September 2014), IntAct (International Action for Primary Forests) (November 2014) and "*the Lima Challenge*" (December 2014). Bonn Challenge on forests, climate change and biodiversity 2011, driven by Global Partnership on Forest Landscape Restoration, is the largest restoration initiatives in history, commits to restore 150 million hectares of the World's degraded and deforested lands by 2020. It calls on leaders, landowners and local communities to allocate and commit landscapes in order to reach the global target. To the date, formal commitments have already reached to 59.2 million hectares; 39% of the total target. New York Declaration on Forests (NYDF) is a non-legally binding political declaration which calls to

[6] Trade Record Analysis of Flora and Fauna in Commerce

restore 350 million hectares (including 150 million hectares of Bonn Challenge commitments) of degraded landscapes and forestlands by 2030 worldwide. This is the first time world leaders endorse a global timeline to cut natural forest loss in half by 2020, and strive to end it by 2030 (United Nations, 2014b). The declaration received a broader support not only by the countries, but also by private co-operations, by jurisdictions at province level, by civil society, and by indigenous people. IntAct was lunched at IUCN World Parks Congress in Sydney, calls for the world's remaining primary forests to be set aside as `no-go' or 'zero-logging' areas. Clearly, no reductions regime would be successful without meaningful developing country reductions (Santilli et al., 2005). In December 2014, in a joint ministerial announcement by fourteen developing country signatories to the NYDF called "*the Lima Challenge*" - a critical mass of developing forest countries[7] challenged developed countries to join them in achieving deeper emission reductions through international collaboration (Dahl-Jørgensen, 2014).

Another commendable achievement of recent years to tackle the global problem is engagement of private sectors toward deforestation supply chains. Fifty three companies including Golden Agri-Resources, Cargill, Asia Pulp and Paper, McDonald's, Nestle, Marks & Spencer, Unilever, Barclays and Kellogg's endorsed the New York Declaration on Forests. Several of them already committed to 'zero-net deforestation' or pledged to eliminate deforestation from their complete global supply chain.

1.1.7 Evolution of REDD+ and context of jurisdictional REDD+ implementation

Concept of using forest sinks for mitigating climate change has been intensely controversial since its inception (Smith and Applegate, 2004). The concept came up as 'avoided deforestation' in Kyoto (COP 3, 1997) as a potential opportunity to be included in Kyoto Protocol. At the time of the Kyoto negotiation, parties raised several technical and methodological limitations that could allow the parties to have robust measurement, reporting and verification (MRV) system to implement the concept addressing issues such as additionality, non-permanence, data availability, monitoring capacity and establishing reference level/reference emissions level (RL/REL) (Santilli et al., 2005; Karky and Banskota, 2006; Fearnside, 2001; Skutsch et al., 2007; Schlamadinger et al., 2007; Alvarado and Wertz-Kanounnikoff, 2007; Luttrell et al., 2007; Mollicone et al., 2007). The concept of avoided deforestation was left out by Kyoto Protocol due to the limitations. For the first time, RED was proposed during the COP 11 in Montreal (Brockhaus et al., 2012). This initiated a two year work program under the UNFCCC's Subsidiary Body for Scientific and Technological Advice (SBSTA) (Maniatis et al., 2013). Main idea of the scheme was to provide positive financial incentives to countries that would reduce emissions from avoided deforestation and compensate these countries based on their performance via carbon credits (*ibid.*). In 2007, RED became REDD to include the dimension of forest degradation in COP 13 in Bali. In 2010, Parties added 'plus' component and agreed five activities of REDD+ approach in COP 16 in Cancun. The plus component includes three additional activities: conservation of forest carbon stocks, sustainable management of forests, and enhancement of forest carbon stocks.

[7] Endorsers of "*the Lima Challenge*" include Colombia, Chile, Costa Rica, Democratic Republic of the Congo, the Dominican Republic, Ethiopia, Guatemala, Guyana, Liberia, Nepal, Panama, Paraguay, Peru and the Philippines.

After the Cancun agreement, Parties focused on rules on how REDD+ mechanism will work. In COP 19 (Warsaw, 2013), governments decided to adopt Warsaw Framework for REDD+ (WFREDD+), which is known as rule book and contains seven decisions. In the WFREDD+, they agreed upon elements countries need to develop to access result-based finance, elements of coordination of support for implementation of REDD+ activities; and five design elements of REDD+: national forest monitoring system, safeguards, guidance and procedures for assessment of RL/RELs, MRV and drivers of deforestation. However, the parties could not agree upon the need of further methodological guidance for three technical issues: safeguards, non-carbon benefits, and non-market based approaches. With a sudden leap forward, delegates in Bonn Climate Change Conference/forty-second sessions of the SBSTA under the UNFCCC (June 1-11, 2015) ended the technical negotiations. To resolve those long-standing three technical issues, the SBSTA adopted draft conclusions and three decisions, which have been forwarded to the COP 21 to be adopted in Paris (30 November – 11 December 2015).

Nation-wide performance evaluation and national-level carbon accounting framework are widely conceived for REDD+ under the UNFCCC climate negotiations. REDD+ implementing countries are developing national policies and data, and building capacities to design and implement these national frameworks. As an interim measure, sub-national activities (activities that takes place at state/province and local/project levels) are accepted (Eickhoff et al., 2014) and are rapidly evolving (Chagas et al., 2011). The REDD+ decision adopted in Cancun in 2010 (COP 16) also formally acknowledged[8] the subnational approaches to REDD+ accounting and monitoring. Cancun integration of these different accounting scales might enhance environmental integrity of the system as a whole by ensuring consistent and coherent REL, MRV and crediting approaches. While broader policy reforms may take years to be implemented, REDD+ action can be developed faster at jurisdictional level (state/province level), delivering near-term reductions in emissions (*ibid.*).

Several governments (including state/provincial governments) have started to implement Jurisdictional and Nested REDD+ (JNR) Pilot Programs around the world under Governors' Task Force on Climate and Forests. The programs are closely linked with JNR initiative of Verified Carbon Standard (VCS). State of Acre and State of Pará (Brazil), Costa Rica, Chiapas (Mexico), Central Kalimantan (Indonesia), San Martin and Madre de Dios (Peru), and Mai Ndombe Province (Democratic Republic of the Congo) are among few and successful examples. By establishing jurisdiction-wide frameworks, the governments are producing billions of VCS compliant verified carbon units which are eligible to be sold on voluntary carbon markets. The measured emission reductions are also being rewarded in the form of results-based payments by bilateral REDD+ funding (such as, German REDD Early Movers (REM) Program, Amazon Fund)). Lessons learnt from the programs suggested jurisdictional REDD+ ensures a broader and inclusive participation of local governments and local communities - the real carbon service providers; supports to establish appropriate governance; equitable sharing of climate benefits, and mobilizes public and private investments. However, there are several issues and challenges that need to be resolved.

[8] Encourages developing country Parties aiming to undertake REDD+ activities to develop "a national forest reference emission level and/or forest reference level or, if appropriate, as an interim measure, subnational forest reference emission levels and/or forest reference levels, in accordance with national circumstances, and with provisions contained in decision 4/CP. 15, and with any further elaboration of those provisions adopted by the Conference of the Parties."

1.2 Theoretical background of the study

Tropical forests provide a wide range of forest products and services other than timber (section 1.1). Some of these are directly in demand among local population, for instance, non-timber forest products (NTFPs). Few forest services have no specific local demand or cannot be allocated to individuals such as carbon sequestration and biodiversity conservation. According to Pretzsch (1998), it is useful to differentiate the demand of the services among five (valuation) levels: enterprise or farm, local or community, regional, national, and international level. Pagiola et al. (2002) also confirm usefulness of categorizing different benefits according to those that bring benefits directly to local decision-makers (such as, harvest of timber and NTFPs), those that bring national-level benefits (such as, regulation of hydrological services) and those that bring global-level benefits (such as, carbon sequestration) (Figure 1a).

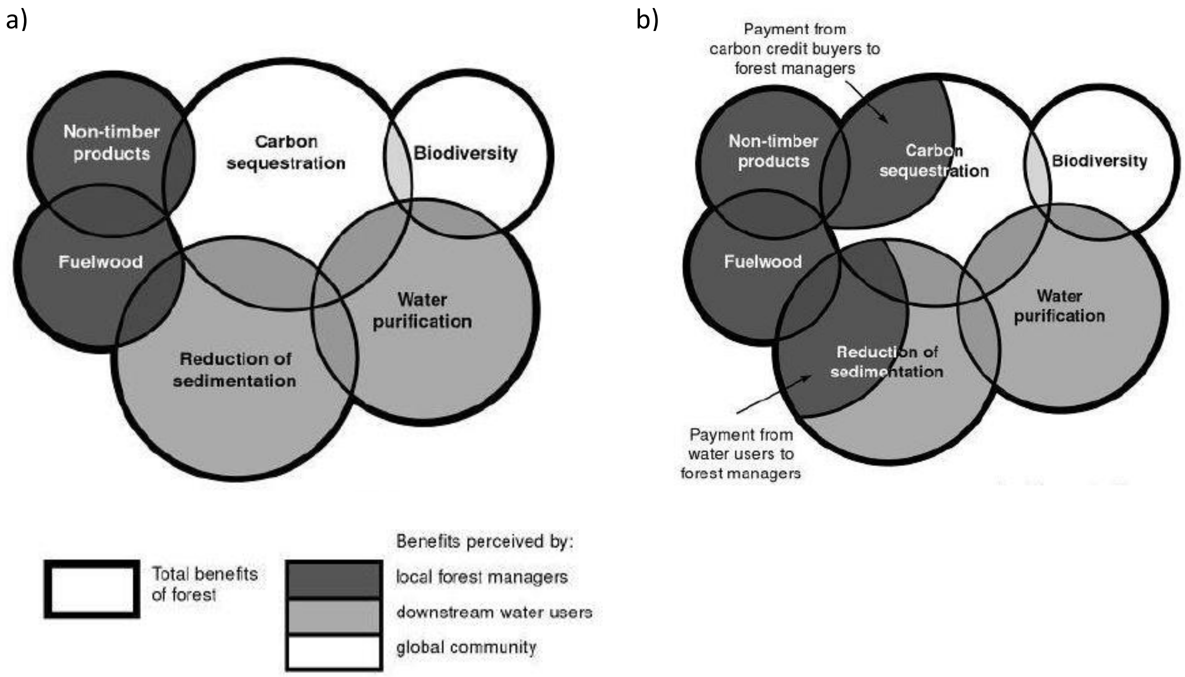

Figure 1.1 Products and services provided by forests other than timber: a) shows forest products and services, and their beneficiaries at different levels, and b) shows market-based mechanism for forest services (carbon sequestration and reduction of sedimentation).
Source: Pagiola et al., 2002

'Local' benefits are perceived by decision-makers on the ground. Value of the environmental services or services of 'no specific local demand' (Pretzsch, 1998), which brings national and global level benefits (Pagiola et al., 2002) are insufficiently integrated in markets (Alvarado and Wertz-Kanounnikoff, 2007; Köhl et al., 2014). As long as local decision makers receive no compensation for providing those benefits, decision makers are unlikely to give them much consideration while making land-use decisions (Pagiola et al., 2002). It is equally applicable for a state as a forest owner that only a small fraction of stumpage value or ground rent is actually paid (Repetto and Gillis, 1998; cited by Pretzsch, 1998). In turn, conservation of forests for the services competes with a range of seemingly more profitable land-uses including agriculture, logging, human settlements and infrastructure projects (Alvarado and Wertz-Kanounnikoff, 2007). When value of forest appears to be far lower than it really is, deforestation and forest degradation occur. In other words, as external costs associated with forest destruction are not recognized, decisions about forests are apt to lead to forest degradation and deforestation (Köhl et al., 2014). ISU (2015) perceived under-valuation of tropical forest as a 'meta-driver' of tropical deforestation and forest degradation. Pretzsch (1998) further stresses international community should compensate for indirect use value (climate effect, watershed protection, carbon fixing), option value and existence value of forests to provide adequate incentives to land managers. He cites Hess (1996) who observed unless additional income sources are created, locally available resources are not sufficient to permit sustainable forest management (SFM) at community level.

Many believe market-based mechanisms provide powerful incentives and efficient means of conserving tropical forests and public goods they provide, while at the same time offering new sources of income to support rural livelihoods. In Figure 1b, two hypothetical market-based mechanisms are shown: one that sells sedimentation reduction service to downstream water users and another that sells carbon credits. REDD+ is a potentially significant financial mechanism that seeks to recognize value of carbon stored in forests, and shift incentives from deforestation and land-use change to forest conservation and sustainability (Larson and Petkova, 2011). In this context, REDD+ is a response to the under-valuation of tropical forests. In the mechanism, countries that are willing and able to reduce emissions by sources and removals by sinks from the five activities will be financially rewarded for doing so based on verifiable results. REDD+ '*is an effort to create a financial value for the carbon stored in forests, offering incentives for developing countries to reduce emissions from forested lands and invest in low-carbon paths to sustainable development*' (UN-REDD, 2015).

There is a possible misunderstanding when REDD+ is anticipated as a panacea for the ambiguous tropical forest problems. REDD+ is a market driven mechanism. According to Folmer and Van Kooten (2007), policy failure is more important driver of tropical deforestation than market failure. It seems increasingly less clear, if the carbon related revenues will be able to compete with revenues from other land uses such as conversion for agricultural production to meet increased food and fuel demands (Watson and Nakhooda, 2012). A full accounting of all benefits would not necessarily lead to preservation of all forests, but it would almost certainly result in a lower rate of deforestation compared to the current rate (Pagiola et al., 2002).

1.3 Scope of the study

1.3.1 Relevance and rise of REDD+ jurisdictional approach

Since 2005, strategies and incentives for REDD have emerged as one of the most discussed areas in international climate change negotiations (Mollicone et al., 2007). Cancun agreements added 'plus' encompassing three more elements (section 1.1.7) and mandated several safeguards while undertaking REDD+ activities. REDD+ now is a part of a complex picture, closely linked with issues such as people's livelihoods, rural development needs, agricultural practices, local cultural and political circumstances, and impacts of global economic drivers (Hyvarinen, 2014). On the other side of the picture, the objectives and mandates have created potential for REDD+ to mitigate climate change, achieve sustainable development, and alleviate poverty, whilst also conserving biodiversity and sustaining vital ecosystem services (ISU, 2015). This in turn has fostered several new ideas, including jurisdictional model and sustainable forest landscapes concept, which have spurred creation of new multilateral funds[9] that seek to harness the innovations as routes for achieving REDD+ objectives at scale (*ibid*.). With tropical countries making advances toward REDD+ readiness, jurisdictional frameworks are on the rise.

Often, larger forest areas with greater risks of forest loss are focused under REDD+ activities in majority of REDD+ implementing countries. While focus of REDD+ has already moved from carbon to multi-objective, it is yet to include wider geographical landscapes (location, extent, carbon stock, and other ecosystem services) and recognize specific characteristics of forests. In contexts of Sydney calls for `no-go' to remaining primary forests and NYDF's goal to restore 300 millions of degraded forestlands by 2030, jurisdictional model is highly relevant for valuable remnants and degraded forests with a high potential for recovery. Moreover, participatory forest management practices such as community forestry, leasehold forestry and household-based forestry must be included as a participant under the REDD+ mechanism to achieve its' boarder objectives of mitigation and sustainable development. Jurisdictional model could serve several purposes, including: greater visibility on state of particular forests, and consequent prioritization of actions; better understanding of interplay of carbon and ecosystem services in specific contexts; and a tool to develop management and protection plans (ISU, 2015). Ultimately, this model would redress one of the perceived weakness of current REDD+ approach-tendency for action to be catalyzed at the point of deforestation risk ('the forest frontier') (the Amazon, West and Central Africa, and South-East-Asia) (*ibid*.). In this context, the jurisdictional REDD+ is impressively applicable in REDD+ implementing countries characterized by diverse geography, high ecosystem and species diversity, community based forest management, ambitious forest restoration target, and small area of intact forests of high conservation value.

REDD+ is a compliance and/or voluntary market driven and result-based financial mechanism. The demand side of this market, i.e., demand for REDD+ forest credits, is weak. There is still a huge emissions gap towards the planetary goals. If 2014 announcements of the EU, USA and China for 2025 and 2030 are fully implemented, it would reduce global temperature increase only by 0.2^{o}C to 0.4^{o}C (Höhne et al., 2014). Though, Member States are preparing their intended nationally determined contributions (INDCs), many doubt the aggregate effect of the INDCs in terms of global emissions of GHGs suffices to stay within the planetary limits. To create a strong demand for REDD+ forest credit, ambitious and science-based INDCs, not only of developed governments, but also of emerging economies ("BASIC"-Brazil, South Africa, India, China; and Indonesia) is needed, which is very unlikely to develop.

From 2006 to 2014 (March), more than US$8.7 billion fund is already received by REDD+ implementing countries (Norman and Nakhooda, 2014) and it is suggested a huge development in REDD+ technical capital and capacity building in the countries. Nevertheless, supply side issues, such as: coherent sustainable development strategies that balance multiple objectives; land-use planning and associated laws and regulations that provide basis for achieving forest protection; good governance; and

[9] REM-Germany's REDD+ Early Movers Program (US$61 million), BioCarbon Initiative for Sustainable Forest Landscapes (US$311 million), Amazon Fund (US$1.03 billion), FCPF Carbon Fund (US$388 million), Norway/Indonesia Partnership (US$1 billion) and GRIF-Guyana REDD+ Investment Fund (US$250 million) (Norman and Nakhooda, 2014)

clarification and legal recognition of land tenure and customary and traditional rights of local communities, and their free prior and informed consent with regard to forest management schemes, were neglected at the inception of REDD+ on the presumption that the key problem was provision of finance (ISU, 2015). Because of the ignorance on enabling environment of the supply-side, there is still a serious shortage of absorption capacity (*ibid*.). This prevents REDD+ implementing countries to be able to fully spend the funds (or grants) in an effective and efficient way they garnered from Forest Carbon Partnership Facility (FCPF), the UN collaborative program on REDD (UN-REDD), Forest Investment Program and other public and private funds. The World Bank administered FCPF is typified by rushed decision-making, non-inclusiveness, and a narrow focus on carbon stocks (White, 2014).

Under Ad-Hoc Durban Platform of the UNFCCC, global communities are currently negotiating a new global climate agreement including an international REDD+ mechanism (Brockhaus et al., 2012). Many expect a protocol, another legal instrument or an agreed outcome with legal force under the UNFCCC from Paris climate conference. However, UN framework conventions and treaties are multilayer processes. Debates over scope of treaties or legal instruments, institutional and financial mechanisms, and, sometimes, even over a phrase may extend up to many years (Kutney, 2014; Schneider and Neupane, 2014). For instance, architecture of REDD+ has been discussed since Cancun climate conference and yet to be finalized. Furthermore, a significant gap between available funding and required level of funding, as prescribed in Stern (2007) and Eliasch (2008) review, is one of the strongest impediments to realize a fully operational REDD+ in near future. In this situation, until fully operational REDD+ mechanism takes place under the expected global climate treaty, carbon credits generated from jurisdictional REDD+ implementation can be sold to existing voluntary carbon markets. The market might be bolstered by the NYDF led private sector engagements as described earlier (section 1.1.6). Jurisdictional REDD+, by then, lays the foundation for National REDD+ to be built on it. In 2013, stakeholders around the world purchased 24.7 $MtCO_2e$ REDD offsets, i.e., more than 80% of the total transacted forest carbon offsets[10] in the year (Goldstein and Gonzalez, 2014). The state of Acre, Brazil secured a € 19 million ($40 million) agreement with German Development Bank KfW (under the REM) for 8 $MtCO_2e$ in emission reductions (Goldstein and Gonzalez, 2014; Norman and Nakhooda, 2014).

National-level approaches are preferred to facilitate monitoring of emission reductions and reduce risk of leakage. Nevertheless, financial compensations for REDD may not reach ultimate providers of REDD-services (land managers) due to weak public governance (Alvarado and Wertz-Kanounnikoff, 2007). Subnational and local governments are important players who can contribute to a REDD+ design that reflects and adapts local realities and needs (Larson and Petkova, 2011). It could be argued that jurisdictional framework will create a stronger verifiable and visible supply chain for credits than when they are sourced from a multiplicity of projects.

REDD+ framework should address many factors such as land tenure, effective land use planning, recognition and respect for rights, and strong and accessible institutions and process (ISU, 2015). REDD+ success depends on its legitimacy: both legal and traditional. To increase local legitimacy, rather than declaring blanket regulatory reforms, REDD+ may need to be designed in a way to promote participatory and locally appropriate decision making. This is particularly important in terms of rules and solutions to

[10] AFOLU (Agriculture, Forestry and Other Land Use)

forest degradation and deforestation, such as through adaptive management models and participatory monitoring (Larson and Petkova, 2011). To promote informed decision-making process, substantive participation of local stakeholders, i.e., communities and households managing forests, people living in or near to forests, local governments and local forestry authorities, is indispensable. Generating and compiling knowledge on multi-functional forests, their use and their cross-sectoral linkages, contribution to local economy including household income, employment opportunity, is key for sustainable management and informed decision-making (UNEP, 2011a). Furthermore, policy decisions should be supplemented by scientific information on multiple functions of forests, biomass, diversity and forest disturbances. Particularly, local non-state stakeholders should be fully informed of implications, i.e., benefits, obligations and burdens, of REDD+ activities. Participation of local stakeholders is considered as building block for efficiency of REDD+ (Ratsimbazafy et al., 2012). Thus, to promote participatory and locally appropriate decision-making, which tends to increase local legitimacy of REDD+, jurisdictional implementation seems as a promising model.

1.3.2 Rationale and assumptions of the study

Vietnam recognized green growth/economy, a relatively new and emerging policy discourse, as a key pillar of its' sustainable development strategy for 2011-2020. While addressing and mitigating climate change impacts (GSRV, 2012b), the country aims to ensure efficient and sustainable growth. Nineteen subject areas were identified as prioritized areas for implementation of Strategic Orientation for Sustainable Development in Vietnam (Prime Minister Decision No. 153/2004/QD-TTg). Forest protection and development; biodiversity conservation; and implementation of measures aimed at mitigating climate change are three prioritized areas among the 19 (GSRV, 2012b).

Discourses have shaped forestry, forests use and forest policies, and give rise to programs (IUFRO, 2015). Continuous forest policy reforms along with policy discourses, for instance, decentralization of forestry and SFM (chapter 2), and design and implementation of new financial incentives through different mechanisms including forest land allocation (FLA) are crucial steps to place forests at the base of green economy. Implementation of Five Million Hectare Reforestation Program (5MHRP), initiation of forest certification, implementation of payment for environmental services (PES) schemes, introduction of forest law enforcement, governance and trade (FLEGT) and participation in REDD+ are major initiatives the government has delivered in line to green economy. Vietnam has already moved into Phase II of its' REDD readiness and is currently preparing emission reductions program (ER Program) for carbon fund of the FCPF (chapter 2).

'*Paper reforms that legislate but do not implement, are always a possibility*' (Rudel, 2008). Impacts of the discourse on household-based forestry, livelihoods of forest dependent communities and participatory governance are still not clear (IUFRO, 2015). Prior to implementation of REDD+ within a jurisdiction, enabling conditions ensuring the ignored supply-side issues (section 1.3.1), should be in place. Though much progress has been made in REDD+ technical capital and capacity building at country level, it is yet to achieve at landscape level. Enhanced local legitimacy and capacity building tends to increase feasibility, i.e., political realism of the REDD+.

A core precept of REDD+ is that actions to protect forests need to be in response to the proven threats, and those actions must be additional (ISU, 2015). The additionality meaning REDD+ activities do not replace actions that are already being undertaken. Geist and Lambin (2002) indicated abrupt policy shifts might lead to further forest degradation and deforestation. REDD+ should not be politically costly, instead should favor concurrent policies. This implies REDD+ is used as an opportunity to support and promote prevailing and well-functioning forestry development policies, programs and incentives. In this background, the present study assumes:

Coherent forest development policies and programs, local legitimacy, and local peoples' positive perceptions towards forest management and positive attitudes towards forest land allocation and REDD+ are initial preconditions for viable jurisdictional REDD+ implementation.

1.3.3 Thesis aims and objectives

The overall goal of the thesis is to assess viability of jurisdictional REDD+ implementation (JRI) in North Vietnam. To meet the goal, the following objectives were formulated:

1. To assess technical feasibility of jurisdictional REDD+ implementation by exploring potential REDD+ activities;
2. To investigate operational feasibility of jurisdictional REDD+ implementation;
3. To evaluate whether existing forest management practices are financially viable for jurisdictional REDD+ implementation; and
4. To explore whether national policy and REDD+ institutional arrangements supports jurisdictional REDD+ implementation.

1.3.4 Implications of the study

Vietnam supports a national framework for its ultimate domestic REDD+ approach, and is exploring possibility of nested REDD+ approaches for establishing voluntary carbon markets, regulating REDD+ project-based investments, and maintain environment integrity (To et al., 2012). The country is one of leading southeast Asian countries in REDD+ institutional development, however, sub-national/ jurisdictional implementation of REDD+ is still a challenge in the country (Eickhoff et al., 2014). The study assesses technical, operational, financial, and political viability of jurisdictional REDD+ in North Vietnam.

The study provides an understanding of potentials to integrate REDD+ activities with concomitant forest development policies. It demonstrates required interventions to address REDD+ supply side issues, to enhance operational and political realism of REDD+ mechanism at operational level. Specifically, the study provides insights of potentials and need of inclusion of household-based forestry through jurisdictional implementation of REDD+. Household-based forestry is one of major forest management regimes (chapter 2) in the country and, however, receiving inadequate attention in REDD+ mechanism. Potentials of participation of the small forest-holder households (small-holders) in REDD+ are many. Firstly, this redresses weakness of 'forest frontier approach' of REDD+. Secondly, this may increase legitimacy and social inclusiveness of REDD+ program. Third, mitigating adverse impacts of climate change while improving forest-dependent livelihoods, the goals of green economy and multi-objective REDD+, might be achieved through the involvement of the small-holders.

In accordance with National REDD+ Action Plan 2011-2020 (NRAP), national RL/RELs[11] will principally be aggregates of sub-national RELs. With support from Phase II UN-REDD Program, the government establishes National REDD+ Information System and REDD+ National Forest Monitoring System. A phased MRV system will be designed as a function of the monitoring system. The MRV includes three major elements including activity data, emission factor and REDD+ GHG inventory. In this context, the present study provides information about forest/land-use categories (conversion of forest to non-forest, forests reaming as forests, and conversion of non-forest to forest) and suggests potential REDD+ activities to be considered while establishing such jurisdiction-wise (provincial) RELs. The study provides data on soil organic carbon, litter and understorey carbon pools which are currently scarce, and can be used while developing the MRV system.

REDD+ benefit distribution system is being discussed and is under preparation. The distribution system guides provincial REDD+ staff to distribute REDD+ revenues (gross REDD+ revenue minus implementation and opportunity costs, incurred by the provincial government) to district REDD+ fund or for disbursement to ultimate beneficiaries. Present study undertook socio-economic study to define costs of and benefits from forest management. The study estimated household incomes (gross) from forest products and forestry activities in the study area. The household income indicates opportunity costs of REDD+ to the household in the area. The information might be useful to establish socio-economic baseline for provincial REDD+ programs.

1.4 Structure of the thesis

The thesis consists of nine chapters. Chapter one provides overview of tropical forest and its role to mitigate climate change, theoretical background of the research and describes REDD+ evolution. It also comprises scope, assumptions, objectives and implications of the study and thesis structure. Country context is dealt in chapter two in two-fold: historical context of forestry and present status of forests in Vietnam; and REDD+ in the contexts of country's targets on forest protection development and GHG emission reductions. This chapter also updates REDD+ readiness of the country and describes forest policies and programmes relevant to the study area. Chapter three is about methodology and includes a brief characterization of the study area, provides research framework, and describes methods used for data collection, data handling and analysis. Chapter four, five, six and seven contain results of the study. Chapter four encompasses findings of forest inventory. Chapter five deals with historical land use/land cover change in the study area. Using part of the findings from chapter four, the chapter identifies potential REDD+ activities. Chapter six presents and discusses perception, understanding and attitude of forest owners towards forest management practices, forest land allocation and REDD+. Outcomes of assessment of economic viability of forest management are presented and discussed in chapter seven. Chapter eight provides an overview of findings from the previous four (result) chapters, and assesses technical, operational, economic and political viability of jurisdictional REDD+ implementation. The final chapter draws overall conclusion of the study and discusses outlook for relevant research area.

[11] The RELs are the amount of gross emissions emitted into the atmosphere from deforestation and forest degradation at a reference time period, or the baseline reflecting the change of emission levels at different time periods in the past and predicting the future trends of emission (GSRV, 2012b).

2 Country context

2.1 Country overview

Socialist Republic of Vietnam, a south-east Asian nation, has one of the fastest growing economies in the region. Vietnam has an area of approximately 331,000 square km (MONRE, 2010). The country is mountainous in Northwest and in Central Highlands. Two-third of mainland territorial area is covered by hills, highlands or high mountains. Elevation generally decreases from north to south. Vietnam features monsoon tropical climate with annual mean temperature varying from 13^0C to 28^0C (*ibid.*). For the period of 2002 to 2009, average annual rainfall was 1893 mm. Vietnam has dense river network of 2360 rivers and streams.

Figure 2.1 Location of Vietnam.

In 2012, estimated population was 90.8 million with an annual growth of 1% (2010-2015) (United Nations, 2014c). Gross domestic products and gross national income were US$1716 and US$1641 per capita respectively. There are more than 54 ethnic minorities in the country.

After decades of war against colonial powers, the country became unified once more in 1975. Vietnam is a one-party communist state. State governance system has four levels: national, provincial, district and commune. Vietnam consists of 59 provinces, 5 municipalities, 565 districts and 10,511 communes.

Major natural resources consist of coal, phosphates, manganese, bauxite, chromate, offshore oil and gas deposits, forest and hydropower. Major agricultural products are paddy rice, coffee, fish, seafood, rubber, cotton, tea, pepper, soybean, cashew, sugarcane, peanut, banana, and poultry. Major land use types (2010) are forestry land (46%), agricultural land (31%), non-agricultural land (11%), unused land (10%) and aqua-cultural land (2%) (VNFOREST, 2013).

2.2 Forests and forestry in Vietnam

2.2.1 Forest policy discourse

History of forest policy discourse in Vietnam shows different trajectories after independence of the country. From state-led '*command and control*' discourse (until 1975) to introduction of green economy and REDD+ (2010), Vietnam's forest policy has undergone radical reform. The state forestry was based on principles of centralized state forest management and forest exploitation (Arts and Buizer, 2009). From 1960's through 1980's, the policy bolstered Vietnam's economy by accelerating exploitation of natural forests at a rate that resulted in a rapid decline in forest resources (Sikor, 1998). Selective harvesting of timber species with high economic value beyond biomass growth (annual allowable cut) and removal of inferior or lesser known tree species to improve forest condition resulted in persistent forest degradation and biodiversity loss. In addition, war, infrastructure development, illegal harvesting, forest fire, waste dumping and mining accelerated deforestation and forest degradation (section 2.2.3).

Poor management capacity of forestry sector and a deficient institutional and legal framework failed to abate the ferocious loss of natural forests (UNFF, 2005; De Jong et al., 2006). By late 1980s, Vietnam's economy was in serious crisis and Vietnam's forestry was not freed from the crisis (Phung, 2008). In 1992, the government imposed logging ban that led to financial crisis in most state forest enterprises and to a collapse of centralized state forest management (Sikor, 1998).

The *Doi Moi*,[12] economic renovation policy in 1986, served as back drop for forestry reform and facilitated discourses of socialization and sustainable forest management (SFM) (Arts and Buizer, 2009; Dang et al., 2012). The concepts of forestry socialization and SFM were institutionalized in 'Vietnam General Forestry Development Plan' (1990), the Law on Forest Protection and Development 1991 (LFPD) and the Law on Land 1993. The Law on Land regulates allocation of (agriculture, non-agriculture and unused) land to households, communities and organizations, and rights and obligations of the land users (GSRV, 2003). The LFPD (revised in 2004) legalized the state to allocate forests and forest lands to establish forest plantations to the users including households to protect, develop and use for long-term purposes (Arts and Buizer, 2009). The logging ban (in 1992) and the new classification of forests provided the context for execution of national forestry programs such as Program 327 (Dang et al., 2012) and Five Million Hectare Reforestation Program (5MHRP).

Until 1990s, SFM was predominantly interpreted as ecological sustainability, and forest rehabilitation was focused mainly on protection of natural forests (Dang et al., 2012). From researchers and policy makers, SFM received resounding criticism: conservation oriented, focused on expansion and strict-management of Special use forests, increasing protected areas but declining species and ecosystem biodiversity, not considering socio-economic factor, ignoring people's traditional rights and removing people from protected areas, and not addressing livelihoods of forest dependent people. Vietnam has shown to be nimble and responsive to those criticisms. The government introduced community forestry in 2005. Vietnam Forest Development Strategy 2006-2020 includes missing social and economic aspects as part of the SFM (Dang et al., 2012). Vietnam recognized green growth as a key pillar of its' sustainable development strategy for 2011-2020, which aims to ensure efficient and sustainable growth while addressing and mitigating climate change impacts (GSRV, 2012b). Strategic Orientation for Sustainable Development in Vietnam (Prime Minister Decision No. 153/2004/QD-TTg) identified 19 priority areas for its implementation. Forest protection and development, biodiversity conservation and implementation of measures aimed at mitigating climate change are three prioritized areas among the 19 (GSRV, 2012b).

Since midst of 2000s, integration of the economic and social perspective/purpose into management of Special use and Protection forests became a key issue in discussions among policy/decision makers, government officials, concerned ministries, forest sector support partners, scientific communities and researchers. One of the momentous outcomes of the persistent discussions might be the explosion of interests in REDD+ in 2008. Vietnam is one of the few countries now preparing Emission Reductions Program (ER Program).

[12] A political and economic renewal campaign that introduced reforms intended to facilitate the transition from a centralized economy to a 'socialist-oriented market economy'.

2.2.2 Current forest status

In 2011, Vietnam had a total forest area of 13.51 million ha with a forest cover rate[13] of 41%. Natural forests occupied 10.28 million ha (76%) and planted forests covered 3.23 million ha (24%) (VNFOREST, 2013).

The Law on Forest Protection and Development, and the Ministry of Agriculture and Rural Development (MARD) (Circular No. 34/2009/TT-BNNPTNT) classified forests according to designated ecological functions and use purposes into three categories: Special use forest, Protection forest and Production forest (GSRV, 2004; MARD, 2009; Dang et al., 2012). Table 2.1 shows forest area occupied by the forest categories in 2011.

Table 2.1 Forest area according to forest types classified based on designated ecological functions in Vietnam. Each type is represented with forest area (in 2011), proportion of the area to the total forest area in the country and designated ecological functions of the forests.

Forest type	Area (million ha)	% of the total forest area	Designated function
Special use	2.01	15	Nature conservation, protection of historical and cultural relics, tourism and environmental protection
Protection	4.64	35	Protection of water streams and soils, prevention of soil erosion and natural disaster mitigation
Production	6.68	50	Timber and NTFPs supply and environmental protection

Source: GSRV, 2004; De Jong et al., 2006; MARD, 2009; VNFOREST, 2013

In 2011, the state owned majority of the total forest area, though, a significant proportion of the forest area (26%) was allocated to individual households (Fig. 2.2). Commune people's committees owned 16% of the total forest area which will be gradually handed over to other users, particularly to the households.

Vietnam's diverse climate and geography explain its diversity of natural forest formations and forest ecosystems. Figure 2.3 shows the forest formations in Vietnam. Major forest ecosystems include tropical closed evergreen moist broadleaf rainforest, evergreen broad-leaved forest on limestone mountains, decidious broadleaved forest (dipterocarp open forest), mangrove forest, tropical closed semi-deciduous broad-leaved moist forest, natural coniferous forest, *Melalauca* forest, and bamboo forest ecosystems.

[13] Forest cover rate = $\frac{100\,(\text{area with forest} - \text{area with forest plantation} < 3\ years)}{(\text{total national land area})}$

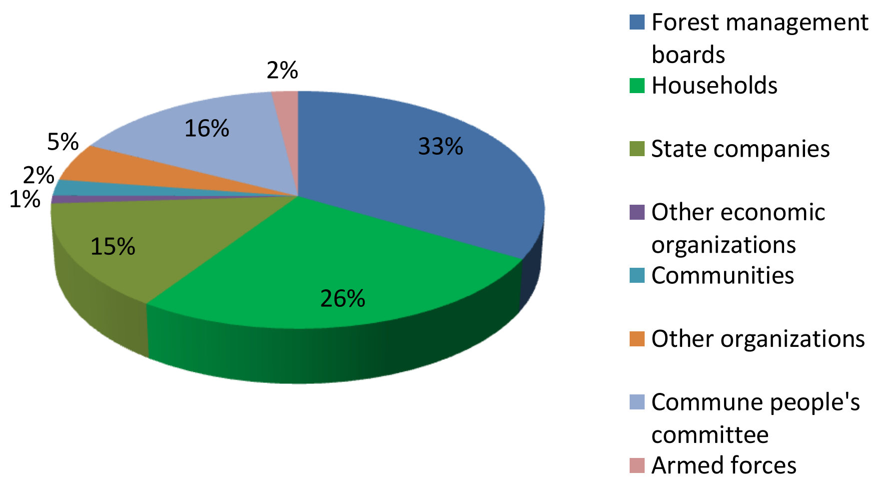

Figure 2.2 Ownership of forest area by forest users in Vietnam (2011).

Source: VNFOREST, 2013

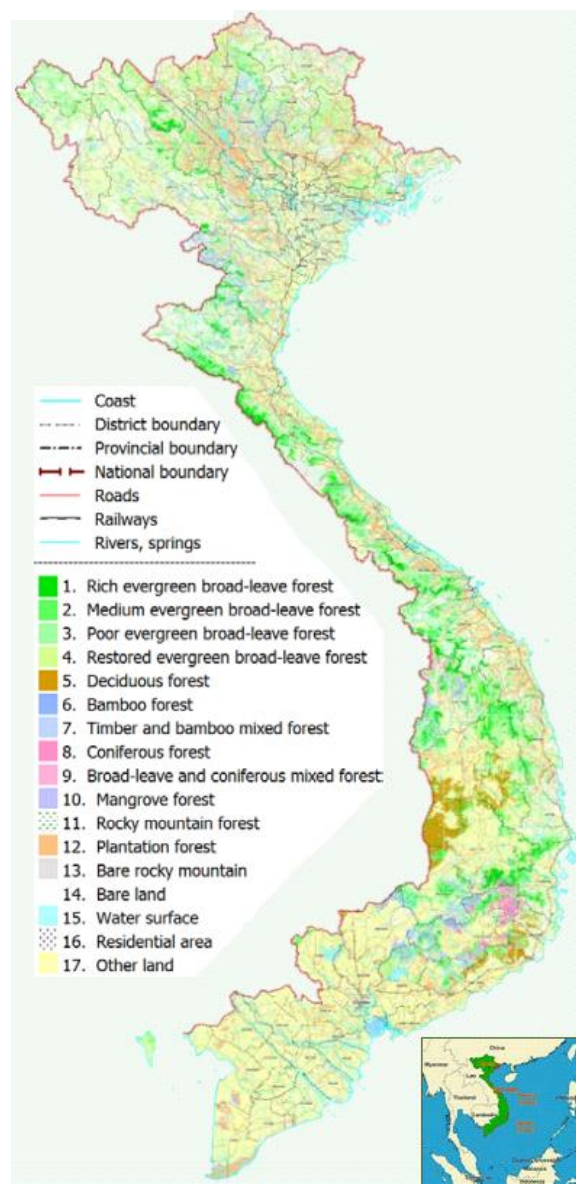

Figure 2.3 Land uses, forest formations and forest ecosystems in Vietnam (2011).

Source: VNFOREST, 2013

2.2.3 Forest rehabilitation in Vietnam

In 1943, the country had 14.3 million ha of forest area (UNFF, 2005; Nghia, 2007), which is 43% of the national land territory. The forest area decreased dramatically, especially during war time (1945-1954 and 1961-1975) and post war recovery period (1976-1985). In 1990, forest cover declined to 27.2% (9.18 million ha) (De Jong et al., 2006). Major direct causes for the rampant deforestation from 1943 to 1990 were: impacts of armed conflict, over exploitation of forests at the time of economic recovery, illegal logging, land conversion into farm land, shifting cultivation, conversion of forest land for national priority programs (aquaculture, national irrigation works, hydro power plants, transportation systems, plantations of agro-industrial crops such as coffee, cashew nut, rubber and tea), toxic chemical defoliants, and increasing demand for forest products. Poverty in rural areas, poorly defined land tenure, and lack of forest law enforcement underpinned the direct causes.

In order to deal with the alarming deforestation and forest degradation, the Government of Vietnam launched various reforestation programs. The major programs implemented by the government were PAM in period of 1976-2000 (United Nations World Food Program supported reforestation program), National Program for Upland Development from 1993 to 1998 (known as Program 327) and Five Million Hectares Reforestation Program from 1998 to 2010 (5MHRP) (also known as Program 661) (Hung, 2008). PAM through its' six forestry projects managed to restore 450,000 ha of production forest and scattered tree plantations and fruit orchards. Program 327 was focused on afforestation and reforestation of barren lands and hills including protection of existing forest areas, natural regeneration and plantations. The program succeeded to protect 1.6 million ha of forests (largely through contracting) and to restore 1.5 million ha of forest (through natural regeneration and industrial plantations) (Sam et al., 2004).

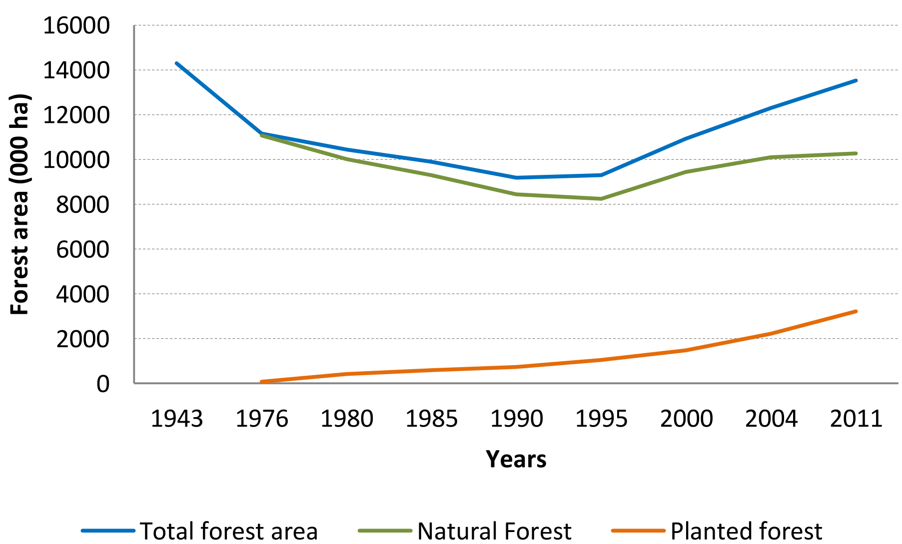

Figure 2.4 Vietnam's forest cover trend (1943 to 2011).
Data source: Nghia, 2007; VNFOREST, 2013

Program 661 (5MHRP) was implemented to establish three million ha of new plantations and two million ha of naturally regenerated forests by 2010. The ambitious reforestation efforts established Vietnam as one of the few countries in the world with increasing forest cover (Figure 2.4). The country experiencing serious forest cover change during second half of the 20th century, at present, is about to bring the forest cover back to the 1943 level (Sam et al., 2004).

2.3 Context of REDD+ in Vietnam

2.3.1 REDD+ in the context of climate change mitigation and forest management goals

Vietnam emits approximately 150 million tonnes (in 2000) of CO_2 equivalent in a year (MONRE, 2010), i.e., 1.7 tCO_2e per capita (United Nations, 2014c). However, the country is considered as one of very few countries in the world, hardest hit by climate change (GSRV, 2012b). The country has been facing serious climate stresses including mean temperature rises, changing rainfall patterns, drought and flooding, salinization and sea level rise (United Nations, 2014a). Growing evidences suggest Vietnam is one of the most vulnerable countries to the adverse effects of climate change and predicted to face increasing and intensifying extreme weather events in the coming decades. According to the Germanwatch Global Climate Risk Index, Vietnam was one (6th) of the top six countries[14] most affected by extreme weather events between 1993 to 2012 (Eckstein and Kreft 2013). The country is ranked 13th out of the 170 countries, deemed vulnerable to the impacts of climate change over the next 30 years and is one of the 16 'extreme risk' countries (United Nations, 2012). Along the Gulf of Tonkin, the South China Sea and the Gulf of Thailand, Vietnam's coastline measures 3444 km. About 7% of Vietnam's agriculture land may be submerged under sea water due to one meter sea level rise (IPCC, 2014b). With the sea level rise by 2100, damage to Vietnamese economy will be US$17 billion every year with 12% of coastal area submerged, and 23% of population in this area will be affected (GSRV, 2012b). Cumulative impacts of seasonal flooding increase outmigration rates in Mekong delta (IPCC, 2014a). To respond the climate change and its impacts, the government approved National Target Program to Respond to Climate Change (NTP-RCC) in 2008. Strategic objectives of the NTP-RCC are to assess climate change impacts on sectors and regions and to develop feasible action plans. Action plans are developed in such a way that they would; effectively respond to climate change in short and long-term, ensure sustainable development of Vietnam, take opportunities to develop towards a low carbon economy, and join international community's efforts in mitigating and responding to climate change (GSRV, 2008a). REDD+ is considered as a key component of the NTP-RCC.

In 2012, Vietnam approved Forest Protection and Development Plan 2011-2020 (FPDP), which aims at increasing forest cover to 45% (15.1 million ha) by 2020, and improve quality of natural forests and productivity of planted forests by 25% in 2020 compared with that in 2011 (GSRV, 2012a). To achieve the objectives, the FPDP specifies several tasks including: protection and development of 13.5 million ha existing forests, afforestation of 2.6 million ha, 0.75 million ha zoning for regeneration, rehabilitation of 0.35 million ha of severally degraded natural forests, and plantation of 500 million scattered trees (GSRV, 2012a; VNFOREST, 2013). REDD+ implementation in Vietnam aims, among others, to contribute for achieving the (two) ambitious national targets: to increase overall forest cover to 45%, and to reduce emissions from agricultural and rural development sector by 20%, by 2020 (GSRV, 2012c).

[14] Ranked 6th (1993-2012) with an overall Long-Term Climate Risk Index (CRI) of 24 following to Honduras, Myanmar, Haiti, Nicaragua and Bangladesh

2.3.2 REDD+ and REDD+ readiness

Vietnam is one of the pioneer countries to receive supports for REDD+ readiness from UN-REDD Program and FCPF. The country entered into REDD+ process through a submission to the UNFCCC secretariat, and submission of Readiness Plan Idea Note (R-PIN) to FCPF in 2008. Development of national REDD+ Readiness Plan (R-PP) - a roadmap detailing how Vietnam will develop a national REDD+ strategy to contribute to achieve country targets of forest development and emissions reductions - began in October 2010. The R-PP was approved in November 2011 by Policy Board of the FCPF. In 2010, MARD established National REDD+ Network and REDD+ Technical Working Group (TWG) to increase awareness of REDD+ and build capacity at national and local levels to coordinate activities by ministries, international agencies, and organizations (To et al., 2012). In January 2011, the government established a National REDD+ Steering Committee chaired by the MARD to coordinate all efforts and activities among government and non-government agencies and development partners at scales of REDD+ implementation. Vietnam REDD+ Office formed in January 2011 serves as standing office for the steering committee.

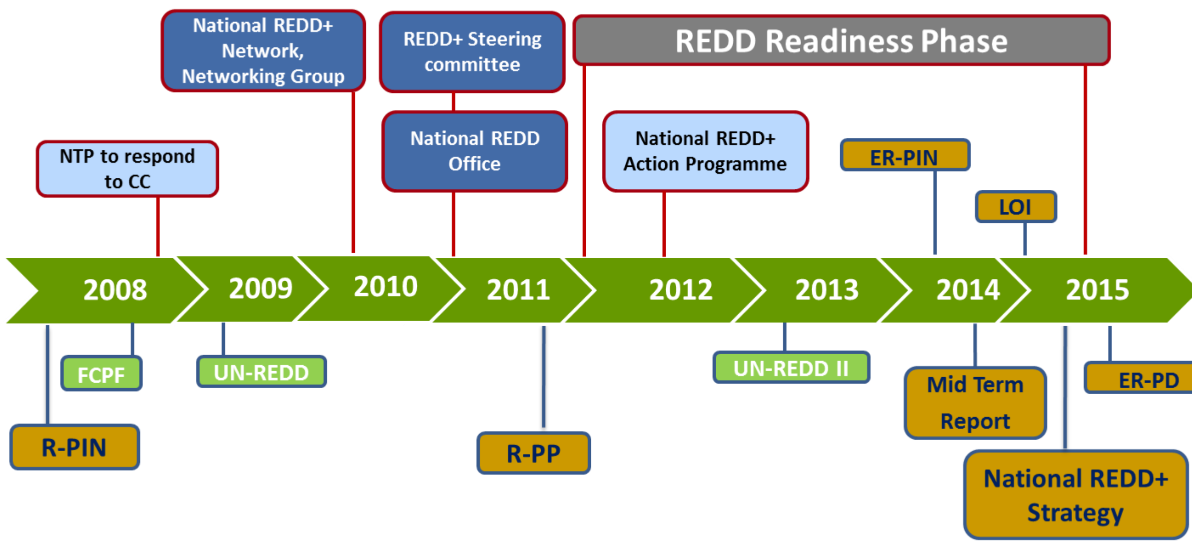

Figure 2.5 National REDD+ readiness landscape of Vietnam.

In June 2012, the government approved a National REDD+ Action Program 2011-2020 (NRAP) - major framework for REDD+ implementation. The NRAP is pursuant to national laws (Law on Forest Protection and Development 2004, Law on Land 2003) and strategies (National Strategy on Climate Change, National Forestry Development Strategy 2006-2020 (NFDS)); designed in accordance with national policies (PES of forests); in compliance with the NTP-RCC; and consistent to provisions of the UNFCCC, relevant treaties and international conventions (GSRV, 2012c). The NRAP has set ambitious and time-bound objectives (section 2.3.1) in line to the FPDP and NFDS. The country aims to decrease emissions in all economic sectors, and expects to demonstrate a 20% reduction of GHG emissions in agricultural sector, and a reduction of 19 million tonnes of CO_2 equivalent per decade through reduced deforestation and forest degradation (REDD Vietnam, 2015b). REDD+ is therefore an important component of Vietnam's climate change mitigation efforts, and is central to the National Climate Change Strategy.

In May 2014, Vietnam submitted its Emission Reductions Program Idea Note (ER-PIN) for a program - 'Sustainable Management of Forests through Low Emission Development Planning for Green Growth in the North Central Agro-Ecological Region' in Vietnam (ER Program) to carbon fund of the FCPF. In December 2014, a letter of intent (LOI) was signed between the country (MARD) and International Bank for Reconstruction and Development (IBRD) acting as trustee of the carbon fund. The letter of intent confirms principal terms of understanding about the interest of the IBRD in possible purchase of rights, title, and interest associated with GHG emission reductions (ERs) resulting from the ER Program described in the ER-PIN. According to the letter of intent, the IRBD and the FCPF purchase ten million and three hundred thousand (maximum) ERs.

Vietnam's REDD+ process benefits from the readiness initiatives of FCPF and UN-REDD; bilateral supports from the governments of Norway, Japan and Germany; and by various national and international organizations including Asian Development Bank (ADB), CARE international, Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ), Fauna and Flora International, Japan International Cooperation Agency, Lowering Emissions in Asia' Forests (USAID LEAF), Netherlands Development Organization (SNV), Research Centre for Forest Ecology and Environment, World Agroforestry Centre (ICRAF) and World Wide Fund for Nature (WWF). At the time of the research, the country was preparing its national REDD+ strategy and ER-Program Document (ER-PD) for the ER Program. Several stakeholders have been involved in development of the national REDD+ strategy. These consist of state and non-state stakeholders as described earlier. Strategic environment and social assessment for the NRAP, and environmental and social management framework for readiness package (R-Package) assessment were in progress, and expected to be completed within 2015. Figure 2.5 presents the REDD+ readiness landscape 2008-2015 of Vietnam.

2.3.3 Institutional arrangement for REDD+ implementation

Actors' interests and beliefs shape patterns of interactions, ranging from cooperation to conflict, and these interactions influence a country's direction and progress in REDD+ policy formulation and implementation (Brockhaus and Di Gregorio, 2014). Since REDD+ is a multi-governance and multi-layered approach involving multi-stakeholders, arrangements for its implementation should include institutions at scales and ensure effective coordination and interaction among the institutions. The country's institutional arrangement for REDD+ implementation constitutes a network of institutions at scales of REDD+ implementation from national to commune level.

National REDD+ Steering Committee is a cross-sectoral committee at policy-making level and includes representatives from government agencies including MONRE, Ministry of Planning and Investment, Ministry of Finance, Ministry of Science and Technology, Ministry of Foreign Affairs, and National Ethnic Committee. The REDD+ steering committee assists a national steering committee chaired by the Prime Minister for the NTP-RCC. National REDD+ Network is a multi-stakeholder network and chaired by Vietnam Administration of Forestry - one of key agencies of the MARD and is in charge of overall development of forestry sector in Vietnam. National REDD+ Network and Vietnam REDD+ Office are responsible entities at management and coordinating level. Under the TWG, there are six sub-Technical Working Groups (sub-TWG). They are: i) MRV, ii) REDD+ governance, iii) REDD+ financing and benefit distribution system, iv) Local implementation of REDD+, v) Private sector engagement, and vi)

Safeguards. The TWG and sub-TWGs assist operations of the network on technical and administrative aspects. The TWG, sub-TWG, Provincial REDD+ Taskforce, District REDD+ Taskforce, and commune foresters are working at implementation level. Figure 2.6 presents the institutional set-up for REDD+ implementation in Vietnam.

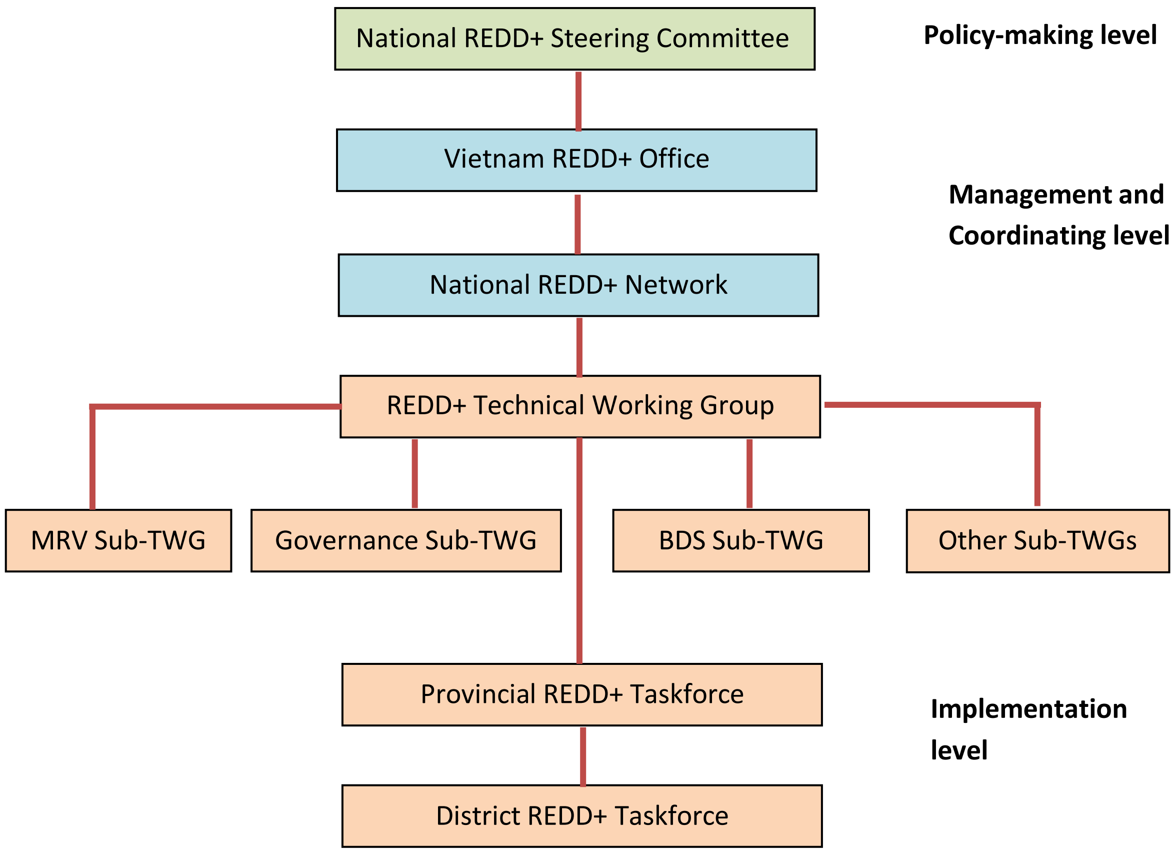

Figure 2.6 Institutional arrangements for REDD+ implementation in Vietnam.
Source: REDD Vietnam, 2015a

2.4 Forest policies relevant to forest and forestland management in Dinh Hoa district

Vietnam has promulgated a number of forest policies in the form of forest law, decrees, resolutions, decisions, regulations, circulars and ministerial guidance. Among them, Law on Forest Protection and Development (2004) (LFPD), Law on Land (2003), Government Resolution 01/CP (1995)[15], Government Resolution 02/CP[16], Prime Minister Decision 661/QD-TTg (1998)[17], Government Decree No. 163/1999/ND-CP[18], MARD Circular No. 56/1999/TT/BNN-KL (1999)[19], Prime Minister Decision No. 08/2001/QD-TTg (2001)[20], and Prime Minister Decision No. 178/2001/QD-TTg (2001)[21] are important and core forestry policies (Sam and Trung, 2003). Moreover, two circulars issued by the MARD -Circular 56/1999/TT/BNN-KL related to community forestry and Circular 99/2006/TT-BNN related to allocation of degraded natural forests are important footsteps to encourage participatory forestry in the country.

The LFPD 2004 and the Law on Land 2003 have gone through multiple revisions to comply with emergence of policy concepts on national economy, for example, *Doi Moi*, and forestry discourses, for instance, devolution and decentralisation of forestry and SFM. The LFPD, the Law on Land, Resolution 01/CP and Resolution 02/CP contain provisions of land allocation: allocating lands to households, individuals and organizations for long-term use and management for forestry, agriculture and aquaculture. The households are allowed to exercise a bundle of land-use rights (use, management, exchange, transfer, lease, inherit, and mortgage) over allocated agriculture land. However, the use rights are more restricted in case of forest lands, particularly of Special use and Protection forests. Though the laws provide title of 'forest owner' and land-use certificate, according to Vietnamese constitution, land/forest ownership belongs to the entire people and administered by the state. Forest lands are allocated for 50 years and land-use levies are exempted. The duration can be prolonged/renewed as long as the lands have been used for specified purpose by the laws, and the users (households) are interested to extend.

National Forest Development Strategy 2006-2020 targets to increase forest cover 47% by 2020 and to increase forestry sectors' contribution to national gross domestic product from 1% (in 2006) to 2-3% by 2020 (GSRV, 2007). The strategy recognizes natural forest protection as one of the main tasks not only to secure environmental stability but also to generate substantial revenue from environmental services. The strategy designated nearly half of Vietnam's forest areas as Protection and Special use forest for the period of 2006-2020 (Dang et al., 2012).

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[15] on the allocation and contracting of land for agriculture, forestry, and aquaculture production to state enterprises

[16] on the allocation of forest land to various sectoral economics for management and use for long-term and sustainable forestry development

[17] on the objectives, tasks, policies, and organizations for the establishment of five million hectares of new forest

[18] concerning allocation and lease of forest land to organizations, households, and individuals for long-term forestry purpose

[19] guiding the development of the regulations on forest protection and development to village/hamlets and communities

[20] issuing regulation on management rules of Special use forest, Protection forest, and Production forest

[21] on the rights and obligations of households/individuals allocated and contracted forest and forest land for benefit-sharing

In response to massive deforestation, Vietnam introduced Program 327 under Decision No. 327/1992/QD-TTG. The program aimed at reforesting barren lands, protection of remaining forests, and replacing slash-and-burn based shifting cultivation by more productive and intensive sedentary farming. The decree is the foundation for current activities designed to eliminate swidden (slash-and-burn) agriculture in central Viet Nam (Webb, 2008, p. 34).

The 5MHRP, formulated under Decision 661/1998/QD-TTg, aimed at gaining five million hectare forest cover through rehabilitation/restoration of degraded forest/bare land and afforestation. The program is mostly a continuation of its predecessor (Program 327). The program is incorporated into household forest land allocation program, the contemporary policy of which is Decision No. 178/2001/QD-TTg (Webb, 2008). In addition to the ambitious goal of establishing five million hectare of forests, the program aims at reducing poverty locally by increasing income sources of forest dependent people by creating employment opportunities in the mountainous areas. It also aims to increase forestry sector's contribution to national economy by strengthening forest-based enterprises and markets. Furthermore, the program embraces policies to compensate households and individuals for forest protection, to support for natural regeneration, forest plantations and management, and to provide soft-loans, and scientific research and forestry extension. Massive monoculture plantations established under the program, have been contributing to the increasing forest cover of the country. However, the massive plantations masked the continuing deforestation of natural forests.

Degraded forest land allocation policy was one of the cornerstones of the decentralization policies (Thiha, 2007b). Until 1999, only barren/unused lands, and forest plantations could be allocated to households. The policy was enacted by Decree163/1999/ND-CP in 1999. The decree authorizes the government to allocate and lease forest lands to the users including households for stable and long term forestry use/activities (UNFF, 2005). According to the decree, forest land refers to land with forest (natural forest or planted forest) or land with no forests, i.e., barren lands but planned for forestry purpose such as afforestation, marked off for restoration, and rehabilitation of tree cover (Article 3). Article 4 of the decree states the state shall assign forest land without collecting land use levy to households who are directly engaged in forestry, agriculture and fishery activities that generate major source of income for their livelihood.

Decision no 178/2001/QD-TTG (in 2001) illustrates benefits to and obligations of households to the forests and forest lands allocated, leased or contracted to them. According to the decision, households' access to and use rights over the different forest types (Special use, Protection, and Production) differs considerably.

In 2003, natural forest land allocation policy was enacted. The policy allowed provincial government to withdraw some natural forests from state forest enterprise (SFE) management and allocate the forests to households and communities (Thiha, 2007b). The policy further decentralized forest management responsibility to provincial government as the implementing agency of the natural forest land allocation. In 2006, the MARD issued Circular 99/TT-BNN which allows the forest management boards to allocate the (severely) degraded natural forests to households and local communities.

In 2008, Vietnam issued regulation No. 30a/2008/NQ-CP on the implementation of a support program for fast and sustainable poverty reduction in 61 poor districts of 20 provinces. Those districts were characterized by mountainous region with little cultivated lands and poor infrastructure development, unfavorable weather conditions, over 90% of population of ethnic minority people practicing subsistence agriculture, and low income (< US$100/person/year). Dinh Hoa was one of the districts selected for the program. The program targets to reduce poverty rate to the provincial average by 2015 and to the regional average by 2020 of the respective districts. The program comprised of interdisciplinary activities: forest land allocation, forest protection and development including forest plantation, agro-forestry, modernization/mechanization and commoditization of agriculture, rural infrastructure development, activities designated to vulnerability of ethnic monitories and other rural people, and generate more green jobs for local people to raise their income.

In 2008, Decision No. 1134/QD-TTg approved the Scheme on Forest Protection and Development in Dinh Hoa Safety Zone, Thai Nguyen Province (ATK Scheme) (GSRV, 2008b). Since 2008, Dinh Hoa District People's Committee has been managing the ATK Scheme for sustainable management of forests in the district. Besides SFM, the scheme aims to create more jobs and contribute to enhanced living standards of ethnic minority people residing in the district. Between 2008 and 2020, the scheme aims to increase forest area of the district by 12000 ha and plans to have approximately 36000 ha of forests by 2020. To achieve the goals, the scheme specified several forest protection and development oriented tasks: protection of existing/recovered forests, restoration of degraded forest lands through assisted natural regeneration (ANR), Afforestation and reforestation (A/R), and enrichment planting.

3 Methodology

3.1 Study area

The study was conducted in Dinh Hoa district of Thai Nguyen province,[22] Vietnam. The mountainous district[23] lies in northeast region (Đông Bắc)[24] of Vietnam and has 23 communes and one town. Agriculture and forestry are major land uses. The district has inhabitants of 25000 households and is deeply poverty stricken. Nearly 57% of the total households are poor[25] earning less than US$1 per day in average (Thai Nguyen Statistics Office, 2014). The district is heavily degraded due to unsustainable agricultural practices (such as, slash-and-burn) and over-exploitation of forest resources in the past. Though, most of the natural forests are severely degraded and lack tree species of high economic value, they are rich in tree species diversity, bamboos and palms diversity. Major tree species in natural forests are *Manglietia conifera*, *Vernicia montana, Styrax tonkinensis*, *Macaranga denticulate, Melia azedarach* and *Ficus* species. Planted forests mostly consist of tropical 'fastwood' such as acacia and eucalypts.

In the district, process of forest land allocation to households was started in 1992 to achieve two objectives: poverty reduction and forest protection/restoration. Table 3.1 describes the study area presenting major characteristics.

Table 3.1 Characteristics of the study area.

Feature/characteristic	Description
Latitude	21^0 45' to 22^0 30 N
Longitude	$105^0$2 9' to 105^0 43' E
Total area	516.43 km^2
Altitude	75-851 m as
Physiography	Higher mountain zone and Lower mountain zone; Small valleys between Limestone Mountains and other hilly areas
Geilogy, Rock and Soil	Decaying magma, sedimentary and calcareous rocks
Soil types	Luvic calcisoles, acrisoles, rhoddic ferralsols and dystric fluvisols
Climate	Tropical
Average annual temperature	22.5 ^oC
Average annual rainfall	1750 mm/year
Total forest area (2013)	30826 ha.
Forest types (natural forest)	Tropical moist forests
Agriculture and Livestock	Crops: paddy, maize, tea, cassava, sweet potato, Livestock: buffalo, cattle, pig, poultry, chicken, goat, horse
Total households (2013)	24944
Population (2013)	87885 (93% rural), (170 person/ km^2)
Ethnicity	Tay, Kinh, San Chay, Nung, Dao, San Diu, Hoa, and Hmong

[22] Thai Nguyen is a mountainous and midland province, and is divided into one city, one town and seven districts.
[23] Vietnam encompasses 64 provinces which are divided into 565 districts.
[24] Vietnam is divided into eight regions. Northeast region contains 11 provinces.
[25] Poor households have average yearly income of ≤US$229 (rural area) and of ≤US$286 (urban area); Near poor households have average yearly income of US$229-US$286 (rural area) and of US$286- US$371 (urban area).

The rationale for selecting that particular district was from previous working experience in the area. World Forestry, University of Hamburg and Thai Nguyen University, Thai Nguyen, Vietnam have been jointly carried out several scientific studies related to forest management in the district since 2007. Among the 23 communes in the district, six communes were selected to carry out the study (Figure 3.1). Communes were selected in a way that each of the communes share a common (forest) land tenure system. Other sub-ordinate criteria were:

1. Communes consisting of particular forest types- according to designated ecological function (Special use forest, Protection forest and Production forest), and method of regeneration (natural forest and planted forest);
2. Forest structure and vegetation composition of natural forests;
3. Communes where forest land allocation has been undertaken at least 15 years ago; and
4. Communes representing districts' geographical and altitudinal variation.

3.2 Research framework

The viability of REDD+ implementation at jurisdictional level was assessed as a combination of four aspects: technical, operational, financial and political; which is analogous to the factors used by Eickhoff et al. (2014). Several research questions were formulated to address issues associated with the four mentioned aspects. Research framework of the study is shown in Figure 3.2.

The study uses multiple methods and analytical techniques and adopted both quantitative and qualitative approaches. A ground-based forest inventory or field measurement approach was used (section 3.3) to estimate carbon density across different carbon pools and forest types. Traditional remote sensing and geographic information systems techniques combined with a narrative approach of policy analysis (Thiha, 2007b) was used to assess 1993-2010 forest cover change (section 3.4). Based on findings of the forest inventory and the forest cover change analysis, technically feasible REDD+ activities were identified. The study used household survey and personal observation (section 3.5) to understand households' perceptions towards forest management practices, to explore households' attitudes towards forest land allocation and REDD+, and to assess local stakeholders' willingness to participate in and capacity to implement REDD+. Impacts of forest management practices and forest land allocation on local livelihoods were assessed using information collected during the survey. Economic viability of existing forest management, particularly collection of information of costs of and benefits from natural and planted forests, was done by conducting a household survey. The financial viability was assessed using benefit-cost ratio and net present value (section 3.6). A rigorous review of national policy and polity set up, and REDD+ related documents and institutional arrangements was conducted to explore whether the national policy and REDD+ institutional arrangements support jurisdictional implementation of REDD+.

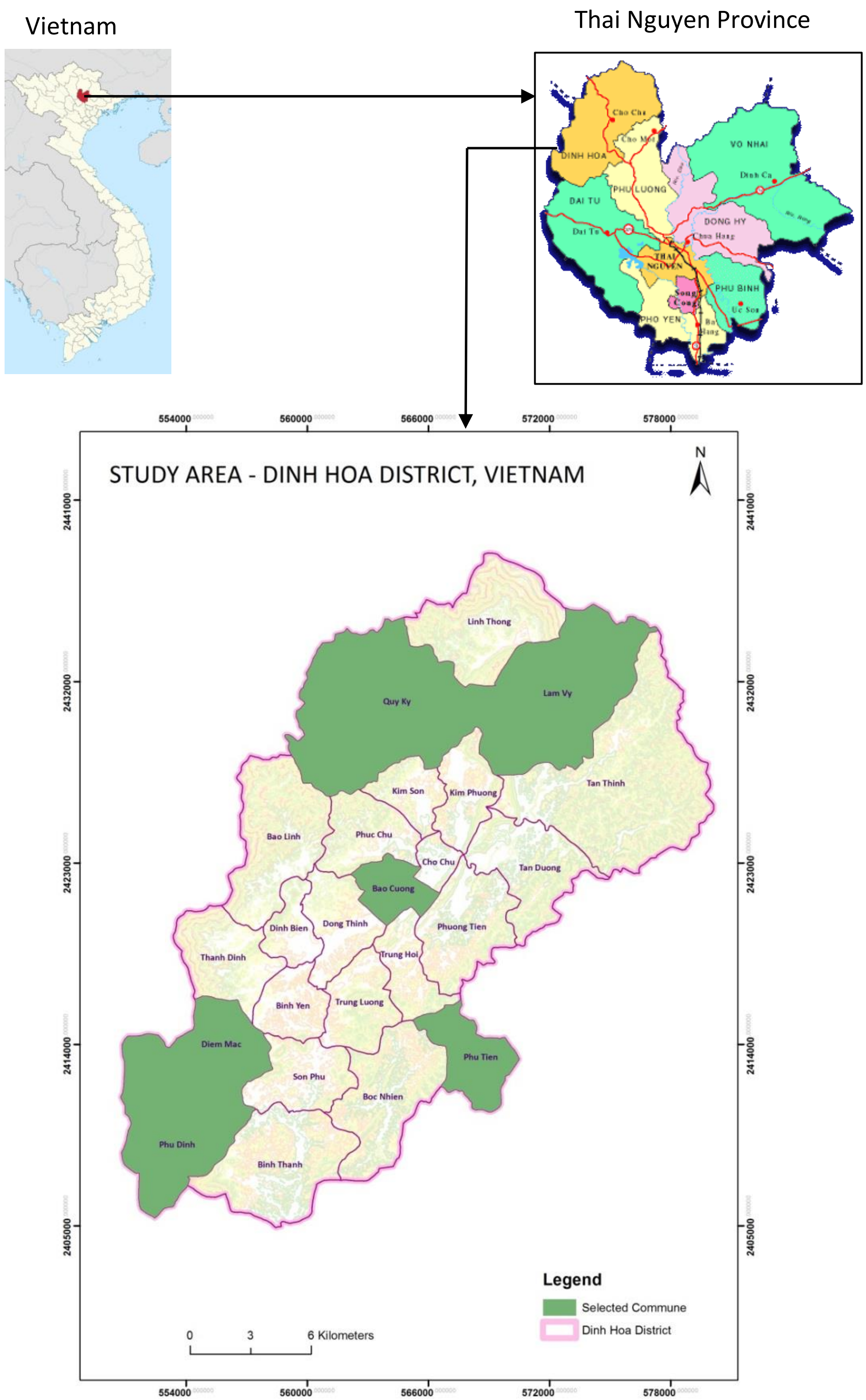


Figure 3.1 Map showing the study area.

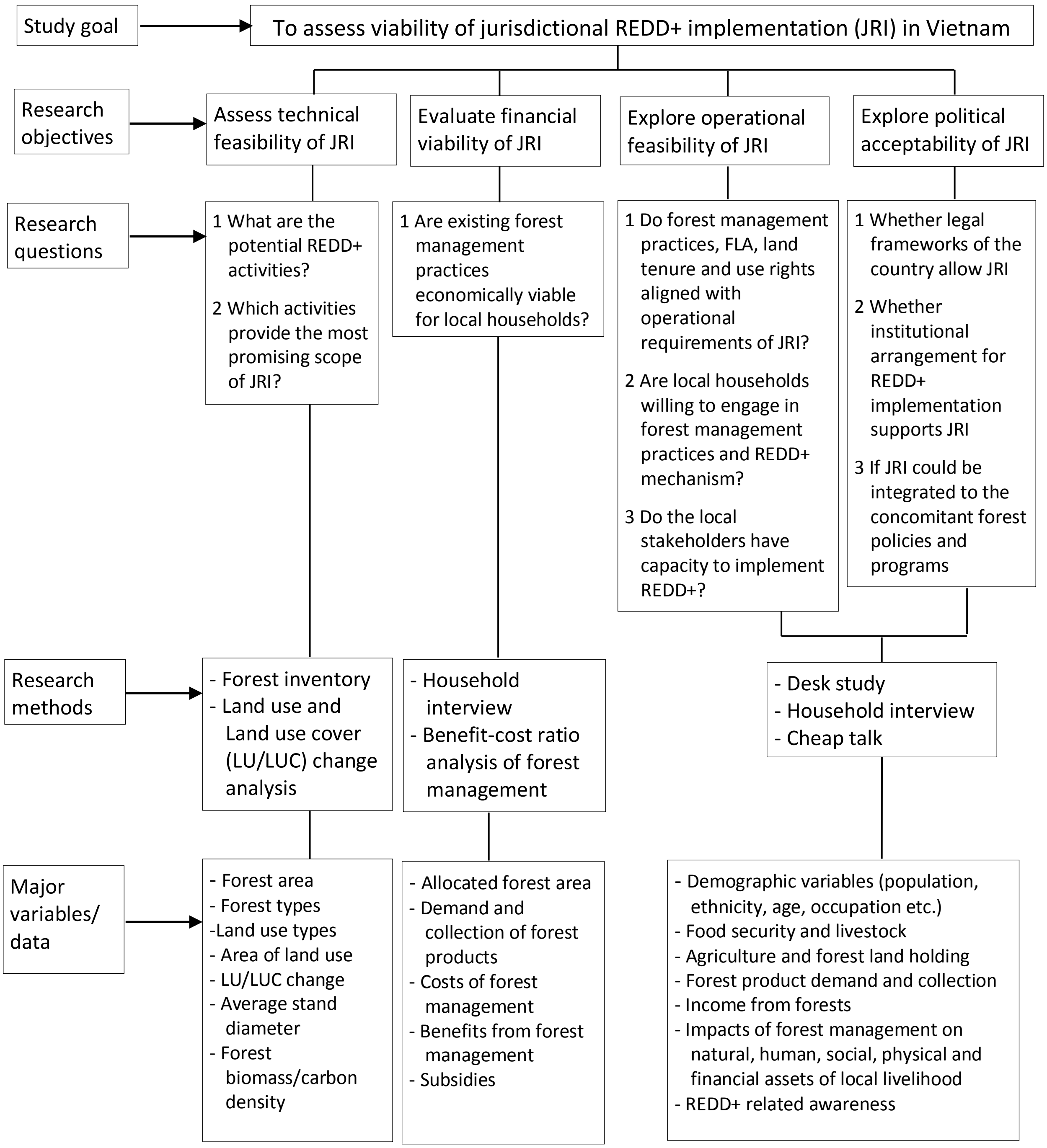


Figure 3.2 Research framework.

3.3 Forest inventory

Forest inventory is a process for obtaining information on quality and quantity of forest resources (Köhl et al., 2006). In order to assess wood production (standing volume, accessibility, structure), biodiversity (tree species diversity), pasturage (traces of other use, game damage), protective functions (such as, evidence of surface erosions, stand density, evidence of rock fall) and forest carbon stocks, forest inventory was conducted in the study area in 2011. The inventory task commenced with managing administrative and logistics requirements. District Peoples' Committee and Commune Peoples' Committees (CPCs) were visited and informed about the inventory objectives, and permissions of accessing forests in the communes were collected from the committees.

3.3.1 Sampling design

3.3.1.1 Sample size

A pilot inventory was conducted to estimate variance of a leading variable (basal area), which was used as a basis for calculating the number of sample plots required for forest inventory. The pilot inventory included 68 randomly selected sample points in the six communes and adopted angle count sampling method, to estimate basal area per ha for each sample point. The pilot inventory calculated coefficient of variation for mean basal area to be 45.83%. Required number of sample plots for forest inventory was estimated using an equation suggested by Avery and Burkhart (2001) as following:

$$n = [\frac{(t)(cv)}{A}]^2 \qquad \text{Equation 3.1}$$

where, n = number of samples, t = t value at the desired confidence interval and appropriate degrees of freedom (df), cv = coefficient of variation, and A = allowable error.

Based on the cv, 81 sample points were needed for all communes for forest inventory. Avery and Burkhart (2001) suggested to use ≥ 30 sample plots in natural timber stands for reliable estimates. Larger samples will invariably result in greater statistical confidence (Fowler et al., 1998). The sample size was increased more than two times to ensure that each forest type receives more than 30 sample plots. Table 3.2 presents the distribution of sample plots to different forest types and communes. The number of allocated sample plots to each commune was proportional to the forest area each commune contains.

Table 3.2 Distribution of sample plots in different forest types and communes.

Classification of forests	Forest types	Total no. of sample plots	No. of sample plots in different communes					
			Quy ky	Phu Tien	Phu Dinh	Bao Cuong	Lam Vi	Diem Mac
Designated ecological function	Special use forest	60	10		28	3	1	18
	Protection forest	59	44				15	
	Production forest	81	7	27	11	13	22	1
Method of regeneration	Natural forest	150	47	13	30	14	33	13
	Planted forest	50	14	14	9	2	5	6
Total no. of sample plots		200	61	27	39	16	38	19

3.3.1.2 Preparation of forest inventory maps

District forest cover maps were prepared according to forest types: Special use, Protection and Production forests; and natural and planted forests (Annex 1). This was mainly done by query and grouping same attributes of forest status using ArcGIS Toolbox (ArcGIS 9.3). Digital elevation model (DEM) and soil map were prepared for the district (Annex 1). The maps and the model were used as input variables to select study area considering multi-criteria: forest types, elevation and geographical representation. After selection of the study area (Bao Cuong, Diem Mac, Lam Vi, Phu Dinh, Phu Tien, and Quy Ky communes), forest inventory base maps were prepared for each commune. Figure 3.3 describes procedure of forest inventory map preparation and Figure 3.4 shows forest inventory base maps prepared for each commune.

Spatial data, which includes background data and thematic maps, of the district were obtained from two sources. Background data were gathered from Centre of Data and Information of MONRE, Hanoi. The data were in the Micro station (.dgn) and .mapInfo formats. Thematic maps such as land use and soil type were collected from Department of Agriculture and Rural Development, Thai Nguyen (DARD) in mapinfo (.tab). Those data were projected in VN2000 projection. Before the projection, data were converted to a common format, ESRI shape file. The data were standardized following government degree 17/2010/TT-BTNMT.

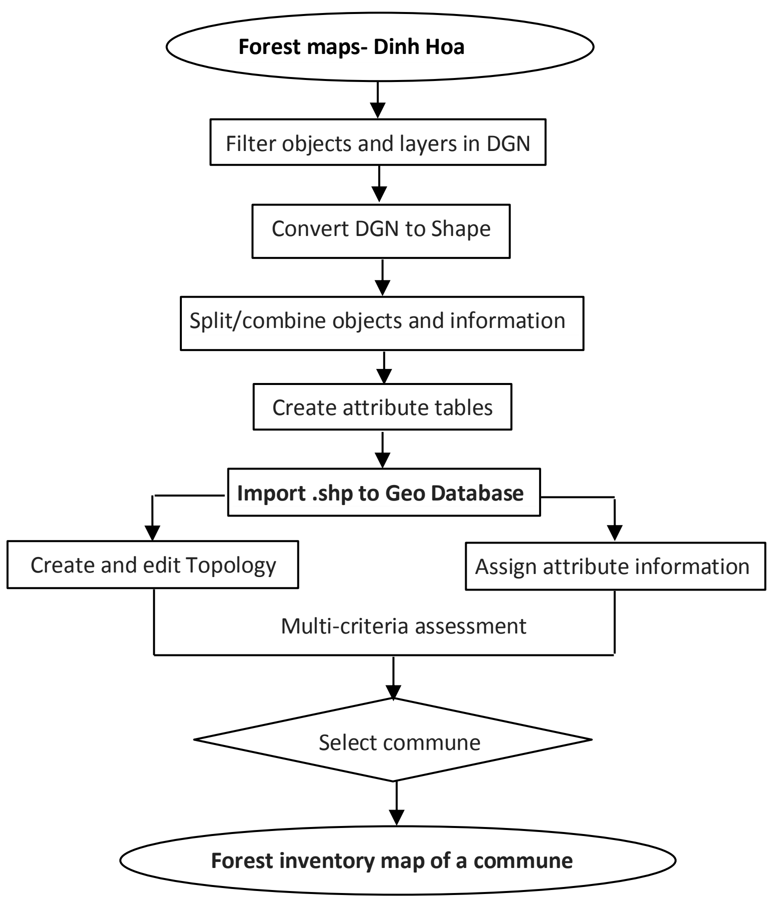
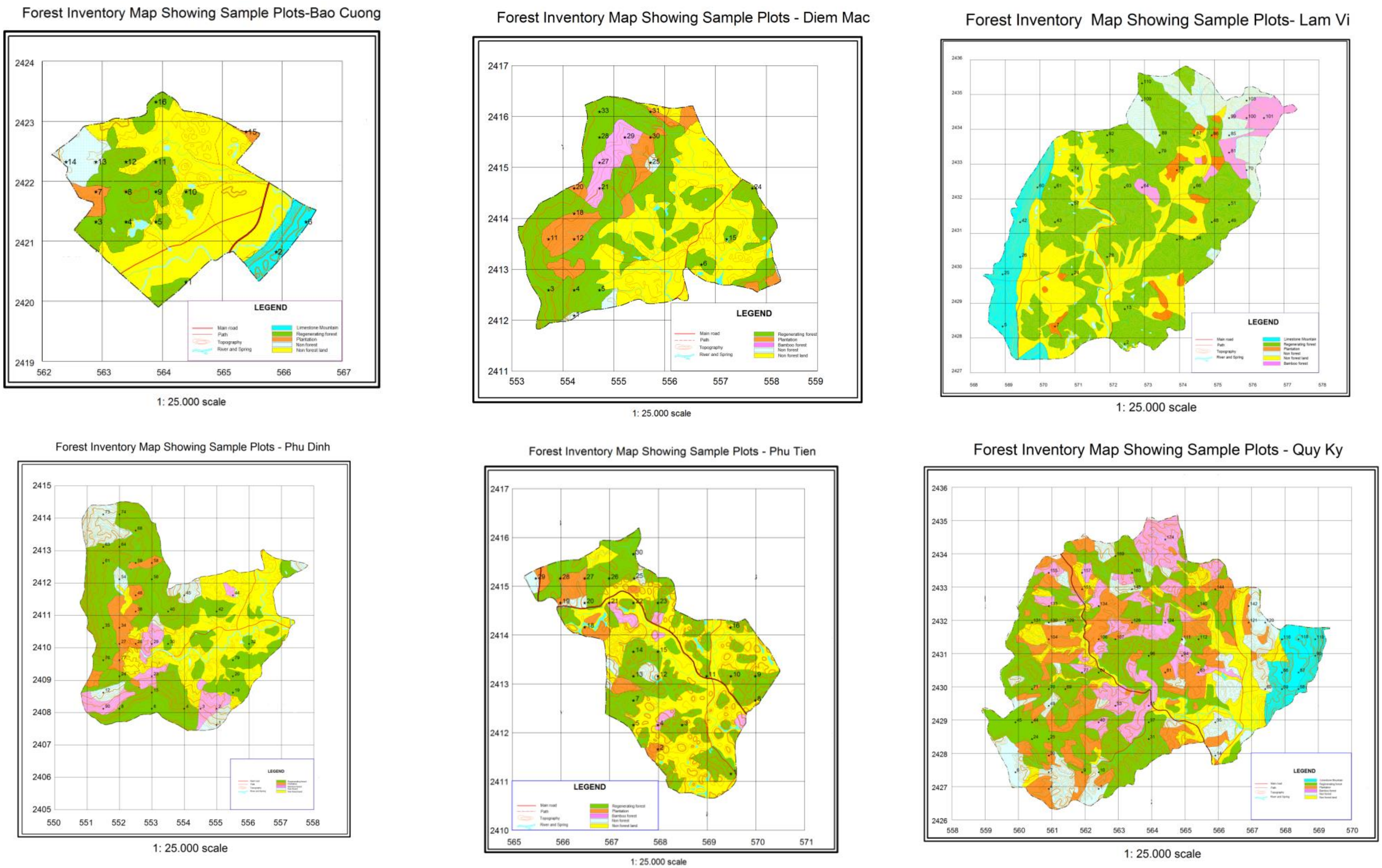


Figure 3.3 Procedures of the preparation of forest inventory base maps for the selected communes.



Limestone forest ☐ Regenerating forest ☐ Planted forest ☐ Bamboo forest ☐ Non-forest ☐ Non forest land ☐

Figure 3.4 Forest inventory base maps showing assessed inventory sample plots in the selected communes of Dinh Hoa district.

3.3.1.3 Locating sample plots on forest inventory maps

Grid of 0.5 Km x 0.5 Km grid was superimposed with reference to a randomly chosen transect (grid-starting) point on the land use map (section 3.3.1.1) consisting of all selected commune boundaries. Altogether, 448 grid cells were generated inside the forest area of the communes (Table 3.3).

Table 3.3 Distribution of the total sample plots in selected communes under study.

	Communes						
	Quy Ky	Phu Tien	Phu Dinh	Bao Cuong	Lam Vi	Diem Mac	Total plots
Natural forests	133	24	72	14	111	25	379
Planted forests	43	5	8	2	3	8	69
Total number of	176	29	80	16	114	33	448

Each intersection of grid coordinates that lies inside forest area of each commune was assigned a unique number (1). All the points were marked by asterisks and numbered systematically. An attribute table constituting plot serial number, plot ID, forest types (by designated ecological function and by mode of forest origin), soil type, latitude, longitude and elevation for each point (plot) was extracted from the maps. Number of the plots ranged from 16 to 176 among the communes (Table 3.3). Required numbers of sample plots as shown in Table 3.2, were randomly selected from the grid with reference to random numbers generated in excel using RAND function.

3.3.1.4 Design of inventory plot

Concentric Circular Sample Plots, consisted of four circular nested plots with different radii (Figure 3.5a) were used. Center of the sample plots coincided with the intersection of grid coordinates (Figure 3.5b).

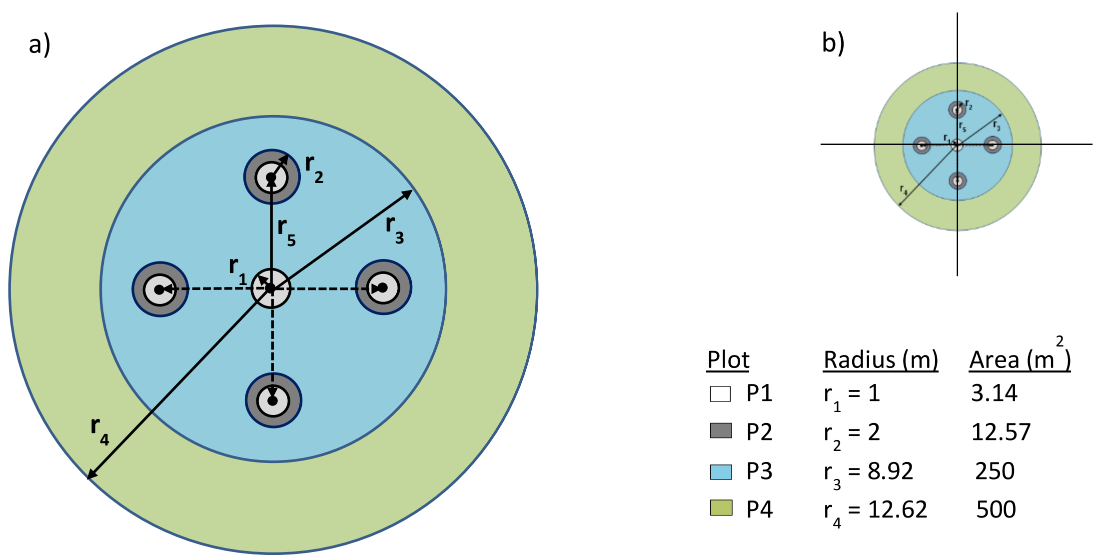


Figure 3.5 Layout of an inventory plot showing: a) design of forest inventory plot, b) plot centre coinciding with intersection of grid coordinates. r represents radii of nested plots. P1, P2, P3 and P4 are plot 1, plot 2, plot 3 and plot 4 respectively. If P1 and P2, at a distance of r_5 (5.64 m) at cardinal point N, are not accessible, then the plots are established towards E, or S, or W, as shown by dotted lines.

Table 3.4 Plot radius and corresponding trees to be measured. Radius and area of sample plot, classification of trees, specification for measurement and tree attributes are shown.

Radius (r) (m)	Area (m^2)	Classification of trees	Specification for measurement	Attributes
1.0 (r_1)	3.14	Wilding/seedling	Diameter: <1cm Height (*h*): ≤ 1.3 m	Species and frequency
2.0 (r_2)	12.56	Sapling	1cm ≤ dbh <5cm	Species, dbh (cm) and height (*h*)
8.92 (r_3)	250	Small tree	5cm ≤ dbh <25 cm	Species, dbh (cm) over bark, total height (m)
12.62 (r_4)	500	Big tree	dbh ≥25cm	same as small trees (above)

The minimum tree size tallied got progressively larger with increase in the plot radius as described in Table 3.4. All live and standing trees within plot 3 and plot 4 were tallied. Seedlings were counted in plot 1 at the distance of r_5 and saplings were recorded in plot 2 (Figure 3.5). Samples of understory woody and herbaceous plants were taken from plot 1 at the distance of r_5 (5.64m). Litter samples and soil samples were taken from plot 1 at the plot center.

3.3.1.5 Plot expansion factor

In order to expand the plot estimates (of growing stock, biomass and carbon) to per hectare, the following plot expansion factor was used.

$$Plot\ expansion\ factor = \ 10000\ (m^2)/Area\ of\ circular\ plot\ (m^2) \qquad \text{Equation 3.2}$$

3.3.2 Locating sample plots and plot center marking

A GPS uploaded with geographic coordinates (latitude and longitude) of each grid point (i.e., sample plot center) was used for positioning the plots. When locating a plot center with GPS was not possible, such as in dense forests and bamboo forests, the nearest possible point to the plot center was located with GPS. With reference to this point; the plot center was located with help of measuring tape and compass. After accessing the plot center, it was marked with a wooden peg driven into soil.

3.3.3 Sample plot information

In order to describe general and geographic situation of each sample plot, information of following attributes was collected. The study followed Köhl et al. (2008) for defining and specifying tree and stand attributes.

Sample plot number

Sample plot number corresponds to the number of a plot center. Attribute table as described in section 3.3.3.1 contained the number for each plot.

Altitude

Altitude of a sample plot is its height (z-) coordinate and is referred with reference to sea level. Altitude was taken from the attribute table and additionally measured in field with a GPS and verified with topographic map of each commune. The altitude was recorded in meter (whole number).

Sample plot geo-coordinates

Coordinates (latitude and longitude) of a plot center was taken from the attribute table. VN-2000 reference system (VN-2000/UTM zone 48N) was used to define the coordinates.

Forest types

Forest types (according to designated ecological function: Special use forest, Protection forest and Production forest; and method of forest origin: natural forest and planted forest) of each sample plot was recorded from the attribute table. This was verified by field (plot) observation and with commune forester involved in the forest inventory team.

Slope gradient

Determination of slope gradient of a sample plot

Slope gradient within a sample plot area was measured using clinometers and recorded in degree. The measurement was done as following:

- Angle of elevation was taken to the highest point 15 m upwards slope from the sample plot center;
- Angle of depression was taken to the lowest point 15 m downwards slope from the sample plot center; and
- The slope gradient of the sample plot was determined taking arithmetic average of the two readings.

Application of slope correction

Slope distance for the circle radius (SD) of the sample plot is calculated according to following equation:

$$SD\ (m) = \frac{HD\ (m)}{Cos\ \theta} \qquad \text{Equation 3.3}$$

where, SD = slope distance for a circle radius

HD = horizontal distance of a circle radius as prescribed in Table 3.4

θ = gradient of the plot (average of angle of elevation and angle of depression)

Aspects

Aspect is a direction the slope faces. In the study, aspects were recorded as North, Northeast, East, Southeast, South, South West, West and Northwest using a Sylva compass.

Soil types (or soil groups)

Soil type is a series of soil with a similar range of properties (such as, the proportions of sand, silt and clay in soils). The study followed FAO soil classification system (IUSS Working Group WRB, 2014) to record soil types found in the study area. Soil types, for instance, acrisols, calcisols, ferrasols, fluvisols and luvisols were taken from the attribute table.

Terrain relief

The terrain relief is determined on the whole area around the sample plot. The terrain relief was recorded as: flat, rolling, ridge, valley or ravine.

Sample plot micro relief

The sample plot micro relief is the relief of the sample plot area. The micro relief was recorded as: flat (maximum inclination ≤5^0), upper part of slope, middle part of slope or lower part of slope.

3.3.4 Stand information

Growth location

Growth location is the general location of a stand. The location was indicated where the sample plot center was found, either in mountain, valley/lowland or river/stream/creeks-side.

Crown cover density

Crown cover density of a stand is stand area covered by crowns of live trees, given in percent of sample plot area. In the study, a spherical densitometer was used to measure crown cover density. The device consists of a circular concave mirror with 24 squares. When observed in the understory, percent of shaded squares needs to be observed. In the study, five measurements were taken in each sample plot, one in center of the plot and four measurements at four cardinal points (N, E, S and W) in such a way that each point lies one meter inside from the plot boundary. Then, average reading of the five measurements was multiplied by 1.04 to get the percent of crown cover. Crown cover less than 40% was considered open, the cover between 40 to 70% considered as medium, and crown cover over 70% was considered dense.

Structure

The structure is vertical layering of a forest stand on the sample plot. Simple- only one layer of trees (picture 1), two layers (picture 2 and 3), and complex- equal or more than three layers of trees (picture 4, 5 and 6) classes were defined to specify stand structure in the study (Figure 3.6).

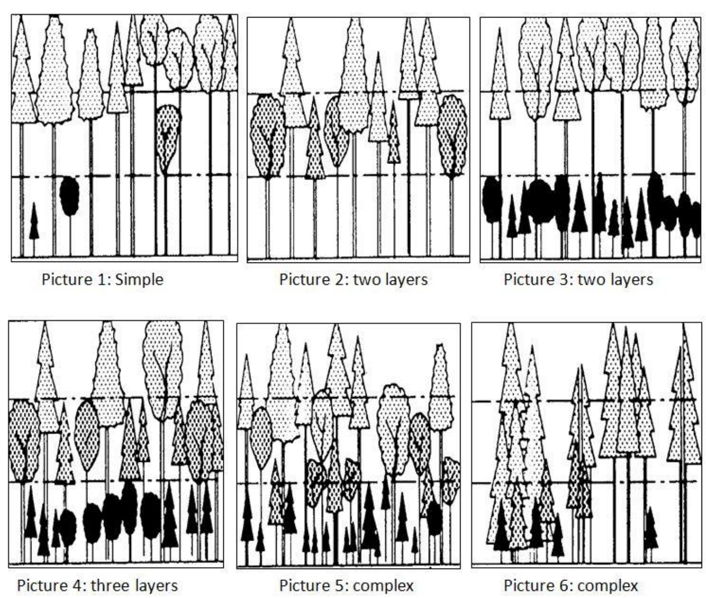


Figure 3.6 Vertical layering of forest stands showing simple (Picture 1), two layers (Picture 2 and 3) and complex stand (Picture 4, 5 and 6) structure.

Source: Köhl et al., 2008

3.3.5 Tree information

Species name

The name of species of each seedling, sapling and tree was recorded in local/Vietnamese name. Forest inventory team comprised of a dendrologist (from Vietnam Forestry University, Xuan Mai), a commune forester and a local inhabitant, mostly village leader. The trio worked as "tree finders" (Köhl et al., 2006). In case of a species that was not identified during the inventory, a photo and specimen of the species were taken (Figure 3.7). While taking the specimen, plot number, tree number and running specimen number (starting from 1 on each plot) was recorded and attached to the specimen.

Figure 3.7 A specimen taken of an unidentified tree species during forest inventory (Diem Mac commune).

Tree number

Tree number is a unique number assigned to each tree in a consecutive order and starts as 1 from magnetic North in clockwise order to total number of measured trees on a sample plot. The numbers were marked with white chalk in a surface of a tree stem facing to the center of a sample plot.

Seedling

Seedling is a young plant with a height of less than 1.3 m. It can be considered as regeneration materials. Species name and frequency of seedlings were recorded in plot 1 at a distance of 5.64m (r_5 m) (Figure 3.5). Seedling plots were established at the distance because of following reasons:

- To avoid plot center, as the area was prone to trampling and crushing seedlings during locating the sample plot and marking plot center.
- Rattan was recorded on the circular plot area of radius of 5.64 m (rattan data are not included in the study). While establishing plot center for the plot 1, the same radius was used to reduce additional effort and time.

Sapling

Sapling is a tall perennial woody plant having a main trunk and branches forming a distinct elevated crown with height greater than 1.3 m and having a diameter at breast height less than 5 cm. For each sapling, species name was recorded, diameter (dbh) was measured and total height was estimated. Saplings were recorded in plot 2 (Figure 3.5).

Tree diameter

Tree diameter refers to a diameter at breast height (dbh), diameter of a living tree stem measured at 1.3 m above ground level. A living tree must have living branches and must be able to survive until next growing season. This measurement was taken from a point where soil covers tree base. A stick with a marked height of 1.3 m was used to obtain the specified height. To avoid overestimation of volume and to compensate measurement errors, dbh was measured to the nearest 0.1 cm with a diameter tape. The dbh measurement included tree bark. Conditions of a terrain on which a tree is standing might be of different kinds, like, level, slope etc. Sample (tallied) trees themselves might have different forms, for instance, leaned, buttressed, forked and deformed. Therefore, care was taken for the position of dbh measurement. Figure 3.8 shows examples of different terrain conditions and tree forms, and corresponding position of the diameter measurements.

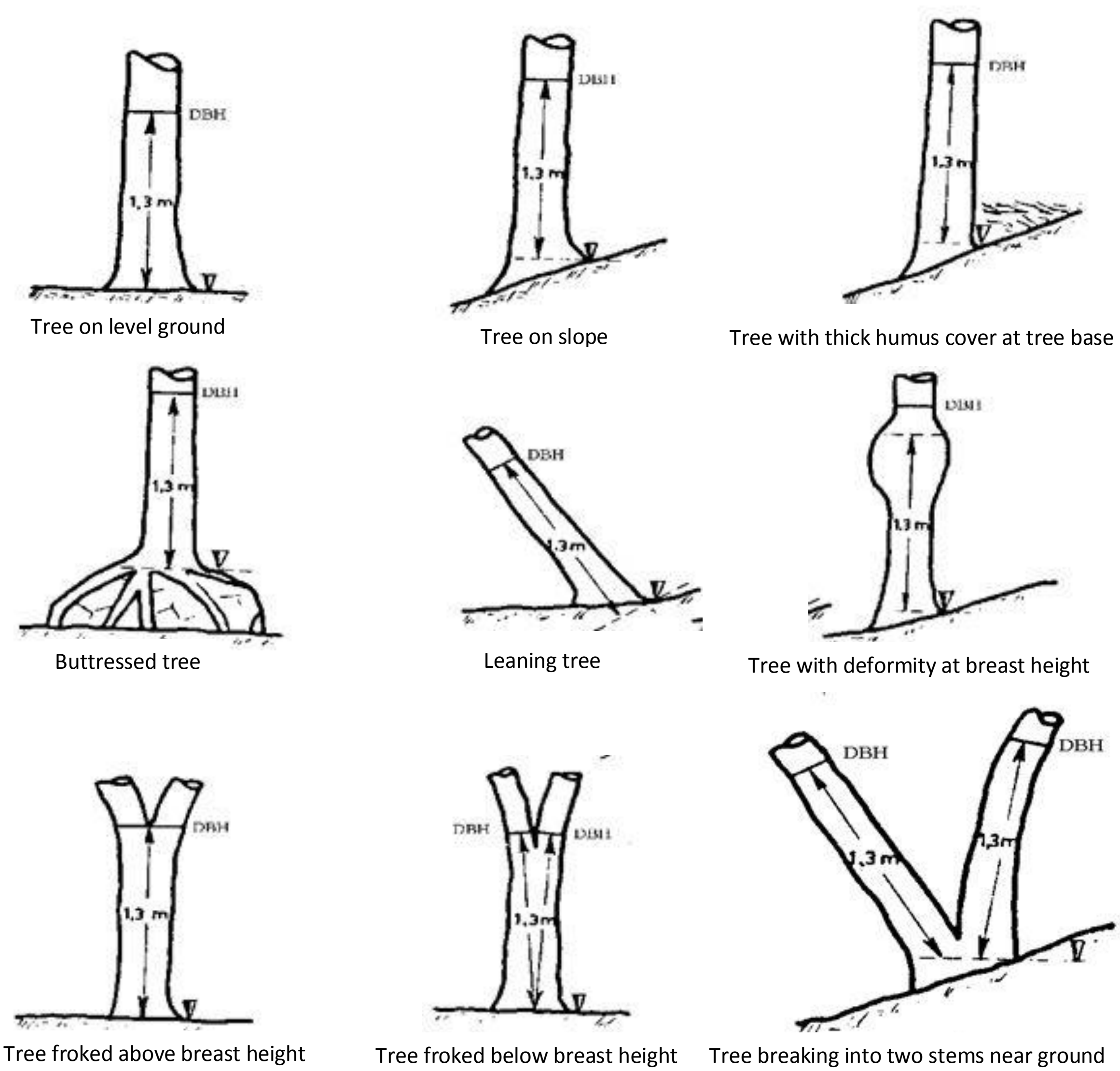


Figure 3.8 Examples of measurement of diameter at breast height of trees standing on different terrain and trees having different forms and conditions.
Source: Lötsch et al., 1973; Köhl, 1993; BMELV, 2007

When a height for diameter measurement differed from 1.3 m, actual height of the diameter measurement was indicated in remarks section. In case where diameter measurement was not possible, dbh value was written as ‘0’ and reason was given in field form.

Total tree height

Total tree height is defined as vertical distance between base of a tree stem (ground level) and the topmost tip of the tree (Köhl et al., 2006). The heights of all smaller (5cm ≤ dbh <25 cm) and bigger (dbh ≥25cm) trees tallied within a sample plot were recorded in meters to one decimal place with a VERTEX height measurement device at a minimum distance of one tree height.

3.3.6 Collection of litter, understory green biomass and soil samples

3.3.6.1 Litter

Litter is the uppermost layer of organic matter on forest floor and consists of plant debris such as leaves, needles, twigs, bark, seeds/nuts, or fruits (Hairiah et al., 2001). Litter includes all non-living biomass with a diameter less than 10 cm, lying dead, in various states of decomposition above mineral or organic soil (IPCC, 2003; FAO, 2010a; IPCC, 2006). Litter can be categorized into coarse woody litter (diameter >6mm), fine woody litter (diameter ≤6mm) and non-woody litter (leaves and reproductive parts) (Ravindranath and Ostwald, 2008).

In this study, litter biomass includes all non-living biomass of non-woody and woody components (< 5 cm in diameter). Fallen and lying woods, more than or equal to 5 cm in diameter and stumps on forest floor were considered as 'deadwood' and measured separately. The deadwood was not included in the analysis. In the study area, wood of diameter ≥5 cm was usually collected as fuelwood for cooking and small round wood for animal shade, fence, and agricultural equipment.

Figure 3.9 Collection and handling of litter sample: a) collection of litter in a 1 m radius micro plot at sample plot center, b) sub-sample preparation, weighing and labeling, and c) weighing sub-sample.

Litter samples were collected from plot 1 (Figure 3.5) located at sample plot center (Figure 3.9a). Samples were collected in a plastic bag immediately after plot center marking (section 3.3.2) to avoid the trampling damage. Fresh weight of the collected litter sample was recorded by reducing weight of the plastic bag. Sample was thoroughly mixed, and between 100g and 300g of the sample litter was taken as sub-sample, and was kept in a plastic bag and weighted. If total weight of litter in the plot 1 was less than 100 g, all litter was taken as a sample. The plastic bag was labeled and sealed (Figure 3.9b). The sub-samples were transferred to lab, and weighted (Figure 3.9c) again, and spread over newspaper sheets for air-drying.

3.3.6.2 Understorey green biomass

All vegetation less than 5 cm dbh including perennial plants, shrubs, herbs and grasses were destructively harvested at level to the ground in plot 1, the plot where seedlings were counted (Figure 3.5). The procedure for (sub) sample collection and handling was similar with the procedures adopted for litter collection (section 3.3.6.1) (Figure 3.10).

Figure 3.10 Collection and handling of understorey biomass samples: a) sub-sample preparation, weighing and labeling, b) air-drying before sending the sub-sample to lab, and c) weighing sub-sample in lab.

3.3.6.3 Soil samples for estimation of bulk density and soil organic carbon concentration

Soil samples were collected from plot 1 (Figure 3.5) located at sample plot center (Figure 3.11). A total of 600 soil sub-samples (soil cores) were collected from 200 soil pits, three from each pit. The sub-samples were taken manually at 0-10, 10-20 and 20-30 cm depth, layers which are most prone to changes. Wet-weight of the individual soil sub-samples were recorded in gram to a decimal place. From each soil sub-sample, approximately 100 g of soils (replicate) were taken out for soil bulk density measurement, stored in plastic bags and labeled.

Figure 3.11 Collection of soil samples for estimation of bulk density and soil organic carbon: a) extraction of soil cores (sub-samples) using a soil core sampler, and b) a hole (within red circle) after extracting the third core (20 cm - 30 cm) in the sample plot.

After collecting the replicates of the soil samples for bulk density measurement, a 'composite' was prepared for each sample plot as following:

- Remaining soils of the three soil cores of each pit were mixed thoroughly by spreading them in a plastic sheet and divided into four quarters; and
- One quarter of the soils (composite sample) were collected, stored in a plastic bag and labelled.

Soil cores were taken using a soil core sampler w/slide hammer (Figure 3.11a). The sampler contained a stainless steel metal cup. The cup contained a plastic tube of 5 cm in diameter and 10 cm in length inside it. During sample collection, the cup fitted with the plastic tube inside was fully pushed in the soil using the slide hammer of the sampler. Once entire depth of the cup was inserted onto the soil, the cup was taken out removing the soil around it by a spade. The plastic tube was then taken out carefully considering no loss of soil occurs from the tube. The metal cup was pushed tangentially into the soil (at the 90^0 of the slope of the sample plot) in order to ensure the soil depth of 30 cm.

For each sampling location, the soil sampling resulted in a total of 3 replicates for three layers, each of 10 cm for bulk density measurement and one composite sample for the 0-30 cm soil depth for SOC determination. Altogether 200 composites and 600 replicates were transported out from the study area. Finally, they were sent to a laboratory of Thai Nguyen University of Agriculture and Forestry, Thai Nguyen for further processing.

3.3.7 Sample processing in laboratory

3.3.7.1 Litter and understorey green biomass

Air-dried sub-samples were oven dried at 65˚C - 75 ˚C until weight of the samples was constant, and the weight was recorded. Usually, oven-drying process took three to four days.

3.3.7.2 Replicates for soil bulk density measurement

Soil replicates (section 3.3.6.3) were transferred to small aluminum containers of known weights. Total weights of the replicates with the containers were recorded. Then, the replicates were oven-dried at 105^0 C for 24 hours (Figure 3.12). After oven-drying, weight of each oven-dried replicate with the container was recorded.

Figure 3.12 Oven drying soil sub-samples (replicates).

3.3.7.3 Composites (soil sub-samples) for the determination of soil organic carbon content

Composite samples were air-dried by spreading them over pieces of newspapers in a well ventilated, and dust and wind free room (Figure 3.13a). After air-drying, soil lumps were crushed, and gravels, roots and large organic residues were removed. Each of the composite was then divided into two parts: c.0.5 kg for chemical analysis (soil pH measurement, soil nitrogen content analysis) including SOC determination; and rest of the soils for archiving (Figure 3.13b). The archives were retained for re-processing and verification if unexpected result is noticed. The part of the soils intended for SOC determination and chemical analysis was sieved through a two mm sieve and grinded in a mortar. A label in each sample was written using a water-proof marker pen and sent to laboratory for SOC determination. In the laboratory, a small amount of soils from each sample were taken out, weighted, placed in small plastic bags and labeled (Figure 3.13c and 3.13d).

Determination of soil organic carbon and nitrogen content was performed using *Carbon Hydrogen Nitrogen (CHN) analyzer* (Figure 3.13e) following the procedures suggested by Ravindranath and Ostwald (2008). After loading the sample to the analyzer, analysis begins automatically. Final results are displayed by the software in a computer monitor at the end of the analysis (Figure 3.13f) and can be printed and transmitted. Soil organic carbon and nitrogen content in the soil are determined in percentage.

CHN analyzer is one of the most precise and reliable methods for estimation of SOC and nitrogen content (Ravindranath and Ostwald, 2008). It can analyze larger numbers of samples at a time (shown by the arrow in Figure 3.13e). The instrument is very expensive, and therefore, the method is almost exclusively used for research and experimental purposes.

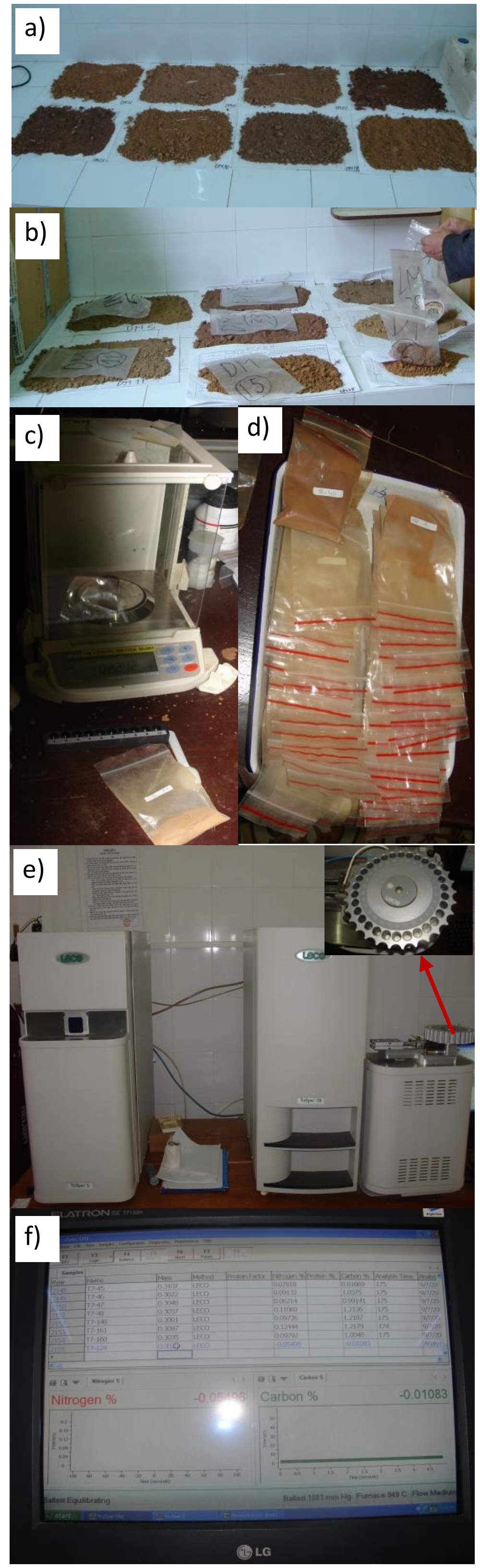


Figure 3.13 Sample preparation and determination of soil organic carbon (SOC) using CHN analyzer: a) air-drying soil composites, b), c) and d) sample preparation for CHN analyzer, e) a CHN analyzer used for SOC analysis, and f) results shown in a computer monitor.

3.3.8 Calculation of tree attributes

Tree attributes measured such as species, dbh ($d_{1.3}$), total height (h) were entered into excel spread sheets. Several tree attributes such as volume (v), biomass and carbon content were calculated using excel.

Average tree diameter

Average tree diameter using quadratic mean ($\overline{d}_q$) for each sample plot of all forest types (Special use forest, Protection forest and Production forest; natural forest and planted forest) was estimated. Arithmetic mean of all of the plot wise quadratic means was taken to estimate average tree dbh for the forests. The study used following equation, suggested by Curtis and Marshall (2000), to estimate the quadratic mean:

$$\overline{d}_q = \sqrt{\frac{\sum d_{1.3i}^2}{n}} \qquad \text{Equation 3.4}$$

where, $d_{1.3i}$ is the diameter at breast height (over bark) of the individual tree and n is the total number of tallied trees in a sample plot.

Volume

Volume (V) was estimated as product of trunk basal area ($(\pi/4) \times \ {d_{1.3}}^2$) of a tree, times total height (h) of the tree, times tree form factor (f) as expressed in the following formula:

$$V = \left(\frac{\pi}{4}\right) \times \ {d_{1.3}}^2 \times h \times f \qquad \text{Equation 3.5}$$

This model assumes taper remains constant irrespective of tree size. A fixed form factor of 0.6 was used as suggested by the used biomass equation to estimate above ground tree biomass (Equation 3.6) for this study.

Above ground tree biomass

Weighing biomass of a complete-tree after felling the tree, is the most accurate method of estimating above ground tree biomass (AGTB), however, it is an extremely time consuming and destructive method, and is generally limited to small areas and small tree sample sizes (Ketterings et al., 2001). Moreover, the destructive method cannot be used for monitoring tree growth by permanent assessments and can entail substantial assessment errors owing to difficult logistics of handling large amounts and volumes of woody materials especially for large trees (Köhl et al., 2006). As alternative to this method, allometric equation is used as a common method for estimating forest biomass which relate biomass of individual trees to easily obtainable non-destructive measurements, such as diameter (Ketterings et al., 2001). When estimating above ground biomass of a forest, use of species-specific equations is preferred as trees of different species may differ greatly in tree architecture and wood density. However, due to a large number of tree species in humid and tropical rain forest, enormous efforts are needed to develop these equations. Relatively few species-specific equations have been developed (Ketterings et al., 2001). One ha of tropical forest may shelter as many as 300 different tree species; one cannot use species-specific regression models as in temperate zone. Instead, mixed species tree biomass regression models must be used (Chave et al., 2005).

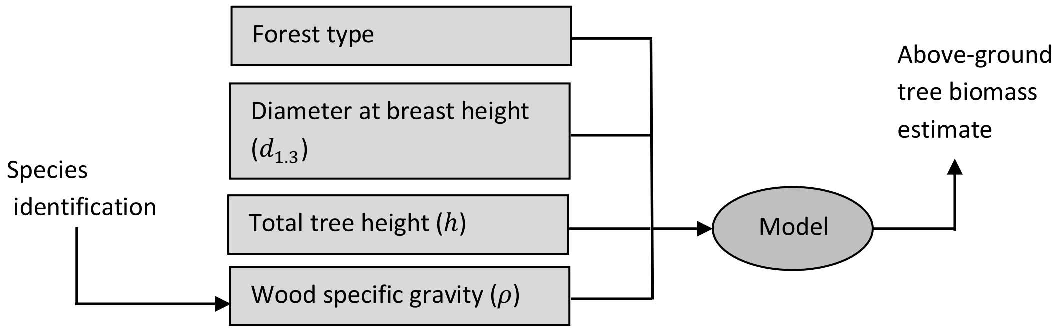


Figure 3.14 Predictable variables for estimation of above ground tree biomass.
Adapted from Chave et al., 2005

The study used a mixed-species regression model (Equation 3.6), suggested by Chave et al. (2005), to estimate AGTB of individual trees. The model is suggested to estimate AGTB in moist forests (broadleaved). Predicting variables are forest type, wood specific gravity (ρ), trunk diameter at breast height ($d_{1.3}$) and tree total height (h) (Figure 3.14).

According to Chave et al. (2005), the model that best predicted stand level AGTB for moist forests is:

$$AGTB_{est} = \exp(-2.977 + \ln(\rho\, {d_{1.3}}^2 h)) \equiv 0.0509 + \rho\, {d_{1.3}}^2 h \qquad \text{Equation 3.6}$$

where,

$AGTB_{est}$ = estimated AGTB (Kg) for individual trees in a sample plot;
ρ = wood specific gravity (g/cm^3) (oven-dry weight over green volume);
$d_{1.3}$= diameter at 1.3 m height (cm); and
h = total tree height (m).

The model suggested compound variable ($\rho\, {d_{1.3}}^2 h$) is only predictor of AGTB. Validity of the model applies: $d_{1.3}$ = between 5 cm and 156 cm, ($\rho\, {d_{1.3}}^2 h$) = 50 - 100000 and only broadleaved species. The model was developed by applying regression equations derived from destructively harvested 2410 trees (≥ 5 cm in diameter) in 27 study sites and tested 1808 trees in 20 sites across the tropics.

Summation of AGTB of all the tallied trees in a plot gives total AGTB of the plot. The plot estimate was expanded to AGTB per ha using a plot expansion factor (section 3.3.1.5).

Wood specific density

For value of wood specific density, different sources of literature and database were cited. Major sources referred to collect species level wood specific densities were: wood density database of World Agroforestry Centre (ICRAF) (http://db.worldagroforestry.org/wd); Jackson, 1994; FIPI, 1996; Brown, 1997; Ketterings et al., 2001; MARD, 2002; IPCC, 2006; WWF and GIZ, 2011; the plant list of the Royal

Botanic Gardens, Kew and Missouri Botanical Garden (http://www.theplantlist.org/); and Vietnam Plant Data Center (http://www.botanyvn.com/default.asp?lg=en). For species with known wood specific density, we used densities as provided in the sources. In case where the species' wood specific density was available in a range with low, medium and high, the study used the lowest value. For species with unknown species level wood specific density, the study used wood specific value of nearest sub-species/variety level, species average, genus level, plot-weighted average and site average (Table 3.5).

Table 3.5 Level of wood specific density used. Reference level of wood specific density values, and number of species are shown.

S N	Reference level of wood specific density values	No. of species
1	Species-level[26]	121
2	Sub-species/variety level[27]	4
3	Species average[28]	76
4	Genus level[29]	16
5	Plot-weighted average	21
6	Site average[30]	3
7	Plot-weighted average and site average	4
Total tree species (trees ≥ 5cm dbh)		245

Wood density based on oven dry mass

Most of the wood specific densities reported in the literatures were based on 12% or 15% moisture content. The study converted the wood specific densities (assuming all the wood specific densities are given in 12% moisture content) to oven-dry wood specific density (oven-dry weight over green volume) using a model suggested by Reyes et al. (1992) (cited in Brown, 1997) as following:

$$Y = 0.0134 + 0.0800\,X \qquad (r^2 = 0.99, \text{ number of data points } n = 379) \qquad \text{Equation 3.7}$$

where, Y = wood density based on oven-dry mass/green volume, and X = wood density based on 12% moisture content.

Litter and understorey green biomass

Litter and understorey biomass samples were oven dried at 65˚C to 75˚C until the weight of the samples was constant (usually within 24—72 hours). Dry weight of each sample was determined and wet-to-dry weight ratio was calculated. The amount of biomass per sample plot area is then given by:

$$\boldsymbol{B_{sample.plot} = W_{forest.sample.plot} \times \frac{W_{dried.subsample}}{W_{wet.subsample}}} \qquad \text{Equation 3.8} \quad \text{(Pearson et al., 2013)}$$

[26] e. g., *Canarium album* (Lour.) Raeusch

[27] e. g., for *Cryptocarya infectoria* (Blume) Miq., the value of *Cryptocarya infectoria* Miq. var. *acuminulata* Meissner was taken.

[28] e. g., for *Ilex rotunda* Thunb, the value of *Ilex* spp. was taken.

[29] e. g., for *Syzygium malayanum* (Gagnep.) Merr. & Perry, the value of *Syzygium hancei* Merr. et Perry was taken.

[30] Estimated from the nearest plot with same floristic composition

where, $B_{sample.plot}$ = litter biomass of sample plot (Kg);
$W_{forest.sample.plot}$ = weight of sampled biomass in sample plot (Kg);
$W_{dried.subsample}$ = weight of oven-dried subsample (kg); and
$W_{wet.subsample}$ = weight of fresh subsample (Kg).

Per ha estimate was calculated using plot expansion factor (section 3.3.1.5) as following:

$$\boldsymbol{B} = \frac{\boldsymbol{B_{sample.plot}}}{\mathbf{1000}} \times \frac{\mathbf{10000}}{\boldsymbol{A}} \qquad \text{Equation 3.9}$$

where, B = biomass (t ha^{-1}), and A = area of sample plot (m^2).

Below-ground biomass

Root biomass accumulation is linked to the dynamics of above ground biomass (Ravindranath and Ostwald, 2008). Root to shoot ratios are routinely used to partition plant biomass into above ground and root component (Cairns et al., 1997). Several authors have provided root to shoot ratios as default values (Cairns et al., 1997; Li et al., 2003; MacDicken, 1997; Mokany et al., 2006). The study used root to shoot ratio of 0.205 (low 0.092, high 0.253; SE = 0.036) suggested by Mokany et al. (2006) for the tropical/subtropical moist forest/plantation (AGB <125 t/ha).

3.3.9 Estimation of soil organic carbon

Estimation of bulk density

Bulk density (BD) for each replicate (0-10 cm, 10-20 cm and 20-30 cm) was calculated as the ratio of weight of dry soil in the replicate (Wd) to volume of soil in a sampling tube (or soil core or plastic tube-see section 3.3.6.3) (i.e., 196.35 cm^3).

$$BD\ (g/cm^3) = \frac{weight\ of\ dry\ soil\ in\ a\ replicate\ (Wd)\ (g)}{volume\ of\ sampling\ tube\ (soil\ core)\ (cm^3)} \qquad \text{Equation 3.10}$$

Average soil bulk density for the 30 cm soil profiles was determined as an average of the bulk densities of the three replicates.

To calculate the weight of dry soil in a replicate (Wd), moisture content in the soil replicate (MC) (%) was required. The MC (%) and Wd were calculated as following:

$$MC\ (\%) = \frac{[weight\ of\ wet\ soil\ with\ container\ (g) - weight\ of\ dry\ soil\ with\ container\ (g)]}{weight\ of\ dry\ soil\ with\ container\ (g) - weight\ of\ container\ (g)} * 100$$

Equation 3.11

$$Wd\ (\%) = \frac{[Total\ weight\ of\ wet\ soil\ in\ a\ replicate\ (g) * (100 - Miosture\ content\ (MC)(\%))]}{100}$$

Equation 3.12

Estimation of soil carbon density

To estimate organic carbon in mineral soils, calculation of soil organic carbon (SOC) density (tC/ha) was required. The SOC density estimation involves soil bulk density (BD) (g/cm^3) at a specified depth (i.e., 30 cm) and determination of SOC concentration (%). Procedure for the BD estimation is described in previous section. The SOC concentration was provided by the *CHN analyzer* (section 3.3.7.3).

The SOC concentration was then converted to tonnes per hectare using the BD, soil depth (i.e., 30 cm) and area (1 ha) as following (Ravindranath and Ostwald, 2008):

$$\boldsymbol{SOC\ (tC/ha) = [soil\ mass\ in\ 0-30\ cm\ layer * SOC\ concentration\ (\%)]/100} \quad \text{Equation 3.13}$$

where, $Soil\ mass\ (t/ha) = [area\ (10000\ m^2/ha) * depth\ (0.3\ m) * BD\ (t/m^3)]$ Equation 3.14

3.3.10 Estimation of forest carbon stock

IPCC (2003) suggests five different pools need to be considered in estimating forest biomass and/or carbon. The five pools include: above ground biomass, below ground biomass, dead wood, litter and soil organic matter (Table 3.6). In the study, data of dead wood were collected but excluded from analysis. Bamboos and palms were not included while conducting forest inventory. Total forest carbon stocks were estimated as total sum of carbon in above ground tree biomass, understorey green biomass, below ground (root) biomass, litter biomass and soil organic carbon (Table 3.6). Biomass estimates (t ha^{-1}) were converted to carbon content (tC ha^{-1}) multiplying by 0.5 - the default carbon fraction.

Table 3.6 Carbon pools included in the study. Carbon pools suggested by IPCC good practice guidance, carbon pools included in the study and description of the carbon pools are shown.

Carbon Pool (IPCC, 2003)		Carbon pools included in the study	
		Included/ Not included	Description of carbon pools
Living Biomass	Above ground biomass	Included	1. Above ground tree biomass 2. Understorey green biomass (shrub/herb/grasses)
	Below ground biomass	Included	3. Root biomass
Dead Organic Matter	Dead wood	Not included	
	Litter	Included	4. All non-living biomass on the forest floor with a diameter < 5 cm
Soils	Soil organic matter	Included	5. Soil organic carbon

3.3.11 Data analysis

Analysis of the results was carried out using excel and R version 3.1.1 (Team, 2010). Statistical estimators such as sample mean, variance, standard deviation, standard errors, and confidence intervals of measured and calculated tree and soil attributes were performed, and graphics were made using the R (Team, 2010). Relationship between biomass and carbon stocks and soil attributes and locality (site) factors were analyzed using linear regressions and Kruskal-Wallis chi-square test.

3.4 Land use/forest cover change

The study used combination of traditional remote sensing techniques and geographic information systems (GIS) with a narrative approach of policy analysis (Thiha, 2007b) to assess 1993-2010 land use/forest cover change of Dinh Hoa district.

Remote sensing imagery and sources

Landsat Thematic Mapper (TM) image from 1993, Landsat Multi- Spectral Scanner images from 2000 and 2006, and SPOT image from 2010 were analyzed for the study. The satellite images were acquired from Centre of Remote Sensing, Ministry of Natural Resources and Environment (MONRE) in June 2011. In order to minimize differences in forest conditions (such as, phenology, soil moisture) among different imageries, images were acquired from similar seasonal phase, i.e., between the month of October and December. The image acquisition years were chosen purposely to coincide with important policies and programs on forest and forest land management in Dinh Hoa district. Since different policies were effective in different years, period between images varies between 4 to 7 years (see Table 3.7).

Satellite images were acquired from Centre of Remote Sensing, MONRE in June 2011. They were: four scenes of Spot 5 of 2010 with the spatial resolution of 2.5 m x 2.5 m, and 4 time series of Landsat images (Scene L127-45) with the special resolution of 28.5 m x 28.5 m. Description of the image collected is showed in Table 3.7.

Table 3.7 Remote sensing data used in the study collected for land use/forest cover change detection in Dinh Hoa. Description of satellite and sensors, acquisition year and spatial resolution are given.

Satellite and sensor	Acquisition year	Spatial resolution (m)
Landsat 5 (TM)	1993	60
Landsat 7 (ETM+)	2000	30
Landsat 7 (ETM+)*	2006	28.5
SPOT 5	2010	2.5

* indicates the image was recorded in scan line corrector (SLC) off mode

GIS database

Spatial data and attribute data were collected from different sources. Spatial data includes background data and thematic data. Background data (or base maps) were 2009 topographic maps at 1:10000 scale and were collected from Centre of Data and Information, MONRE, Hanoi. The topographic maps contained five layers: administrative boundaries, road networks, rivers, vegetation cover and resident land. Data were available in hardcopies as well as digital maps.

A number of thematic maps were collected from forestry authorities at district and province levels, including Department of Agriculture and Rural Development (DARD), Dinh Hoa and Provincial DARD, Thai Nguyen. Most of the maps were in paper form (photocopies), and/or were prepared using common mapping tools such as Microstation and Mapinfo. Thematic maps such as forest cover maps, maps showing forest types, digital elevation models and soil maps, those were prepared during forest inventory (section 3.3.1.2) were used. Basic cadastral maps (VN2000 projection) at district level, forest status maps from previous years, maps showing forest land allocation, District Land Use Plan maps (1:50,000 scale) were collected from Department of Forest Management, MARD and the CPCs in Dinh Hoa. All GIS layers were projected into WGS84 Universal Transverse Mercator (UTM) coordinate system. Ground reference information was collected during the field visit for the image classification and post classification accuracy.

Attribute data for each reference point were collected from People's Committees at district and commune levels. The data comprised of previous forest assessment reports, annual reports, documents related to FLA and forest management of the district and the communes. Attribute data were later used for reflectance signature development, forest maps validation, and evaluation and accuracy assessment of the image classification.

Image preprocessing

Image preprocessing was done to minimize spectral noise and geographic distortion, prior to image classification. Preprocessing of satellite images included geometry correction, image co-registration, image sub-setting, image enhancement and color composite (for both of Landsat and SPOT images). The spatial (background and thematic) and attribute data were used for preprocessing images.

SPOT image of 2010 was first registered in reference to ground control points and Landsat images of the years 1993, 2000 and 2006 were then co-registered using image-to-image registration technique. Accuracy of geo-rectification was maintained in such a way that root mean square error was within one image pixel. Co-registered images were subsetted to reduce data processing time. Dinh Hoa's boundary was subsetted from the Landsat images. Dinh Hoa region was extracted from SPOT image 2010, and then Landsat images of 1993, 2000 and 2006 were subsetted according to geocoded corner of SPOT image 2010. Linear transformation using nearest-neighbor resampling was implemented to enhance the images. Natural color composite was applied to all the satellites images, using View Tool in ERDAS for displaying. Besides, false color composite was used to extract vegetation which was represented best in red by displaying in this color composition. ERDAS IMAGINE 9.2 was used for the satellite images preprocessing.

Land cover classification

Based on the Land Use/Land Cover (LULC) classification systems adopted by General Department of Land Administration (GDLA) and Forest Inventory and Planning Institute (FIPI), Vietnam, land-use/land-cover types of Dinh Hoa district were classified into several categories. Following the forest classification criteria suggested by MARD's Circular 34/2009/TT, different forest types based on mode of forest origin, tree species and leaf phenology, and site conditions were recorded.

Land use cover of the district was classified into forest and non-forests classes. Based on mode of origin, forest classes were of two types: natural forest and planted forest. Based on tree species and leaf phenology, and site conditions, natural forest was further interpreted into six classes: Evergreen - Broadleaf forest – Medium, Evergreen-Broadleaf forest- Poor, Evergreen-Broadleaf forest- Regrowth, Bamboo forest, Mixed Wood and Bamboo forest, and Limestone forest. Non-forest land was classified into five categories: Limestone area, Bare land planned for forestry, Water area, Residential area and Other land.

Parameters for classification and development of forest status maps during different periods from 1993 to 2010, based on properties of each type of image (Landsat, Landsat TM, Landsat ETM+, SPOT 5), were derived as follows,

Parameters included-

- normalized difference vegetation index (NDVI)
  NDVI = (NIR-RED)/(NIR+RED)
- total of gray value level index (TRRI)
  TRRI = (Layer1+Layer2+Layer3+………..+Layer n)/(n*255)
- ratio vegetation index (RVI)
  RVI = NIR/RED
- enhancement vegetation index (EVI)
  EVI = 2.5* (NIR-R)/(NIR+6*R-7.5q*B+1)
- green vegetation index (GVI)
  GVI = 1.6225NIR – 2.2978RED + 11.0656

Object-based classification for forest covers in the district was based on segmentation, threshold, and process tree (eCognition guideline by Trimble, 2012). Segmentation was set by compactness, shape and scale; then threshold for each index was customized for each training sample. Forest cover status maps of 1993, 2000, 2006 and 2010 were output of the task. The methods for image classification were carried out using eCognition. Cross verification of classification results was performed comparing with thematic maps, such as, forest maps and land use maps simultaneously. Areas and forest status of doubt were marked and later verified during field verification trip.

Forest map validation

Field verification was done by a field team which included experts from Thai Nguyen University of Agriculture and Forestry; Forest Protection Division, Dinh Hoa; Commune foresters, commune/village leaders, forest entrepreneurs and local people of the respective communes visited. Inconsistent and abrupt changes and locations of changes of two different periods were verified. Results from classified maps were printed out and checked carefully for each forest sampling point. Sampling plots were created by a stratified grid of 200 meters. Permanent sample plots established by the FIPI for national forest inventory were used. Recorded GPS coordinates were used to update boundary of need-to-verify forest polygons; and directly edited status of forest maps on printed forest maps of 2010. The field trip was conducted during the same month as recorded month of the SPOT image.

Accuracy assessment

Accuracy of the 2010 forest and land use map was assessed using randomly created ground truth points across entire Dinh Hoa district. At least 30 ground truth points for each forest type and land use type were assigned. Coordinates for all ground truth points were recorded. At each verification point, land use type and forest type were verified. In addition, several meetings with local stakeholders were organized to receive opinions on land and forest cover changes retrospectively.

Land use/ forest cover change analysis

Land cover and forest cover changes were examined at the image pixel level by overlaying series of classified map pairs from adjacent dates: 1993-2000, 2000-2006, and 2006-2010, and using zonal analysis (a spatial analysis tool in ArcGIS). From the observed changes, area change (in ha) between the classes: forest and non- forest, and between the categories within each class, were estimated. Finally, 1993-2010 land-use and forest cover changes were calculated and compared across the three time periods.

3.5 Perception and attitude of local households towards forest management, forest land allocation and REDD+

Data collection

A comprehensive methodological approach (qualitative and quantitative) was used to assess local peoples' attitudes towards forest management and FLA processes, and outcomes of the processes. The assessment was conducted in 12 villages of the six selected communes (section 3.1) (Table 3.8) from March to June, 2012. Two villages from each commune were selected based on two criteria. Those criteria included: i) area of allocated/contracted forests and/or forest lands, i.e., villages possessing the largest and second largest area at the time of study, and ii) seniority of forest land allocation, i.e., year of FLA started in the villages. In case of more than two villages in a commune, with more or less same area of allocated forest land, the village in which the FLA process started earlier was taken.

Table 3.8 Selected villages, area of allocated forest lands, year of forest land allocation, number of the total households, and distribution of households for questionnaire survey.

Commune	Selected villages	Area of allocated forest land (ha)	Year of FLA	Total households	Proportion to total HHs	Households for survey
Quy Ky	Dong Hau	682.95	1997	57	0.07	18
	Khuon Cam	446.58	1997	83	0.10	27
Lam Vi	Na Toan	662.69	1997 & 2002	85	0.10	27
	Na Lang	415.38	1997 & 2002	52	0.06	17
Diem Mac	Ban Bac 1	86.9	1996	36	0.04	12
	Dong Vinh 4	64.11	1996	33	0.04	11
Phu Tien	Thon 6	90.12	1992	102	0.12	33
	Thon 4	98.6	2002	74	0.09	24
Phu Dinh	Khuon Tat	430	1999	88	0.10	28
	Deo De	230	1999	75	0.09	24
Bao Cuong	Lang Chua 1	75.83	1993	81	0.10	26
	Bai Lenh	24.4	1993	82	0.10	26
Total		3307.56		848	1.00	272

Data sources: records available in the respected communes

Primary data were collected through administration of open-and closed-ended questionnaires. A total of 274 households (HHs) were interviewed. There were 848 HHs residing in the 12 villages. Estimation of household number for interview was done using Solvin's formula (with a confidence level of 95 percent - giving a margin error of 0.05) as given below:

$$n = N/(1 + Ne^2) \qquad \text{Equation 3.15} \qquad \text{(Altares et al., 2003, p.13)}$$

where, n = households number for interview, N = total number of households in the villages, and e = margin of error (error of tolerance).

The model suggested 272 HHs which was 32% of the total HHs in the 12 villages. The HHs were distributed among the villages proportionately to number of HHs the individual village possessed (Table 3.8). Simple random sampling was applied to select HHs for interview. Name lists of each household head of the villages were collected from records, for instance, from voter lists of the respective commune offices. Changes in status of HHs due to recent immigration and emigration, separation of households, and any other reasons were discussed with village leaders and commune officials/forest officers. Individual household for interview was selected using random number (RAND) function in excel.

Understanding and perception of the households were studied in three dimensions: i) perception toward forest management and FLA, ii) awareness among the households about REDD+, and iii) their willingness to participate in and their preference to the REDD+. The questionnaires contained four sections, namely: a) socio-demographic information profiles, b) socio-economic information profiles, c) perception towards forest land allocation, and d) REDD+ related awareness and perception. Socio-demographic variables included gender, age, household size, size of working group, education level, ethnicity, and occupation. The socio-economic information solicited respondent's agricultural land holdings (amount and types), food production, livestock number and types, area and types of allocated forest, forest products use (pattern, amount and prices-where available) and income sources and amount (food sale, livestock, timber, NTFPs, cassava, tea, fisheries, off-farm income). Section c contained a series of statements (92) formulated on various aspects of forest management, forest land allocation and local livelihood assets. The key variables included in the statements were forest cover, availability of forest products and services, floral and faunal diversity, illegal activities including illegal logging, availability of time for household work, opportunity for employment, capacity building, participation on forest management, trust and communication within and between state and non-state actors, and excess to external finance. The status of the variables 'before and after' FLA and forest management scenarios were compared and assessed using statements with dichotomous option- 'agree' or 'disagree'. The key variables included in section d were: knowledge about carbon, REDD+; willingness to afford and costs for alternative means of forest products; type of house materials and energy source for household cooking; and willingness to participate in REDD+ scheme. Mostly, fixed response questions (yes or no) were used to gather information about respondents' understanding of and willingness to participate in REDD+.

Data analysis

Data obtained from household interview were analyzed using excel and R (Team, 2010). For both categorical and continuous variables, descriptive statistics were derived and test of associations were performed, where relevant. Number of household 'agree' or 'disagree' on particular statements, were used to express the respondent's perception towards the key variables embedded in the 92 statements related to forest land allocation and forest management. Furthermore, the 92 statements and associated variables were grouped under five livelihood assets according to their relevance. This facilitated to understand people's perception about impacts of FLA and forest management on local livelihoods. Respondents fixed response (yes or no) to REDD+ related variables were also discussed using frequencies.

3.6 Economic viability of forest management

Data collection

Questionnaires survey using open-and closed-ended questionnaires was conducted to collect primary data. The survey included 158 HHs (30% of the total HHs) from eight villages of four communes: Diem Mac, Lam Vi, Phu Tien and Quy Ky (Table 3.8). Criteria/procedures adopted for selection of the eight villages and individual HHs for the survey were same as described in section 3.5. Out of 158 HHs, three households were not involved in FLA, therefore were excluded from analysis. A pre-set of questionnaires was used to interview 25 households from the villages in February 2012. The questionnaires were revised based on the feed-back from the pre-survey. The questionnaires survey was conducted during March-May, 2012.

The questionnaires elicited information on respondents' socio-demographic variables (gender, age, household size), area of allocated/contracted forest land, agriculture landholding, food production, livestock holding, demand and use pattern of forest products, distance between house and forest boundary, and means of travel to the forests. Some key data on benefits from and contribution to (cost of) natural forest and planted forest management were collected. Key variables included: collection of forest products by types and amount; compensation payments and subsidies (cash and in-kind) from government; frequency of forest visit; forest management/development activities (types and incurred duration for each activity); materials and equipment used (types, quantity, cost, life expectancy, repair-frequency, cost); harvests from planted forest; harvesting (rotation) age; cost of plantation establishment; daily wage rate (village, commune); forest products sold; price of forest products-where available; income from forest products, livestock and off farm income; and total (gross) saving. Questions like what and how the respondents would like to improve natural and planted forest management were asked to understand the prevailing problems and their opinions for the solution.

Data analysis

Social benefit-cost analysis (BCA) assesses cost efficiency of any projects or programs calculating benefits and costs of forest management, and comparing them (Lave, 1996). In BCA, all relevant benefits and costs have monetary value, and are adjusted for time value of money. Therefore, flows of benefits and costs of forest management over time were discounted to express in terms of their present value (PV). According to Do and Bennett (2009) and Rai and Scarborough (2013), non-market values are function of individuals' income, therefore, non-market benefits of forest management were not considered in this analysis. The estimation of BCA shows whether contributions to forest management are economically viable in terms of generating benefits or not. The PV of costs and benefits of the forest management was estimated using following formula:

$$\text{PV}\ (i, N) = \sum_{t-0}^{N} \frac{Rt}{(1+i)^t} \qquad \text{Equation 3.16}$$

where, N is total number of periods, t is time of cash flow, i is discount rate (for this calculation we determined 10%), and Rt is net cash flow.

The analysis was carried out separately for natural forest and planted forest. Recurrent costs of and benefits from forest management were estimated separately for the forests. Costs of forest management were assigned into several headings (Table 3.9). Benefits were same in both forest management regimes, but plantation forests had additional cost activities related to establishment of plantation stands (Est).

Table 3.9 Description of costs of forest management in Dinh Hoa.

Costs	Description
Equipment cost (EC)	Costs of equipment used in forestry activities including motorcycle, bicycle, ox-cart, axe, saws, grass cutter, knife and tractor.
Repair cost (RC)	Cost of maintenance and servicing of the equipment.
Forest development cost (FDC)	Costs of patrolling, fire control, construction of dike, forest trail and fence.
Tending (and cultural) operations cost (TOC) (Forest management cost)	Cost related to tending operations from establishment of regeneration to harvesting. This included planting, weeding, cleaning, pruning, singling, thinning, and harvesting.
Harvesting cost (HC) (Forest products collection cost)	This included forest products harvesting, bucking, piling and transportation costs.

Therefore, total cost (TC) borne by the households can be expressed as,

$$TC = Est + EC + RC + FDC + TOC + HC \qquad \text{Equation 3.17}$$

There were two types of benefits generated from both forest management regimes. Those sources were both internal and external. The internal source was the collection of forest products. It relied mostly on area and condition of forest. The external source was subsidy/compensation from government (including programs/projects) for participating in forest management. Households protecting natural forests (Special use forest and Protection forest) had received compensation based on area of contracted forests. In case of planted forest, household had received subsidies in terms of seedling, fertilizer and their transportation. Therefore, total benefits (TB) generated from forest management at household level can be expressed as,

$$TB = \text{Forest products harvest} + \text{subsidy} \qquad \text{Equation 3.18}$$

Respondents estimated the costs in two terms: monetary and time based on the activities. For instance, equipment and repair costs were in monetary terms whereas forest management costs were mostly in time contribution. In the case of households having natural and planted forest, the equipment and repair costs were estimated for individual forest regimes by dividing total equipment cost and repair cost based on the proportion of forest land (natural and planted). It was assumed that the average equipment and repair costs per ha was equal in all types of forest regime.

There were two types of time contribution: (i) by households, and (ii) hiring labor. The later one was estimated according to the market wage rate, whereas the former one was estimated based on the shadow value of time (Rai and Scarborough, 2013). Similarly, price of forest products harvested for household consumption and did not have monetary transactions was estimated based on the collection time. The time value was converted into monetary value based on market wage rate.

Collected forest products were used for two purposes: (i) household use, and (ii) commercial purpose. Benefits from forest products were estimated according to the purposes. Benefits from forest products used for household consumption were estimated based on collection time, which was estimated as shadow value of market wage rate. Benefits from forest products sold were computed based on market price.

Sensitivity analysis captures uncertainty in benefit-cost analysis (Briggs et al., 1994). In forest management, there are several parameters which may influence the costs and benefits over the management period. Sensitivity analysis examines how outcomes vary as individual assumptions or estimates are changed. This determines important variables that influence costs and benefits of the forest management and suggest forest manager to assess these variables carefully. Sensitivity analysis in different scenarios for natural forest management: i) no subsidy, ii) no NTFPs, iii) forest products collection by hired labor, and iv) (ii) + (iii) were performed. Likewise, for planted forest management: i) no subsidy, ii) monetary value of household time converted using market wage, iii) rotation period of 10 years, and iv) (iii) plus (ii) scenarios were considered for the sensitivity analysis.

Finally, the BCR of natural forest management and planted forest management and of different scenarios of the forest management were calculated and compared.

4 Results and discussions: forest inventory

4.1 Number of stems

Total number of stem (dbh ≥5cm) in Dinh Hoa forest was 14.72 million. Number of stems per hectare (N/ha) (dbh ≥5cm) was 475 N/ha. Number of seedlings and saplings were about 16000 N/ha and 2900 N/ha respectively (Table 4.1).

Table 4.1 Mean stem density (N/ha) and its descriptive statistics. Sample size, mean stem density, standard deviation (SD), standard error (SE) and confidence interval (CI) are given for different tree forms and forest types, classified based on mode of forest origin and designated ecological function.

Criteria	Forest type	Tree form	Sample size (n)	Mean (N/ha)	SD	SE	C I (95%)
Entire forest	Entire forest	Seedlings (height >1.3 m)	200	15915	23935	1692	3317
		Saplings (1cm ≤ dbh <5cm)	200	2905	3674	260	509
		Small trees (5cm ≤ dbh <25 cm)	200	466	462	33	64
		Big trees (dbh ≥25cm)	200	9	20	1	3
		Tree density (dbh ≥5cm)	200	475	462	33	64
Forest type (mode of forest origin)	Natural	Seedlings (height >1.3 m)	150	15746	25381	2072	4062
		Saplings (1cm ≤ dbh <5cm)	150	3098	3993	326	639
		Small trees (5cm ≤ dbh <25 cm)	150	375	389	32	62
		Big trees (dbh ≥25cm)	150	10	21	2	3
		Tree density (dbh ≥5cm)	150	385	392	32	63
	Planted	Seedlings (height >1.3 m)	50	16425	19167	2711	5313
		Saplings (1cm ≤ dbh <5cm)	50	2324	2421	342	671
		Small trees (5cm ≤ dbh <25 cm)	50	741	551	78	153
		Big trees (dbh ≥25cm)	50	5	17	2	5
		Tree density (dbh ≥5cm)	50	746	548	78	152
Forest type (designated ecological function)	Production	Seedlings (height >1.3 m)	81	17880	18592	2066	4049
		Saplings (1cm ≤ dbh <5cm)	81	2358	2848	316	620
		Small trees (5cm ≤ dbh <25 cm)	81	431	388	43	84
		Big trees (dbh ≥25cm)	81	5	12	1	3
		Tree density (dbh ≥5cm)	81	436	389	43	85
	Protection	Seedlings (height >1.3 m)	59	16779	33888	4412	8647
		Saplings (1cm ≤ dbh <5cm)	59	3925	4987	649	1272
		Small trees (5cm ≤ dbh <25 cm)	59	588	625	81	159
		Big trees (dbh ≥25cm)	59	9	18	2	5
		Tree density (dbh ≥5cm)	59	597	624	81	159
	Special use	Seedlings (height >1.3 m)	60	12414	17783	2296	4500
		Saplings (1cm ≤ dbh <5cm)	60	2639	2925	378	740
		Small trees (5cm ≤ dbh <25 cm)	60	394	333	43	84
		Big trees (dbh ≥25cm)	60	14	28	4	7
		Tree density (dbh ≥5cm)	60	408	333	43	84

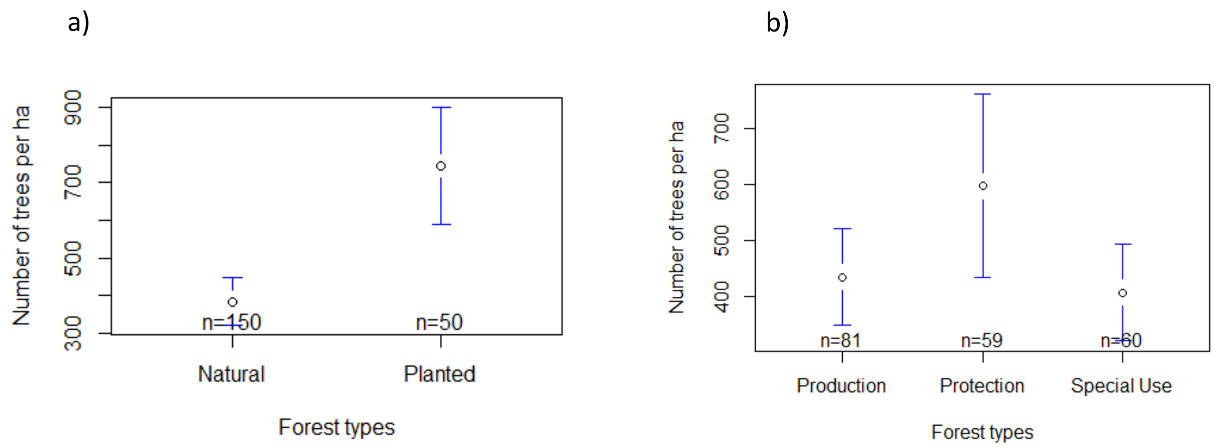


Figure 4.1 Density of trees (dbh ≥5cm) in different forest types. Stem densities of forests are compared between forest types, classified based on a) mode of forest origin, and b) designated ecological function. n indicates sample size.

Planted forests had higher tree density of 746 trees per ha than that of natural forests, i.e., 385 trees per ha (Table 4.1; Figure 4.1). A Kruskal Wallis test revealed a statistically significant effect of mode of forest origin on number of trees (dbh ≥5cm) per ha (χ^2 = 21.7, P <0.01) and non-significant effect on number of seedling (χ^2 = 0.25, P >0.05) and sapling per ha (χ^2 = 0.1, P >0.05). However, the opposite trend was observed with designated ecological functions. Designated ecological function of forest did not affect tree density significantly (χ^2 = 1.5, P >0.05 ns) and sapling per ha (χ^2 = 3.8, P >0.05 ns), while it did affect significantly on number of seedling per ha (χ^2 = 0.7, P <0.05). Protection forest had more than 1.5 times higher number of sapling (1cm ≤ dbh <5cm) per ha than those of Production and Special use forest. The Production, Protection and Special use forests were similar in terms of number of trees (dbh ≥5cm) per ha. Natural and planted forests were similar in terms of seedling and sapling density.

4.2 Distribution of stems according to tree size classes

Distribution of seedlings (height >1.3 m), saplings (1cm ≤ dbh <5cm), small trees (5cm ≤ dbh <25 cm) and big trees (dbh ≥25cm) followed inverse J-shaped curve in all forest types, classified based on mode of forest origin and designated forest functions (Figure 4.2).

Diameter distributions of all types of forests (natural and planted forests; Production, Protection and Special use forests) were similar (Figure 4.2). Diameter distribution curves revealed proportion of small trees was higher than that of large trees, and number of trees decreased with increased diameter (dbh) thresholds. This indicated forests in Dinh Hoa were unevenly aged forests at the time of forest assessment.

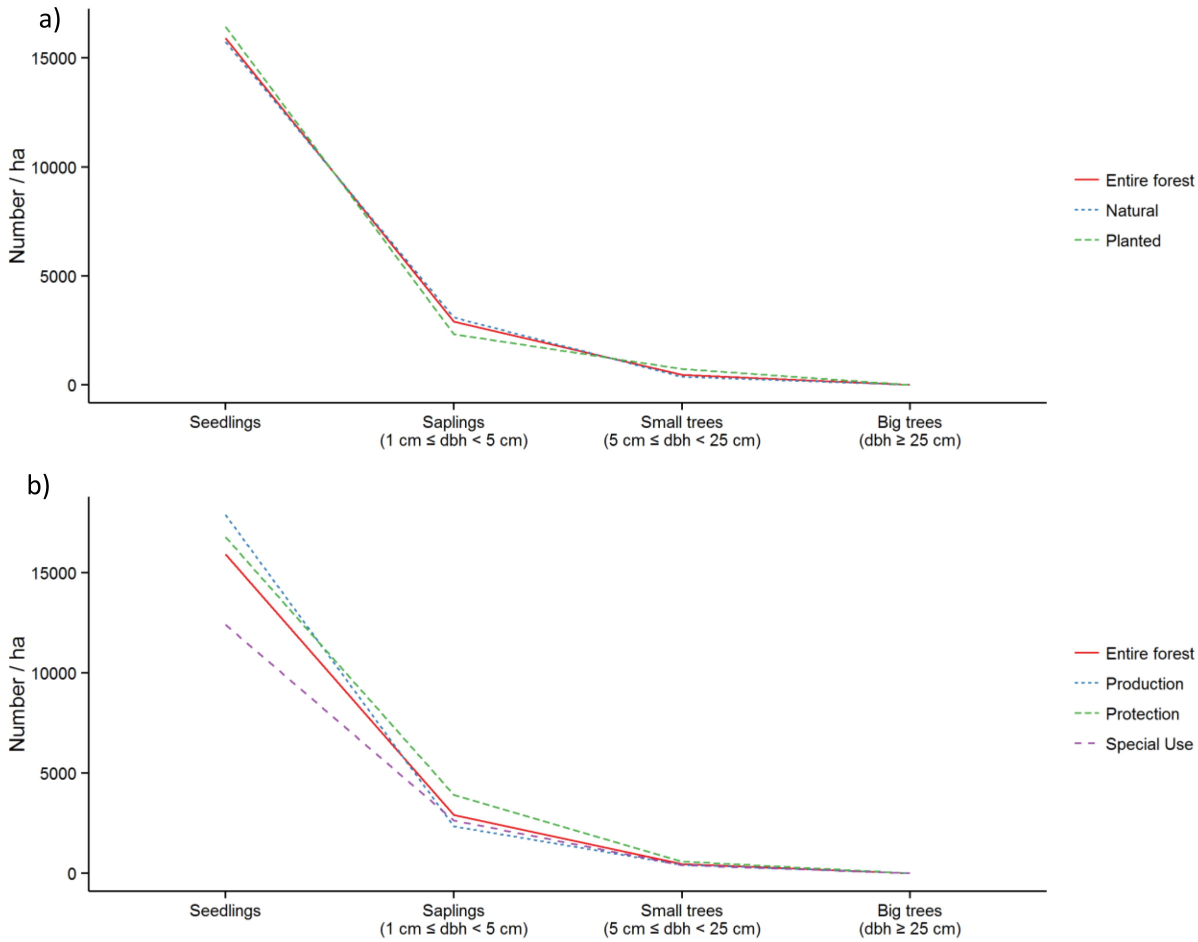


Figure 4.2 Distribution of mean number of seedlings, saplings, small trees (5cm ≤ dbh <25 cm), and big trees (dbh ≥25cm) in different forest types. The distribution is shown according to forest types, classified based on a) mode of forest origin, and b) designated ecological function.

4.3 Average tree

DBH of trees averaged 10.85±7.14 cm which was mean of plot wise (arithmetic) means of the 200 sample plots. The expression of average stand diameter conventionally used in forestry is a quadratic mean of diameters (QMD) ($\overline{d}_q$), not arithmetic mean (Curtis and Marshall, 2000). Hence, the QMD was calculated for each plot. The calculated QMD of Dinh Hoa forest was 11.68±7.49 (n = 200, CI = ± 1.045, p<0.05). The calculated QMD was slightly higher than arithmetic mean, however, it didn't vary significantly among the forest types in the district. In stands with small diameter and narrow range in diameters, difference between arithmetic mean dbh and QMD is small (Curtis and Marshall, 2000).

Out of 200 sample plots, trees ≥5cm cm in dbh were found in 181 sample plots; and maximum dbh observed was 72 cm. Remaining 19 plots did not contain the trees of dbh ≥5cm. The plots either comprised of young plantations or a high density bamboo clumps/culms and/or palm.

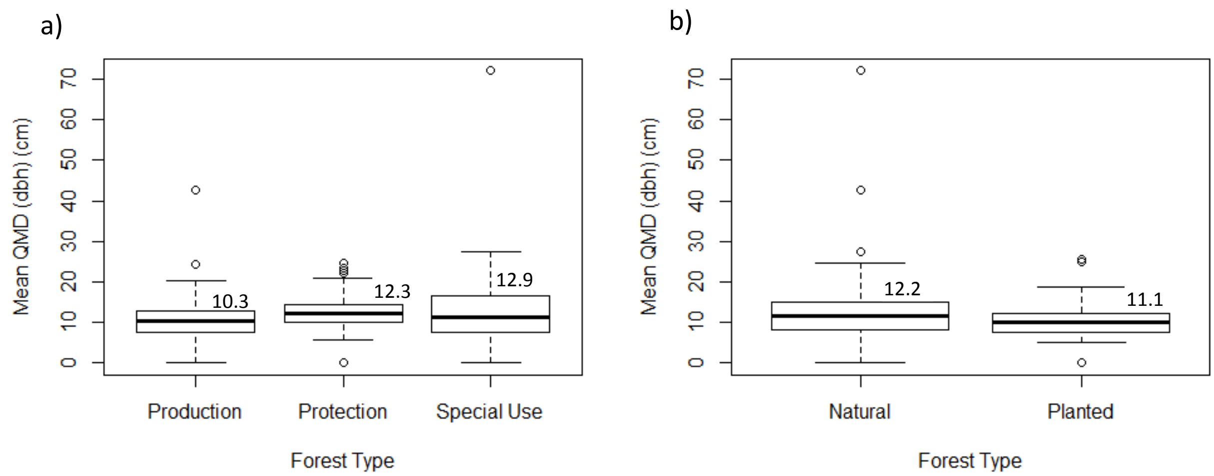


Figure 4.3 Mean of plot wise quadratic mean diameter (QMD) (cm) in different forest types. Medians are shown by horizontal bars inside box plots. The QMD is shown according to forest types, classified based on a) designated ecological function, and b) mode of forest origin.

The QMD of Production, Protection and Special use forests were 10.32 cm (n=81, SD=6.61 cm), 12.29 cm (n=59, SD=5.16 cm) and 12.90 cm (n=60, SD=9.98 cm) respectively. Similarly, the QMD of natural and planted forest were 12.17 cm (n=150, SD= 8.07 cm) and 11.10 cm (n=50, SD= 5.19 cm) respectively.

4.4 Species of trees

Tree species were recorded for seedlings, saplings, trees of dbh 5cm ≤ dbh <25 cm (small trees), and trees of dbh ≥25cm (big trees). More than 430 tree species were found in the 200 sample plots. There were 257 tree species with dbh ≥5cm belonged to 62 families.

Table 4.2 Number of tree species and family recorded for trees of dbh ≥5cm. Number of family and tree species according to forest types, classified based on designated ecological function and mode of forest origin, and number of sample plots in each forest type are given.

	Forest types				
	Designated forest function			Mode of forest origin	
	Production	Protection	Special use	Natural	Planted
Number of family	42	51	47	61	30
Number of species	148	142	137	248	72
Number of sample plots (n)	81	59	60	150	50

Production forest, Protection forest and Special use forest were comprised of 148, 142 and 137 tree species (dbh ≥5cm) respectively (Table 4.2). Occurrence of 72 species of 30 families in planted forests indicated a thriving of natural regeneration of the native trees in forest plantations.

4.5 Volume

Total stem volume of live trees (dbh ≥5cm) in Dinh Hoa forests was 1.24 million m^3 (39.89 m^3/ha). The volume ranged from 0 m^3/ha to nearly 212 m^3/ha. Table 4.3 shows mean stem volume for different forest types.

Table 4.3 Mean stem volume (m^3/ha) for each forest type in Dinh Hoa. Mean volume and its descriptive statistics: sample size, standard deviation (SD), standard error (SE) and confidence interval (CI) are given for different forest types, classified based on designated ecological function and mode of forest origin.

Criteria	Forest types	Sample size	Mean	SD	SE	CI (95%)
Entire Forest	Entire forest	200	39.89	45.35	3.21	6.29
Mode of origin	Natural forest	150	34.71	40.04	3.27	6.41
	Planted forest	50	55.45	56.11	7.93	15.55
Forest function	Production forest	81	31.66	38.14	4.24	8.31
	Protection forest	59	55.60	49.08	6.39	12.59
	Special use forest	60	35.55	47.31	6.11	11.97

In general Protection forest had the highest mean volume among the three forest types classified according to designated ecological functions (Figure 4.4 a, and 4.5 a). While the mean volume of each forest types was compared with the mean volume of the entire forest (39.89 m^3/ha) (Table 4.3), Special use forest and Production forest showed lower volume. Planted forest was found to have higher mean volume than the mean of the entire forest, but natural forest had lower mean volume than that of entire forest (Figure 4.4 b, and 4.5 b).

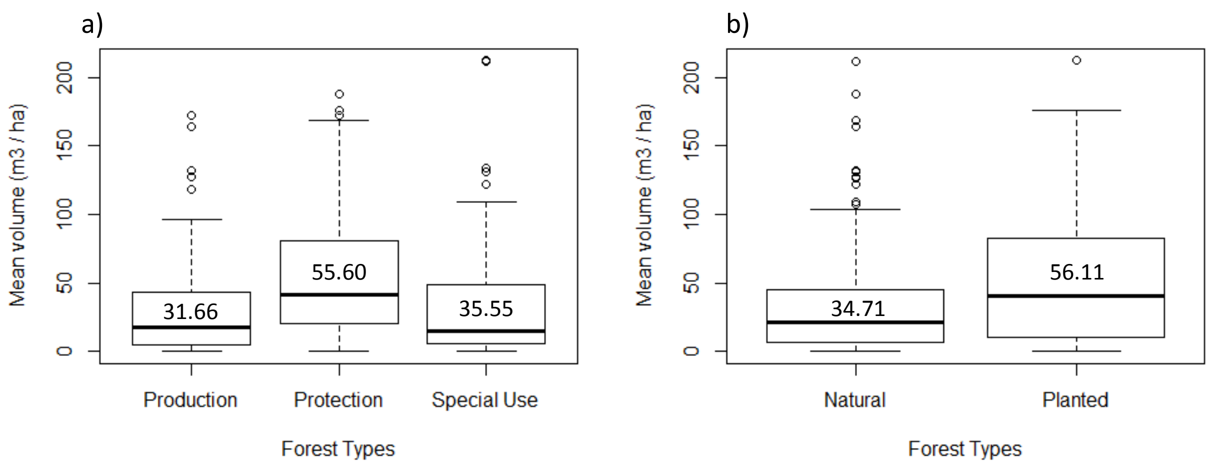


Figure 4.4 Mean and median stem volume of different forest types in Dinh Hoa. Medians are shown by horizontal bars inside box plots. The stem volumes (mean and median) are shown according to forest types, classified based on a) designated ecological function, and b) based on mode of forest origin.

A Kruskal Wallis test revealed significant effects of both, mode of forest origin (χ^2 = 4.16, P = 0.04) and designated ecological function (χ^2 = 13.32, P = 0.001) on stem volume (m^3/ha) of live trees (dbh ≥5cm).

Compared with the effects of mode of origin, the mean stem volume was slightly more affected by designated ecological function.

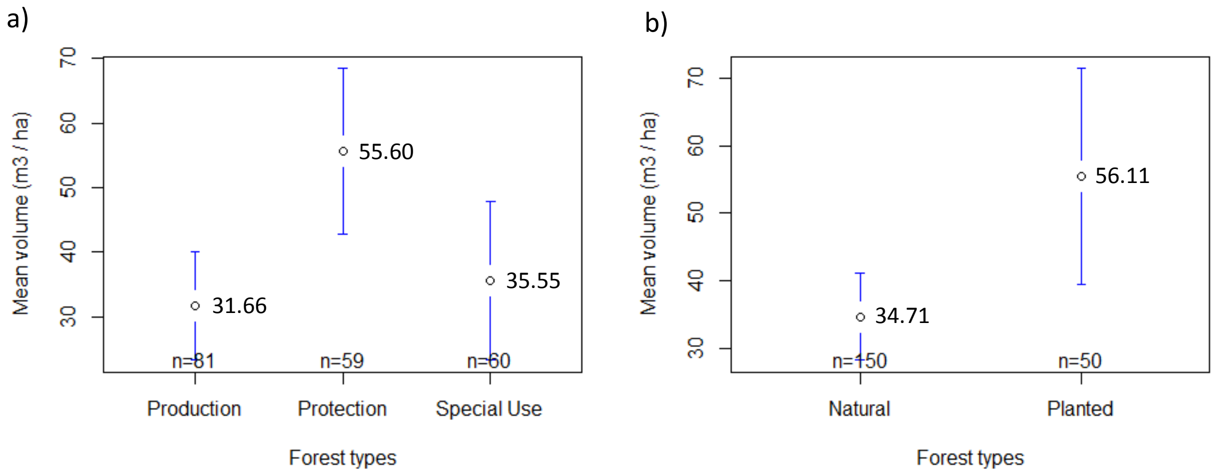


Figure 4.5 Mean stem volume of different forest types in Dinh Hoa. Mean stem volumes are shown according to forest types, classified based on a) designated ecological function, and b) mode of forest origin. n indicates number of sample plots assessed for the forest type.

4.6 Above ground biomass

Above ground biomass included above ground tree biomass (AGTB), biomass in litter, and understorey biomass (biomass in green shrub/herb/grass). Average AGTB of trees (dbh ≥5cm) for entire forest area was 19.34 t/ha (n = 200, SD = 22.42, CI = ±3.12) (Table 4.4). Mean of the AGTB ranged from minimum 0 to maximum 106 t/ha (Figure 4.6). Biomass in litter averaged 2.80±0.26 t/ha (n = 200, SD = 1.9) and ranged from 0.1352 (min.) to 10.34 t/ha (max.) (Figure 4.7). Plot wise average calculated value of understorey biomass ranged from 0.00 (min.) to 25.24 t/ha (max.) (Figure 4.8) with a mean of 3.17 t/ha (n = 200, SD = 3.86, CI = ±0.54) (Table 4.4).

Table 4.4 Distribution of above ground biomass (t/ha) in different biomass pools corresponding to different forest types in Dinh Hoa. Above ground tree biomass, understorey biomass and biomass in litter are presented. Mean biomass density (t/ha) and its descriptive statistics: sample size, standard deviation (SD), standard error (SE) and confidence interval (CI) are given for different forest types.

Criteria	Forest types	Sample size	Mean	SD	SE	CI (95%)
Above Ground Tree (dbh ≥5cm) Biomass (AGTB)						
Entire forest	Entire forest	200	19.34	22.42	1.58	±3.12
Mode of origin	Natural forest	150	16.97	20.27	1.66	±3.27
	Planted forest	50	26.45	26.89	3.8	±7.64
Forest function	Special use forest	60	17.83	24.79	3.2	±6.40
	Protection forest	59	26.12	23.43	3.05	±6.10
	Production forest	81	15.52	18.67	2.07	±4.12
Understorey biomass (oven dry biomass in shrub/herb/grass)						
Entire forest	Entire forest	200	3.17	3.86	0.27	±0.54
Mode of origin	Natural forest	150	3.25	4.07	0.33	±0.66
	Planted forest	50	2.93	3.21	0.45	±0.91
Forest function	Special use forest	60	2.92	3.46	0.45	±0.89
	Protection forest	59	3.25	4.36	0.57	±1.14
	Production forest	81	3.28	3.80	0.42	±0.84
Biomass in litter (oven dry biomass in litter)						
Entire forest	Entire forest	200	2.80	1.9	0.13	±0.26
Mode of origin	Natural forest	150	2.92	1.98	0.16	±0.32
	Planted forest	50	2.44	1.60	0.23	±0.45
Forest function	Special use forest	60	2.48	1.50	0.19	±0.39
	Protection forest	59	3.74	2.44	0.32	±0.63
	Production forest	81	2.36	1.44	1.60	±0.32

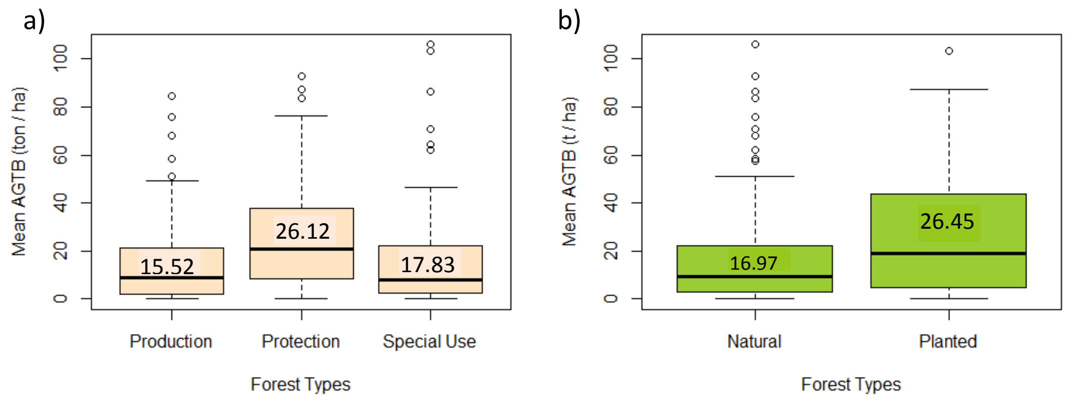


Figure 4.6 Mean and median of above ground tree biomass density (t/ha) of different forest types. Medians are shown by horizontal bars inside box plots. Means and medians are given according to forest types, classified based on a) designated ecological function, and b) mode of forest origin.

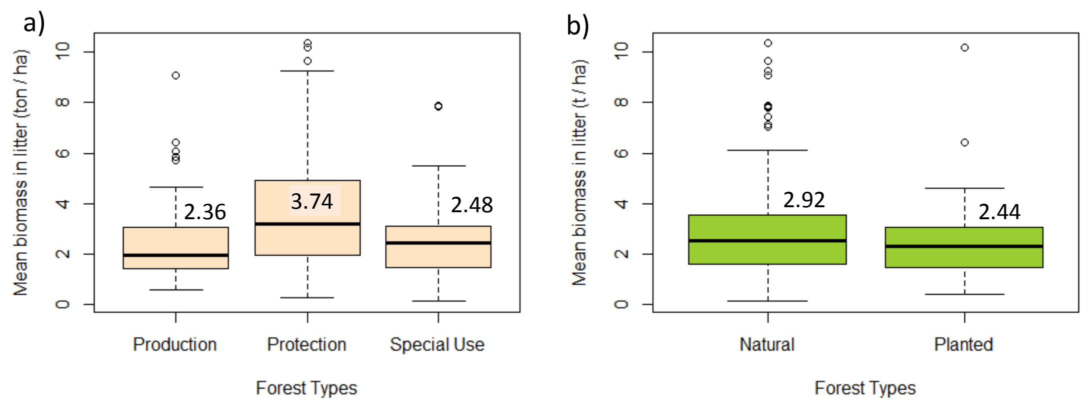


Figure 4.7 Mean and median of litter biomass density (t/ha) of different forest types. Medians are shown by horizontal bars inside box plots. Litter biomass means and medians are given according to forest types, classified based on a) designated ecological function, and b) mode of forest origin.

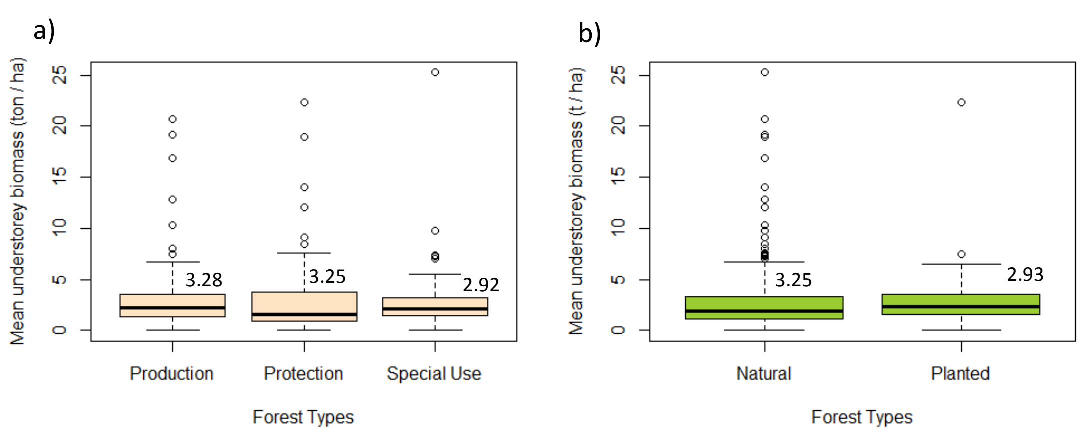


Figure 4.8 Mean and median of understorey biomass density (t/ha) of different forest types. Medians are shown by horizontal bars inside box plots. Understorey biomass means and medians are given according to forest types, classified based on designated ecological function (a), and mode of forest origin (b).

At the time of assessment, total AGTB in Dinh Hoa forests was 0.6 million tonnes. AGTB biomass density (t/ha) was higher in planted forests than in natural forests. Protection forests had the highest AGTB density (t/ha) among the forest types, classified based on designated ecological function. The AGTB density (t/ha) differed significantly within natural forest formations (chapter 5) (data not shown in the study).

Despite a tendency of having higher mean AGTB density (t/ha) (trees of dbh ≥5cm) in planted forests than that of natural forests, Kruskal Wallis test revealed statistically non- significant effects of mode of forest origin on the AGTB (χ^2 = 3.76, P = 0.052). Though the p value (p = 0.052) was quite near to upper value of significance threshold. In contrast to mode of forest origin, designated forest functions have imposed significant effects on the AGTB (χ^2 = 12.25, P = 0.002), with Protection forest having the highest mean AGTB density.

Neither the designated ecological function (χ^2 = 0.98, P = 0.32) nor the mode of forest origin (χ^2 = 1.84, P = 0.39) affected understorey biomass density. However, Kruskal Wallis test revealed that litter biomass was significantly affected by designated forest function (χ^2 = 15.84, P = 0.0003). Forest origin did not exert significant influence on litter biomass density (χ^2 = 2.12, P = 0.14).

4.7 Below ground root biomass

In the study, below ground root biomass included biomass of live root of live trees of dbh ≥5cm. The value was estimated using root to shoot ratio of 20.5%. The mean root biomass was estimated to be 3.96±0.64 t/ha (n = 200, SD = 4.59). Kruskal Wallis test resulted similar result as that of AGTB with both forest types having non-significant effect on the root biomass.

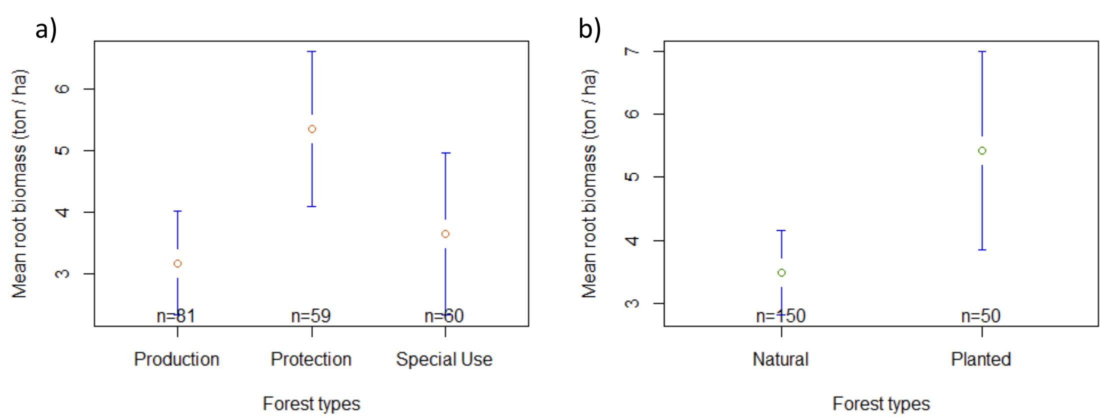


Figure 4.9 Mean root biomass density (t/ha) of different forest types. Root biomass means are shown according to forest types, classified based on a) designated ecological function, and b) mode of forest origin. n indicates number of sample plots assessed for the forest type.

4.8 Forest carbon

4.8.1 Distribution of forest carbon stocks among carbon pools

Carbon stocks were assessed for five carbon pools: above ground tree carbon (AGTC), carbon in understorey biomass, carbon in litter, carbon in live roots of the trees, and soil organic carbon to a depth of 0.3 m (SOC). The five pools were grouped into two broader categories: above ground carbon (comprised of the former three pools) and below ground carbon (included carbon in root biomass and SOC) pools. At the time of assessment, total forest carbon storage on Dinh Hoa forest was about 1.7 million tonnes. Carbon density averaged 54.01±2.82 t/ha (n = 200, SD = 20.33). Average above ground carbon density was 12.65±1.65 t/ha (n = 200, SD = 11.88). Below ground carbon density averaged 41.36±2.31 t/ha (n = 200, SD = 16.66) (Table 4.5).

Table 4.5 Distribution of carbon stock (t/ha) in different forest carbon pools. Mean carbon density (t/ha) and its descriptive statistics: sample size, standard deviation (SD), standard error (SE) and confidence interval (CI) are given for different forest carbon pools.

Description of carbon pool	Sample size (n)	Mean	SD	SE	C I (95%)
Carbon density (t/ha)	200	54.01	20.33	1.44	2.82
Above ground carbon density (t/ha)	200	12.65	11.88	0.84	1.65
Above ground tree carbon (t/ha)	200	9.67	11.21	0.79	1.55
Carbon in understorey biomass (t/ha)	200	1.58	1.93	0.14	0.27
Carbon in litter biomass (t/ha)	200	1.40	0.95	0.07	0.13
Below ground carbon density (t/ha)	200	41.36	16.66	1.18	2.31
Carbon in (tree) root biomass (t/ha)	200	1.98	2.30	0.16	0.32
Soil organic carbon (t/ha)	200	39.37	16.81	1.19	2.33

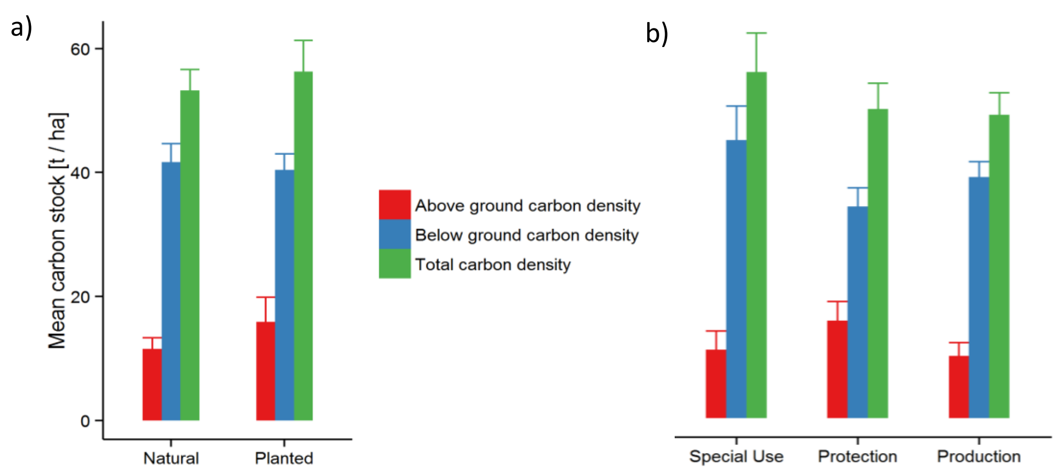


Figure 4.10 Distribution of above and below ground carbon stocks (t/ha) in different types of forests, classified based on a) mode of forest origin, and b) designated ecological function.

Contribution of the carbon pools to total forest carbon stocks varied. Major share was contributed by below ground carbon to the total carbon stocks. Accordingly, SOC pool contributed about 73% to the total forest carbon stock (Figure 4.11) with a mean carbon density of 39.37±2.33 t/ha. Above ground tree carbon was the second largest contributor to the total carbon stock. AGTC shared 18% of the total carbon stock with a mean carbon density of 12.65±1.65 t/ha. Compared with AGTC and SOC, remaining three carbon pools contributed considerably less amount, each pool contributing less than 4% (Table 4.5, Figure 4.11 and 4.12).

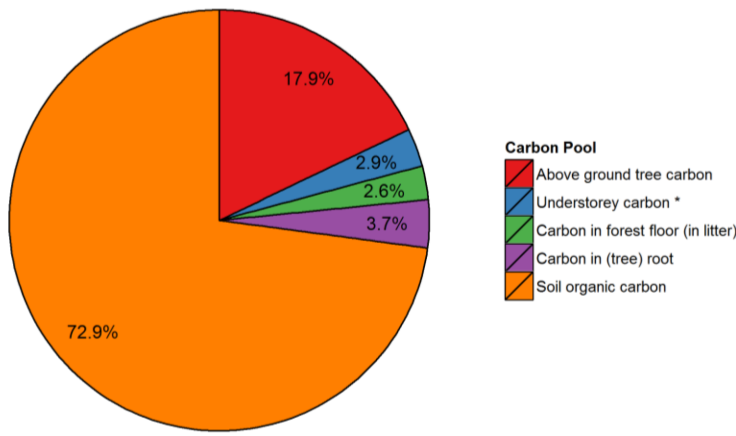


Figure 4.11 Distribution of carbon stock (t/ha) in different forest carbon pools. Soil organic carbon pool contributed 73% to total forest carbon stock.

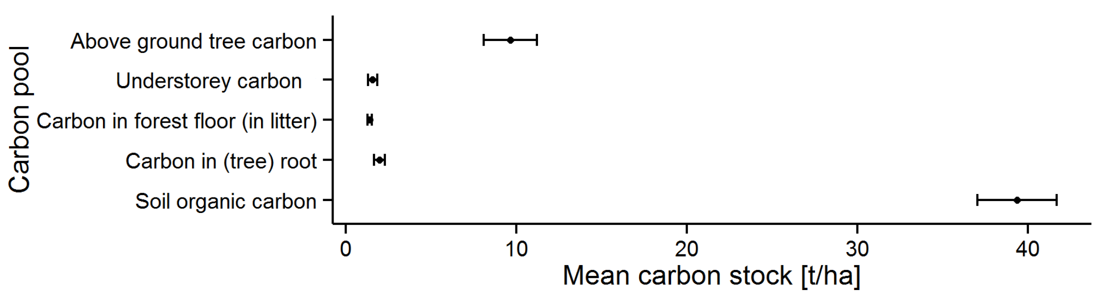


Figure 4.12 Mean carbon density (t/ha) of five different carbon pools in Dinh Hoa. Five carbon pools included above ground tree carbon, carbon in understorey biomass, carbon in litter biomass, carbon in root biomass and soil organic carbon.

4.8.2 Distribution of carbon stocks among carbon pools in natural and planted forests

Average carbon density of 56.31±5 t/ha of planted forests, was slightly higher than that of natural forests. Mean carbon density of natural forests was 53.24±3.37 t/ha (Table 4.6). Mode of forest origin did not show statistically significant effect ($\chi 2 = 3.746$, $P = 0.052$) on the carbon storage between planted forests and natural forests. Total carbon storage in above- and below ground portions of natural and planted forests varied (Table 4.6). Below ground carbon comprised 78% and 72% of the total carbon stocks of natural forests and planted forests respectively.

Table 4.6 Distribution of carbon stock (t/ha) in different forest carbon pools in natural forests and planted forests. Mean carbon density (t/ha) and its descriptive statistics: sample size, standard deviation (SD), standard error (SE) and confidence interval (CI) are given for different forest carbon pools of natural forests and planted forests.

Forest types	Description of variable	Sample size (N)	Mean	SD	SE	C I (95%)
Natural	Carbon density (t/ha)	150	53.24	21.04	1.72	3.37
	Above ground carbon density (t/ha)	150	11.57	10.82	0.88	1.73
	Above ground tree carbon (t/ha)	150	8.48	10.14	0.83	1.62
	Carbon in understorey biomass (t/ha)	150	1.62	2.03	0.17	0.33
	Carbon in litter biomass (t/ha)	150	1.46	0.99	0.08	0.16
	Below ground carbon density (t/ha)	150	41.67	18.48	1.51	2.96
	Carbon in (tree) root biomass (t/ha)	150	1.74	2.08	0.17	0.33
	Soil organic carbon (t/ha)	150	39.94	18.63	1.52	2.98
Planted	Carbon density (t/ha)	50	56.31	18.04	2.55	5.00
	Above ground carbon density (t/ha)	50	15.91	14.26	2.02	3.95
	Above ground tree carbon (t/ha)	50	13.22	13.45	1.90	3.73
	Carbon in understorey biomass (t/ha)	50	1.46	1.61	0.23	0.45
	Carbon in litter biomass (t/ha)	50	1.22	0.80	0.11	0.22
	Below ground carbon density (t/ha)	50	40.40	9.35	1.32	2.59
	Carbon in (tree) root biomass (t/ha)	50	2.71	2.76	0.39	0.76
	Soil organic carbon (t/ha)	50	37.69	9.40	1.33	2.61

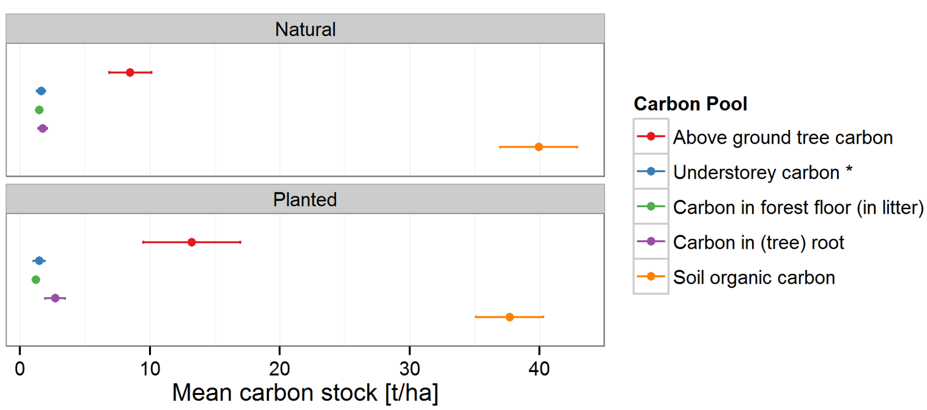


Figure 4.13 Mean carbon density (t/ha) of five different carbon pools in natural forests and planted forests.

Among the five carbon pools, SOC pool contributed 75% of the total carbon of natural forests and 67% of planted forests (Figure 4.14) with a mean carbon densities of 39.94±2.98 t/ha and 37.69±2.61 t/ha respectively (Table 4.6). Above ground tree carbon shared 16% of the total carbon of natural forest with a mean carbon density of 11.57±1.73 t/ha. The AGTC was slightly higher in planted forests than that of natural forests. The pool shared 23.5% of the total stock of planted forest with a mean carbon density of 15.91±3.95 t/ha.

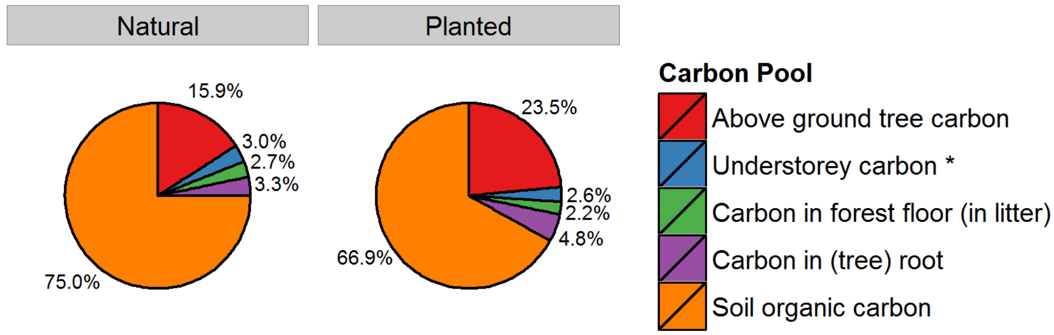


Figure 4.14 Distribution of carbon stock (t/ha) in different forest carbon pools of natural forests and planted forests. Soil organic carbon pool was the largest carbon pool in both types of forests.

4.8.3 Distribution of carbon stocks among carbon pools in Production, Protection, and Special use forests

Mean carbon densities of Production, Protection and Special use forests were 51.55±3.70 t/ha, 52.52±4.36 t/ha and 58.80± 6.61 t/ha respectively (Table 4.7, Figure 4.15). At the time of assessment, Special use forest had the highest carbon density (t/ha) among the three forest types. However, designated ecological functions did not affect the carbon density significantly (χ^2 = 1.99, P = 0.369).

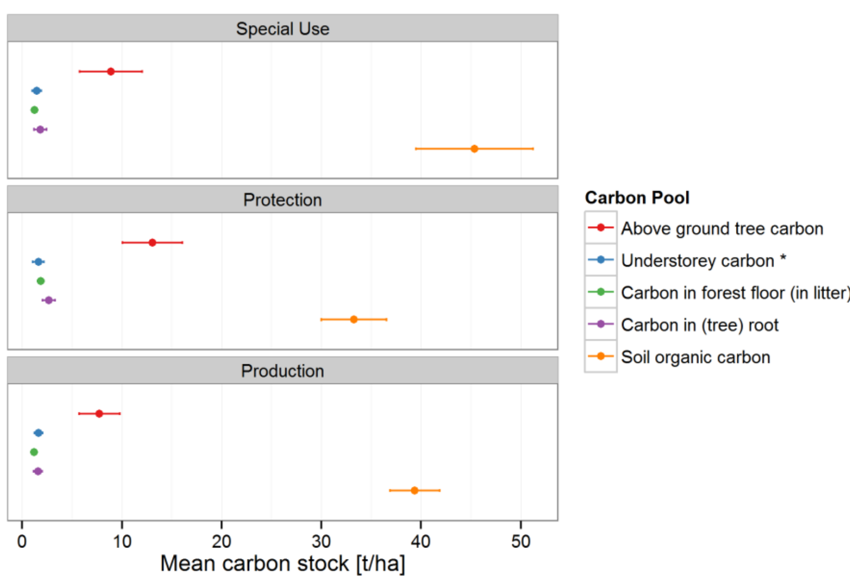


Figure 4.15 Mean carbon density (t/ha) of five different carbon pools in Special use, Protection and Production forests. Five carbon pools included above ground tree carbon, carbon in understorey biomass, carbon in litter biomass, carbon in root biomass, and soil organic carbon.

Table 4.7 Distribution of carbon stock (t/ha) in different forest carbon pools in Production, Protection, and Special use forests. Mean carbon density (t/ha) and its descriptive statistics: sample size, standard deviation (SD), standard error (SE) and confidence interval (CI) are given for different forest carbon pools of the forests.

Forest types	Description of variable	Sample size (n)	Mean	SD	SE	C I (95%)
Production	Carbon density (t/ha)	81	51.55	16.99	1.89	3.70
	Above ground carbon density (t/ha)	81	10.58	10.19	1.13	2.22
	Above ground tree carbon (t/ha)	81	7.76	9.33	1.04	2.03
	Carbon in understorey biomass (t/ha)	81	1.64	1.90	0.21	0.41
	Carbon in litter biomass (t/ha)	81	1.18	0.72	0.08	0.16
	Below ground carbon density (t/ha)	81	40.97	11.78	1.31	2.57
	Carbon in (tree) root biomass (t/ha)	81	1.59	1.91	0.21	0.42
	Soil organic carbon (t/ha)	81	39.38	11.47	1.27	2.50
Protection	Carbon density (t/ha)	59	52.52	17.10	2.23	4.36
	Above ground carbon density (t/ha)	59	16.56	12.75	1.66	3.25
	Above ground tree carbon (t/ha)	59	13.06	11.71	1.53	2.99
	Carbon in understorey biomass (t/ha)	59	1.63	2.18	0.28	0.56
	Carbon in litter biomass (t/ha)	59	1.87	1.22	0.16	0.31
	Below ground carbon density (t/ha)	59	35.96	12.43	1.62	3.17
	Carbon in (tree) root biomass (t/ha)	59	2.68	2.40	0.31	0.61
	Soil organic carbon (t/ha)	59	33.28	12.82	1.67	3.27
Special use	Carbon density (t/ha)	60	58.80	26.11	3.37	6.61
	Above ground carbon density (t/ha)	60	11.62	12.38	1.60	3.13
	Above ground tree carbon (t/ha)	60	8.92	12.40	1.60	3.14
	Carbon in understorey biomass (t/ha)	60	1.46	1.73	0.22	0.44
	Carbon in litter biomass (t/ha)	60	1.24	0.75	0.10	0.19
	Below ground carbon density (t/ha)	60	47.19	23.06	2.98	5.84
	Carbon in (tree) root biomass (t/ha)	60	1.83	2.54	0.33	0.64
	Soil organic carbon (t/ha)	60	45.36	23.24	3.00	5.88

Above ground carbon densities (t/ha) of Production, Protection, and Special use forests were 10.58±2.22 t/ha, 16.56±3.25 t/ha, and 11.62±3.13 t/ha, which represent 21%, 32% and 20% of the total carbon density of each forest type respectively. This implies carbon stocks in the forests were dominated by below ground carbon. Among the forests, Protection forest had the highest above-ground carbon density, due to the highest amount of AGTC in the forest among the three.

Among the five carbon pools, SOC was the largest carbon pool for all types of forests and far-seconded by AGTC pool. SOC pool contributed 77%, 63%, and 76% to total carbon stocks of Special use, Protection, and Production forests respectively (Figure 4.16). AGTC shared 15% of the total carbon stock of Special use forest and Production forest, and 25% of the total carbon of Protection forest. Mean AGTC densities of Production, Protection, and Special use forests were 7.76±2.03 t/ha, 13.06±2.99 t/ha, and 8.92±3.14

t/ha respectively. Carbon in understorey biomass ranged from 2.5% to 3.2%, and carbon in litter biomass ranges from 2.1% to 3.6% of the total carbon stocks of the forests.

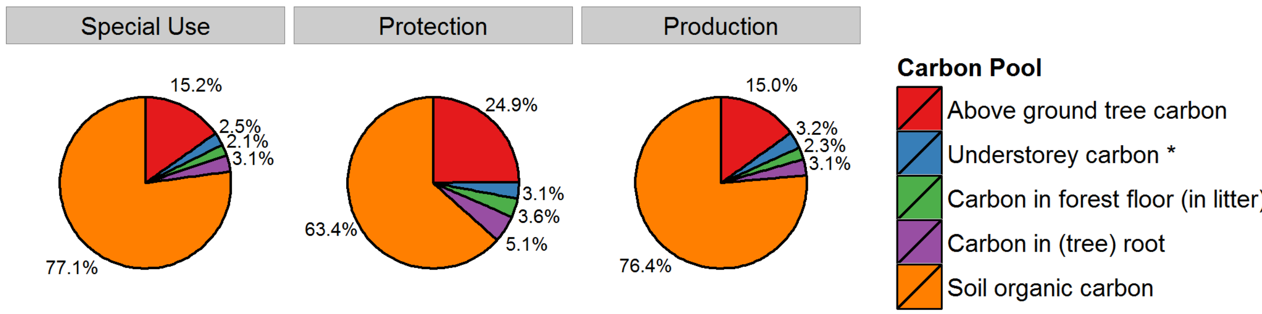


Figure 4.16 Distribution of carbon stock (t/ha) in different forest carbon pools of Special use, Protection and Production forests. Soil organic carbon pool was the largest carbon pool in all of the three types of forests.

4.8.4 Soil organic carbon

Soil organic carbon was the far-largest carbon pool containing 73% of the total carbon stock in Dinh Hoa forests. SOC pool contributed 70% to the total carbon storage of natural forests and 67% of planted forests (Figure 4.14). Though mean SOC density (t/ha) (39.94±2.98 t/ha) of natural forests was slightly higher than that (37.69±2.61) of planted forests (Table 4.6, Figure 4.17a), effect of mode of forest origin was statistically non-significant ($\chi^2 = 0.2934$, $P = 0.59$) on SOC stock of both natural and planted forests.

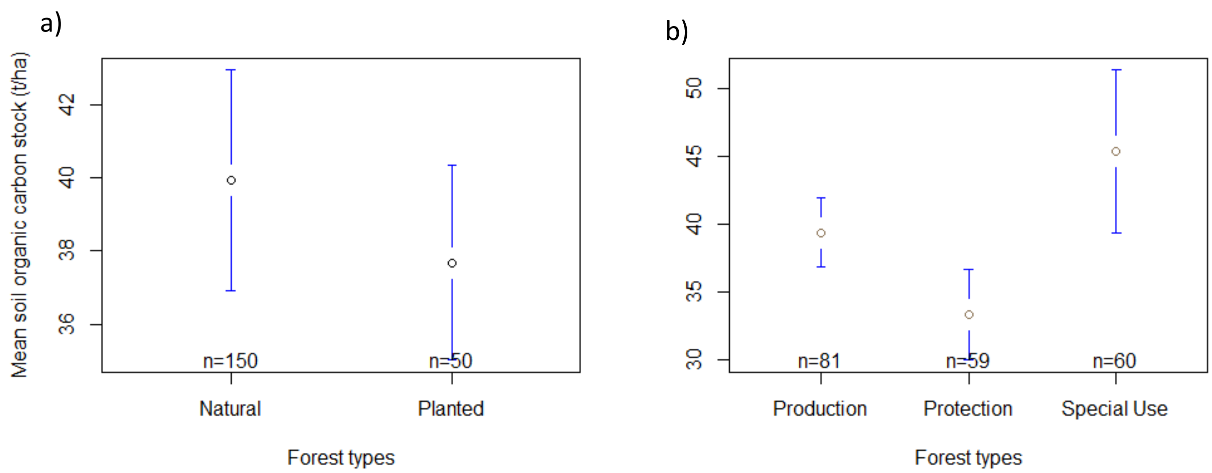


Figure 4.17 Mean soil organic carbon density (SOC) (t/ha) of different forest types. Mean SOC densities are shown according to forest types, classified based on a) mode of forest origin, and b) designated ecological function. n indicates sample size.

The designated forest function showed highly significant impact ($\chi^2 = 22.95$, $P < 0.001$) on soil organic carbon density. Special use forest contained the highest mean SOC density among the three forest types classified based on designated ecological function. Mean SOC densities of Special use, Production, and Protection forests were 45.36±5.88 t/ha, 39.38±2.50 t/ha, and 33.28±3.27 t/ha respectively.

4.8.5 Soil organic carbon and locality factors

The study examined whether soil organic carbon stocks vary predictably with biological and topographic factors of the locality, otherwise known as site factors. Locality factors included in the analysis were forest types, forest structure, canopy cover class, soil types, elevation, aspect, growth location, slope, local relief where stand was located, and plot micro relief which refers to part of the terrain where sample plot was located.

Table 4.8 Relationships between soil organic carbon density and factors of locality in Dinh Hoa. Locality factors, sample size (n), degree of freedom (f), chi-squared statistics and *P*-value are shown.

Locality factors	Sample size (n)	Degree of freedom (f)	Chi-squared χ^2	p-value
Forest types (natural and planted)	200	1	0.29	0.588^{ns}
Forest types (Production, Protection and Special use)	200	2	22.95	0.000***
Stand structure (single layer, two layer and complex)	200	2	7.00	0.030*
Canopy cover class (<10%, 10-<40%, 40-<70% and >70%)	200	3	4.64	0.20^{ns}
Soil types (feralic acrisols, rhoddic ferralsols, luvic calcisols, gleyic acrisols and dystric fluvisols)	200	4	10.06	0.039*
Aspect (north, north east, east, south east, south, south west, west and north west)	200	6	8.55	0.20^{ns}
Growth location (valley/low land, river/stream/creek side and mountain)	200	2	6.48	0.039*
Terrain relief (valley, rolling, ridge, ravine and flat)	200	4	11.94	0.017*
Sample plot micro relief (upper part of the slope, middle part of the slope, lower part of the slope and flat)	200	3	6.62	0.08^{ns}

(*** highly significant, $P < 0.001$; *significant, P = < 0.01 to 0.05; non-significant (ns) $P \geq 0.05$))

Impacts of designated ecological function of forests on SOC density was highly significant (P <0.001). However, mode of forest origin did not impose significant impacts on the same. The results are similar to the results discussed in section 4.8.2 and 4.8.3.

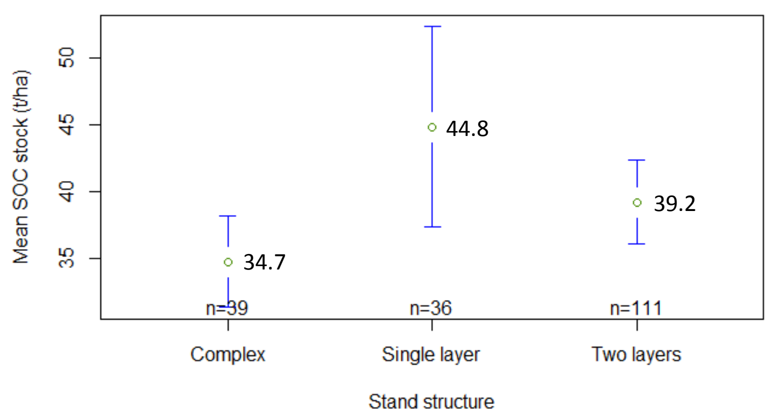


Figure 4.18 Mean soil organic carbon density (t/ha) of forests with different structures which includes single layer, two layer and complex structure.

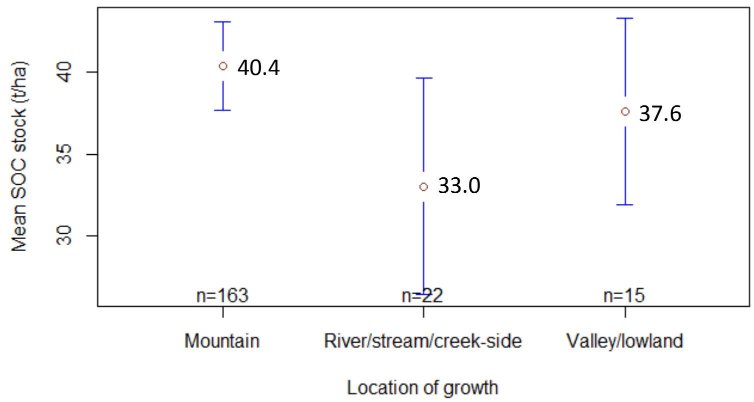


Figure 4.19 Mean soil organic carbon density (t/ha) of forests situated in different locations. The locations include mountain, valley/lowland, and river/stream/creeks-side.

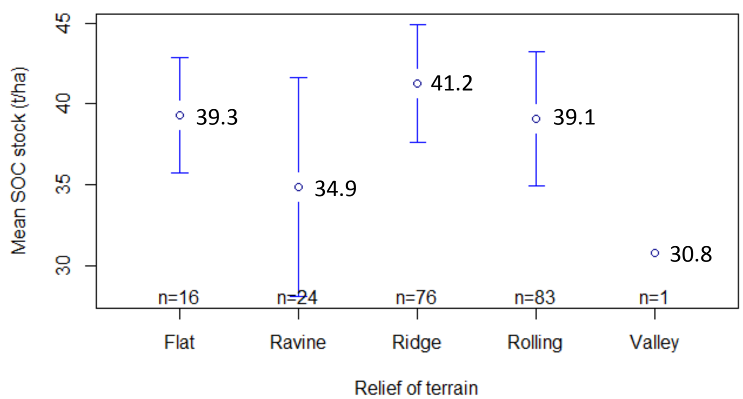


Figure 4.20 Mean soil organic carbon density (t/ha) of forests situated in different terrain relief. The terrain relief was recorded as: flat, ravine, ridge, rolling and valley.

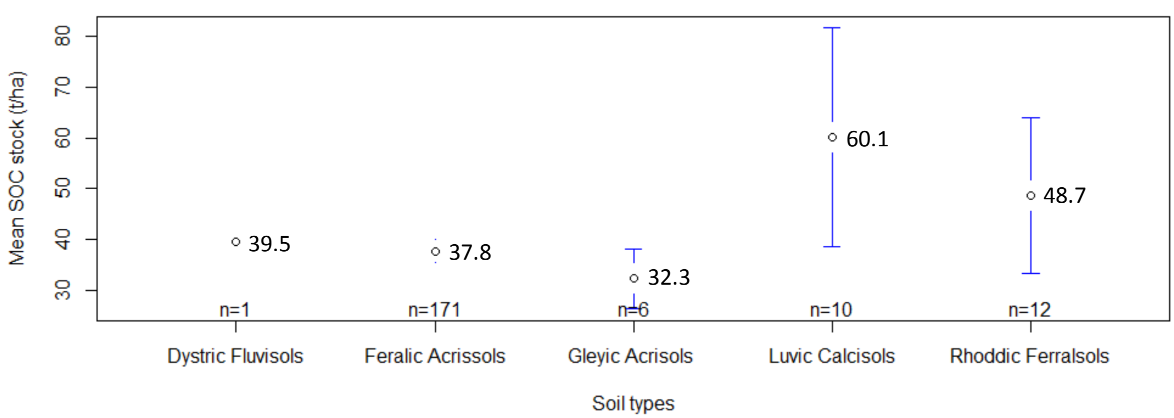


Figure 4.21 Mean soil organic carbon density (t/ha) of forests developed on different soil types. Soil types included dystric fluvisols, feralic acrisols, gleyic acrisols, luvic calcisols and rhoddic ferralsols.

Stand structure is vertical layering of a forest stand and includes simple (single layer), two layer, and complex (equal or more than three layers) structures. Mean SOC density (t/ha) of single layer, two layer, and complex forest structures were 44.8, 39.2 and 34.7 respectively (Figure 4.18). Stand structure affected the SOC density significantly (P = 0.03), but impact of canopy cover remained statistically non-significant (P = 0.20). Out of the 200 sample plots, 163, 22 and 15 plots were located in mountains, river/stream/creeks-side and valley, and mean SOC densities (t/ha) for the growth locations were 40.4, 33.0 and 37.6 respectively (Figure 4.19). Likewise, the sample plots were located in different terrain relief included flat, ravine, ridge, rolling and valley. Majority of the sample plots were located on ridge and rolling terrain. Mean SOC densities (t/ha) for the flat, ravine, ridge, rolling and valley terrain relief were 39.3, 34.8, 41.2, 39.1 and 30.8 respectively (Figure 4.20). Impacts of growth location and terrain relief on SOC density were statistically significant (Table 4.8). However, sample plot micro relief did not affect SOC density significantly.

Soil types on which forests were developed influenced SOC density significantly (P = 0.039). There were 171 composites (soil samples) from feralic acrissols and remaining 29 were from rest of the four types of soils (Figure 4.21).

Elevations of the sample plots ranged from 69 m to 732 m. There was a trend of SOC increase with increasing altitude (R^2=2%, $F_{1,198}$ = 5.84, P = 0.017). However, opposite trend was observed in relation to slope. With increasing slope, decrease in SOC (R^2=2%, $F_{1,198}$ = 4.98, P = 0.027) was observed. No association was observed between the aspect and SOC density.

4.9 Discussions

Forests were regenerating; natural forest expansion has been effective

Larger number of seedlings and saplings, lower number of trees with dbh ≥5cm, and average tree diameter (dbh) less than 12 cm indicated most of forests in the district were regrowth natural forests and dominated by young plantations. The forests were regenerating either following heavy exploitation of timber or in abandoned agricultural land or unused land, i.e., natural forest expansion. The natural forest expansion has been effective due to protection of severely degraded forest patches and barren forest land.

Uneven-aged mixed natural forests

Diameter distribution curves constructed for all types (based on mode of forest origin, and designated ecological function) of forests confirmed reverse-J shaped curve. For natural forests, the reverse-J shaped curve indicates an uneven aged mixed forest. The pattern of stem number distribution (based on breast height diameter distribution) is assumed to be stable. In the study, distribution of tree stem was presented according to measured tree size thresholds, i.e., seedling, sapling, small tree and big tree.

Forests of reduced (or low) harvesting potentials

Average stand diameter (QMD) of 12.17 cm of natural forests indicated that forests were in early stage of development, however, few remnants were still present and distributed sparsely. Low number of trees in larger diameter classes and the *QMD* of ~ 12 cm showed reduced availability of natural forest for timber harvest. Further, QMD of 11.1 cm of planted forests implied either plantations in the district were in early stage (i.e., newly established), or the plantations were being managed under short rotation cycle. Given the reduced harvesting potential of natural forests, short rotation plantations (for instance, acacia 7.6 years) (chapter 6), and timber demand of 0.98 m^3/household/year (chapter 7), a question might raise here about the source from which the timber demand has been met. If this situation prolonged, it might exert more pressure, particularly of illegal logging, on remaining natural forests, or (negative) 'spill over' effect onto protected areas might occur.

Forests of high tree species diversity

Dinh Hoa contains a great diversity in bio-physiographic and climatic condition. Forest vegetation within the district significantly differs in terms of spatial and vertical structures, and geographical locations. Diverse climatic and geographic conditions explain its diversity of natural forest formations. Natural forest formations include Evergreen-Broadleaf forests, Bamboo forest, Mixed Wood and Bamboo forest, Palm forest, forest over the Limestone Mountains, and Pristine forest, which made the district rich in flora and fauna. During forest inventory, 257 tree species belonged to 62 families were found among 2419 tallied trees (≥ 5 cm dbh). Including species of trees <5 cm dbh, total number of species reached to 430. Tree species of medicinal aromatic plants (MAPs) and NTFPs were recorded during forest inventory but not included in this analysis.

Under/poorly stocked forests

Estimated mean stem volume of 40 m^3/ha of live trees (dbh ≥5cm), was considerably lower than average national growing stock, i.e., 63 m^3/ha (in 2010) (FAO, 2010b). This finding suggested that forests were poorly stocked in the district. However, the volume calculation did not include deadwoods, stumps and broken/topped/lopped trees. Tree stumps were included while estimating the national growing stock.

In 2010, planted forests had 23 m^3/ha growing stock, on average, in the country. Though natural forests were poorly stocked (i.e., 35 m^3/ha) in Dinh Hoa, mean stem volume of 55.45 m^3/ha of planted forests in the district, was significantly higher compared to the country average.

Natural forest expansion contributing low average growing stock and small average tree diameter

In 2005, estimated mean growing stock for entire forest of the country was 78 m^3/ha. Between 2005 and 2010, the growing stock has been increased by 1.5-2% per year (FAO, 2010b). With the increased rate of growing stock, the total growing stock of the country was expected to be higher in 2010. According to FAO (2010a), it was found to be only 74m^3/ha. The possible explanation for this might be natural forest expansion which resulted in the increased area but of low growing stock (FAO, 2010a). The same phenomenon might apply in Dinh Hoa. Most of the natural forests in the district were thriving with natural regeneration either after heavy exploitation in the past, or regenerating on abandoned agricultural and bare lands (chapter 5). The expansion of natural forest with low growing stock, might contributed to the small average tree diameter (QMD) in natural forests of the district.

Substantially lower above ground biomass

In Dinh Hoa forests, above ground biomass density was 25.31 t/ha, which was substantially lower than the country average of 120 t/ha. Average above ground tree biomass (AGTB) density of Dinh Hoa forest was 19.34 t/ha. AGTB density contained 76% of the total above-ground biomass density. Shares of understorey biomass, and biomass in litter were substantially lower. That implies the lower AGTB density contributed to the lower total above ground biomass density. As discussed earlier, observed low growing stock in Dinh Hoa forests as a result of natural forest expansion, and exclusion of stumps and deadwoods while calculating above ground growing stock, might have resulted in the low above ground biomass density. FAO (2010a) defines above ground biomass as the sum of all living biomass above soil including stem, stump, branches, bark, seeds, and foliage. Since no data on biomass was available at the country level, forest resource assessments in Vietnam have been using IPCC default values for conversion (Conifers: 0.9, broadleaved: 2) from growing stock to biomass. For below ground biomass the coefficient of 0.275 has been adopted.

Estimated AGTB density of Dinh Hoa forests was much more conservative estimate in many ways. The study used a compound variable ($\rho\, {d_{1.3}}^2 h$) as only predictor of the AGTB. If a tree has a $\rho\, {d_{1.3}}^2 h$ value less than 50[31], the tree was not included in biomass calculation (chapter 3). The AGTB calculation included only living standing trees, and excluded dead, fallen, broken, topped and lopped trees. Standing and fallen dead trees were recorded as deadwood in a separate form. In the compound variable, ρ is wood specific gravity (g/cm^3) based on oven-dry weight over green volume. Most of the tree species recorded in the study was lesser known species. The wood specific gravity values for many of the tree species were in a range of minimum value to maximum value. Wherever the values were given in a range, the study used the lowermost value. For example, we found wood density of *Ficus fistolosa* to be 0.430-0.470 - 0.530 g/cm^3. The lowest value of 0.430 was chosen for biomass estimation, and hence, resulted in lower biomass estimation for the trees of the species. Importantly, the AGTB estimate excluded bamboo and palm. Bamboos are one of the major forest ecosystems in the district.

Forest management regimes/objectives significantly affected the quantity of above ground biomass

Results showed designated ecological function or use purpose of forests, i.e., production, protection and special use imposed significant effects on above ground tree biomass. Impact of mode of forest origin was statistically non-significant. Nevertheless, *P*- value (0.052) was quite near to upper value of significance threshold (i.e., 0.05). The results indicated forest management regimes/objectives were major determinants of the AGTB pool of the forests.

Lower carbon density because of exclusion of substantial amount of carbon in bamboo

Expansion of natural forests generally with low growing-stock, and short-rotation plantation contributed to lower forest carbon densities in the district. Average carbon density of Dinh Hoa forests (54 t/ha) was found nearly half compared to the country average. For 2010, average carbon density for the country was estimated to be 124 t/ha (FAO, 2010a, b). The country carbon stock estimates were solely based on conversion factors and IPCC default values. FAO (2010a) estimated country average of carbon in above ground biomass to be 61.6 t/ha which includes carbon in litter (5.2 t/ha). The country average above

[31] Model restriction/constraint

ground carbon density, was immensely higher than Dinh Hoa average of 12.65 t/ha. One of the potential reasons for the substantially low above ground carbon density in the district compared to the country average might be the exclusion of carbon in bamboo (forest) and palm from the calculation.

Below ground carbon pool included soil organic carbon and carbon in tree root. The study estimated the root carbon density to be 1.98 t/ha. Dinh Hoa forest comprised Bamboo forest and Mixed Wood and Bamboo Forest formations. In the estimate, bamboo was excluded which comprises dense and strong rooting system. Substantial amount of carbon was recorded in the bamboo root system. Isagi (1994) found that above ground carbon stock and below ground carbon stock for a bamboo species (*Phyllostachys bambusoides*) to be 52.3 t/ha and 20.8 t/ha (in Japan) respectively. In Malaysia, above ground biomass of *Gigantochloa scortechnii* was found to be 71.9 t/ha (Panda, 2011, p.236). Similarly, Singh and Singh (1999) found total biomass of *Dendrocalamus strictus* (Roxb.) Nees to be 46.9 t/ha in 3-year old and 74.7 t/ha in 5-year old plantations in a dry tropical region of India.

Soil organic carbon was the largest carbon pool

Soil organic carbon pool was the largest carbon pool for all of the forest types found in the district. The above ground carbon was far-second carbon pool. Despite substantial difference in carbon in above ground biomass between country average and the study area average, soil organic carbon density of the study area (39.37 t/ha) was close to country average of 47.2 t/ha. For the country, the soil organic carbon density was estimated using IPCC default value of 47 t/ha (Tropical, moist climate region; soils with low activity clay).

Mode of forest origin did not influence soil organic carbon stock, but designated ecological functions

Mean soil organic carbon density was slightly higher in natural forests than in planted forests, however, the difference was not statistically significant. On the contrary, the forest types based on designated ecological function showed highly significant impact on soil organic carbon stock. The Special use forest constituted the largest stock of soil organic carbon.

Canopy cover affected above ground tree carbon density, and total above ground carbon density, but not soil organic carbon density and total carbon density

Mean above ground tree carbon density ranged from 0.87 t/ha to 12.92 t/ha for different canopy cover classes. The canopy cover class imposed highly significant impacts on both above ground tree carbon (P <0.001) and on the total above ground carbon density (P <0.001). However, impact of canopy cover class on total forest carbon density (sum of above ground and below ground carbon density) was statistically non-significant. The absence of impact on the total forest carbon density might have resulted due to soil organic carbon pool. Soil organic carbon pool was the largest carbon pool in the forests, and was not affected by the crown cover.

Stand structure affected carbon density significantly

Impacts of stand structure on carbon pools, namely above ground tree carbon, soil organic carbon and total forest carbon densities, were significant. Above ground tree carbon was highly affected by the forest structures.

Significant impacts of soil types on soil organic carbon stock, but non-significant impacts on total carbon stock

Though impact of soil types on forest carbon density was statistically non-significant, there was a significant impact on soil organic carbon density. Similar result was observed by Chaplot et al. (2010) in Laos, where the study assessed the impact of soil types on the soil organic carbon stocks at 0.3 m depth.

Non-significant impacts of aspects on total forest carbon stock and soil organic carbon stock

Slope aspects did not have statistically significant impacts on soil organic carbon density and total carbon density. On the contrary, Sharma et al. (2011) observed soil organic carbon and total carbon densities were significantly higher on northern aspects (northeast and northwest) as compared with southern aspects (southeast and southwest).

Significant impacts of altitude and slope on soil organic carbon stock

Present study found significant impacts of altitude and slope on soil organic carbon stocks. With increasing altitude and decreasing slope, soil organic carbon increases. Studies have found mixed result of altitude and slope gradient affecting carbon density. Similar effects of altitude on soil organic carbon density have been reported by Chaplot et al. (2010). While in the same study, they found non-significant impact of slope gradient on soil organic carbon stock. Sheikh et al. (2009) observed the opposite trend of decreasing soil organic carbon stocks with increasing altitude in Oak (*Quercus leucotrichofora*) and chir pine (*Pinus roxberghii*) forest in India. Higher altitude are associated with the lower mean annual temperature which may increase soil organic carbon storage due to reduction in soil organic carbon turnover (Chaplot et al., 2010; Davidson and Janssens, 2006).

5 Results and discussions: land use/land cover change

5.1 Dinh Hoa district comprised of a mosaic of diverse landscapes

Based on the Land use/land cover (LULC) classification systems adopted by General Department of Land Administration (GDLA) under MONRE, and Forest Inventory and Planning Institute (FIPI) under MARD, the study found several land-use/land-covers in Dinh Hoa district. Likewise, following the forest classification schemes suggested by MARD's Circular 34/2009/TT; a number of forest types (according to mode of forest origin, tree species and leaf phenology, and site conditions) were recorded (Table 5.1). The larger numbers of LULC types and forest ecosystems have built a mosaic of diverse landscapes in the district.

Table 5.1 Land use/land cover (LULC) and forest types found in Dinh Hoa district. LULCs are shown under two broader categories: forested land and non-forested land. The LULCs including forest types are mentioned in English and Vietnamese.

Category (in English)	Category (in Vietnamese)
Forested land	Đất có rừng
Evergreen - Broadleaf forest - Medium	Rừng lá rộng thường xanh trung bình
Evergreen - Broadleaf forest - Poor	Rừng lá rộng thường xanh nghèo
Evergreen - Broadleaf forest - Regrowth	Rừng lá rộng thường xanh phục hồi
Bamboo forest	Rừng tre nứa
Mixed Wood and Bamboo forest	Rừng hỗn giao gỗ tre nứa
Limestone forest	Rừng núi đá
Planted forest	Rừng trồng
Non forested land	Đất không rừng
Limestone area	Núi đá không cây
Bare land planned for forestry	Đất trống
Water area	Mặt nước
Residential area	Dân cư
Other land	Đất khác

5.2 Forests cover majority of land area of Dinh Hoa district

In 2010, forest lands were extended to an area of approximately 31000 ha in Dinh Hoa district. Forests (forest areas) were evenly distributed throughout the district. Out of the total forest area, natural forests accounted for 53% and planted forests for 47% of the area (Table 5.2).

5.3 Total forest area has been increased

By year 2010, forest area has nearly doubled compared to the area in 1993. The forest area was expanded from 15556 ha in 1993 to 30991 ha in 2010 (Figure 5.1). The increase corresponds to an average annual increment of 908 ha/year. Table 5.2 presents area (ha) of LULC including forest types in Dinh Hoa for the year of 1993, 2000, 2006 and 2010.

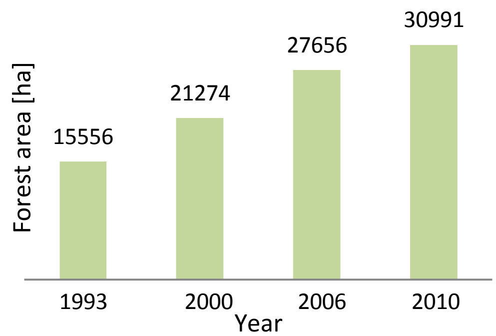


Figure 5.1 Forest area change from 1993 to 2010 in Dinh Hoa district, Vietnam. Total forest area has gradually increased from 1993 to 2010.

Table 5.2 Land use/land cover (LULC) and forest types, and their corresponding area (ha) in Dinh Hoa district, Vietnam. LULCs and forest types in Dinh Hoa, notation used to describe them and their corresponding area (ha) for the year of 1993, 2000, 2006 and 2010 are given.

Land use category	Notation used	Year of assessments			
		1993	2000	2006	2010
Forest land	FL	15556	21274	27656	30991
Natural forest	NF	15026	19171	20843	16518
Evergreen - Broadleaf forest - Medium	EBM	292	101	223	204
Evergreen-Broadleaf forest - Poor	EBP	815	415	356	313
Evergreen - Broadleaf forest – Regrowth/Restored	EBR	5150	8497	11329	8266
Bamboo forest	BF	1105	851	401	540
Mixed Wood and Bamboo forest	WBF	7491	9134	8359	7021
Limestone forest	LM	174	174	174	174
Plantation forest	PL	531	2103	6813	14473
Non-forested land	NFL	35786	30068	23686	20351
Limestone area	LA	1931	1931	1931	1931
Bare land planned for forestry	BL	14533	8438	4680	2763
Water area	WA	595	596	608	612
Residential area	RA	2079	2304	2887	2907
Other land	OL	16648	16799	13580	12138
Total district land area		51342	51342	51342	51342

Note:

Forest land (FL) = NF + PL;

Non-forested land (NFL) = LA + BL + WA + RA + OL;

Natural forest area (NF) = EBM + EBP + EBR + BF + WBF + LM;

Total district land area = FL + NFL

5.4 Natural forest area soaring upwards until 2006, but backsliding in recent years

The study observed different trends in natural forest area change: soaring upwards by 447 ha per annum from 1993 to 2006; and backsliding by 4324 ha in total from 2006 to 2010 (Figure 5.2). According to discussions with experts and local people, the reduction of natural forest area was associated with Circular 99/TT-BNN issued by MARD dated November 6, 2006. The circular authorizes forest management boards to allocate (severely) degraded natural forests (such as, EBP, BF and WBF) to recognized stakeholders (by law) including households to establish productive plantations of commercially valuable species, such as acacia and eucalypts. Pursuant to the circular, allocation of degraded natural forest area to the local stakeholders (for instance, households, forest enterprises) might have contributed to the reduction of natural forest area after 2006.

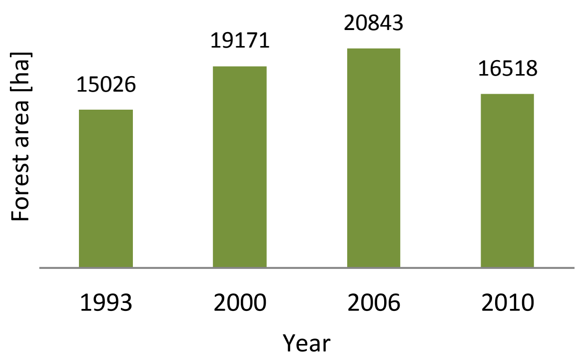


Figure 5.2 Changes in natural forest area from 1993 to 2010 in Dinh Hoa district, Vietnam. Increasing trend of natural forest area until 2006 and declining trend thereafter is apparent.

5.5 Increasing forest plantations- with differing increment rate (area) for different periods corresponding to different policy instruments

Forest trees were planted mainly for commercial purposes, particularly for timber, pulp and veneer, and made up an estimated area of 14473 ha, nearly half of the total forest area of the district. Between 1993 and 2010, area of planted forests increased by 820 ha per year (Figure 5.3). Most of the plantations were established in the forest lands allocated to individual households. The increment in forest plantations between years differed significantly. Between 1993 and 2000, the average increment of the planted area was about 225 ha per year. For that period, forest plantations were mostly established under the Program 327: re-greening bare hills and PAM project.

Establishment of forest plantations increased significantly between 2000 and 2006 under Five Million Hectares Reforestation Program (5MHRP). For the period, average annual increment in the area of planted forest was about 785 ha per year. The circular 99/TT-BNN issued by MARD in 2006 (section 5.4) played a crucial role for the exponential increase in forest plantations after 2006. Average annual increment rate in the area of planted forest was estimated to be more than 1900 ha per year for the period of 2006 to 2010.

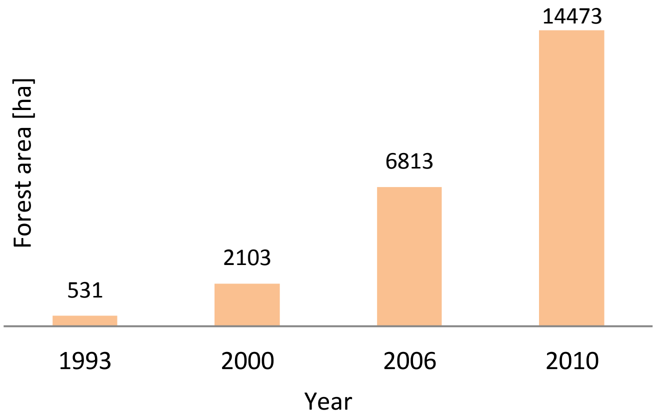


Figure 5.3 Changes in planted forest area from 1993 to 2010 in Dinh Hoa district, Vietnam. Planted forest area has increased at almost exponentially between 2003 and 2010.

5.6 Exponentially increasing forest plantations contributing net gain in forest area

Immense increase in afforestation and gradual expansion of natural forests in the district contributed to overall increase in total forest area between 1993 and 2006. However, as discussed in section 5.4, natural forest area showed decreasing trend after 2006. Between 2006 and 2010, natural forest area declined by 1081 ha per annum, but planted forest area increased by 1900 ha per year for the same period. The exponential increase in planted forest area contributed to net gain in forest area (Figure 5.4).

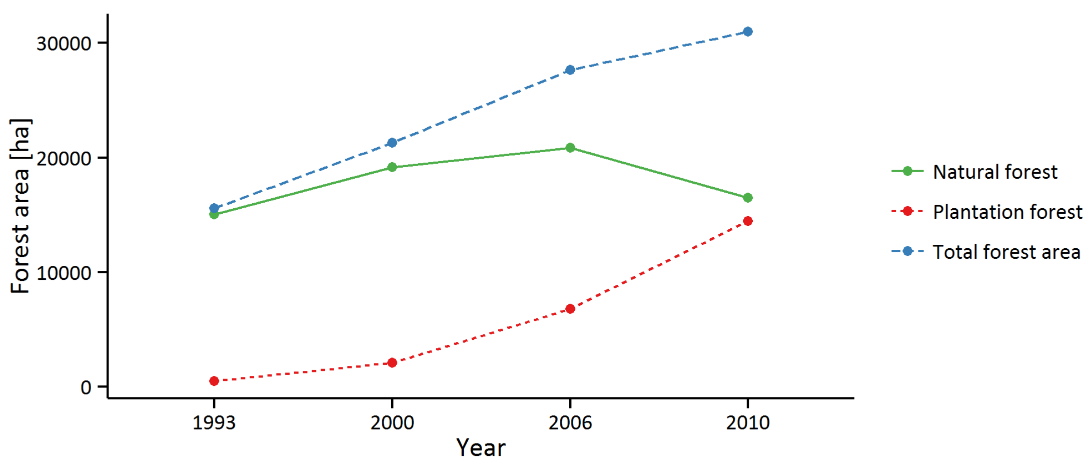


Figure 5.4 Forest cover change trends in Dinh Hoa district, Vietnam from 1993 to 2010. Planted forest area showed a clear trend of area increase. Natural forest area showed declining trend after 2006.

5.7 Increasing plantation area at the expense of non-forested land and degraded natural forests

Most of the plantations were established in bare lands since 1993, and after clearing degraded forest land particularly after 2006. In 1993, the ratio of non-forested land area: natural forest area: planted forest area was 67.4: 28.3: 1. The ratio in 2010 was 1.4: 1.1: 1. The change in the ratio suggested expansion of planted forest and the substantial shrinkage in non-forest land. Considerable reduction in natural forest area can be observed after 2006 (Figure 5.5).

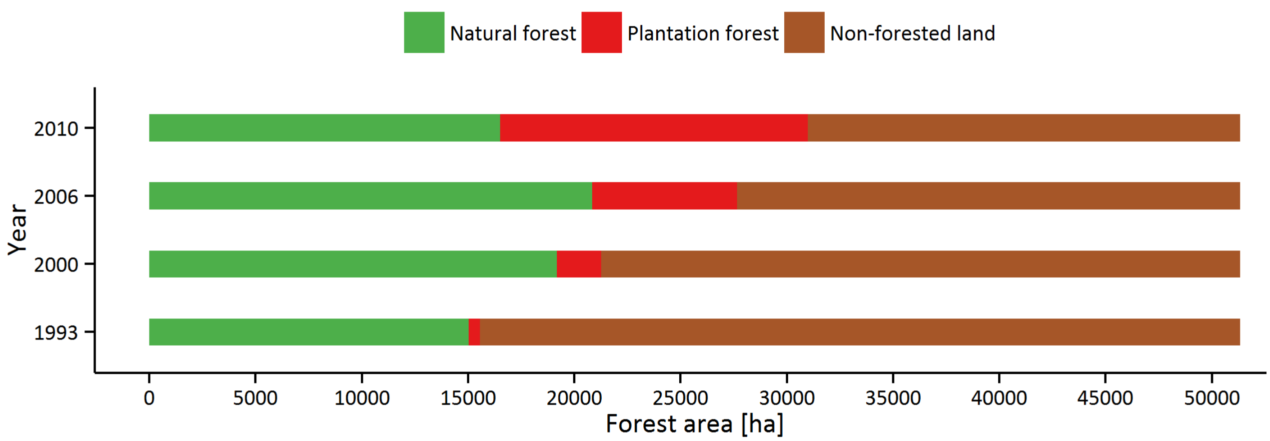


Figure 5.5 Transition of non-forested land to forested lands during year 1993 to 2010. Expanding planted forests and reducing non-forested land over the past 17 years.

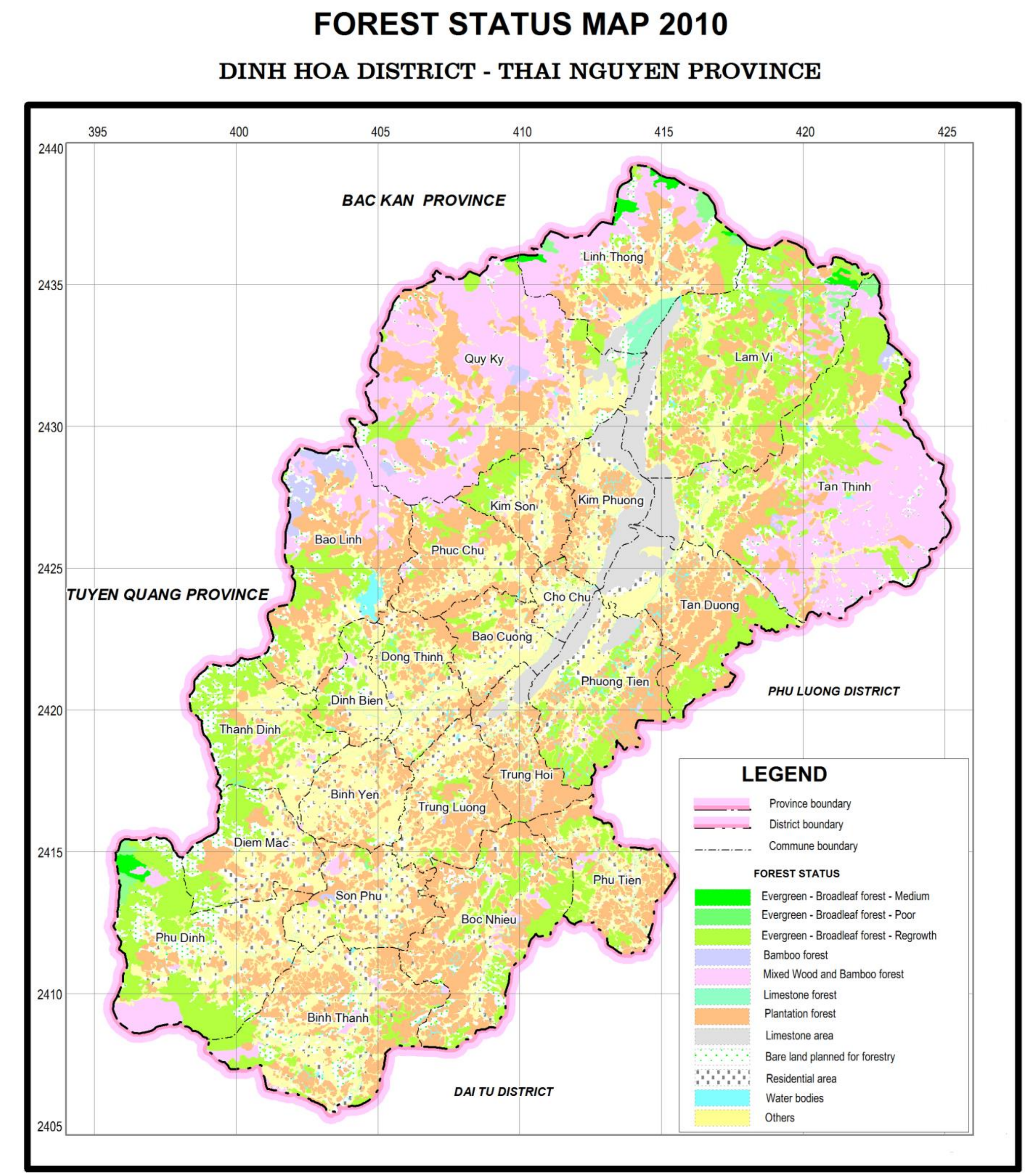


Figure 5.6 Forest status map (2010) of Dinh Hoa district, Vietnam.

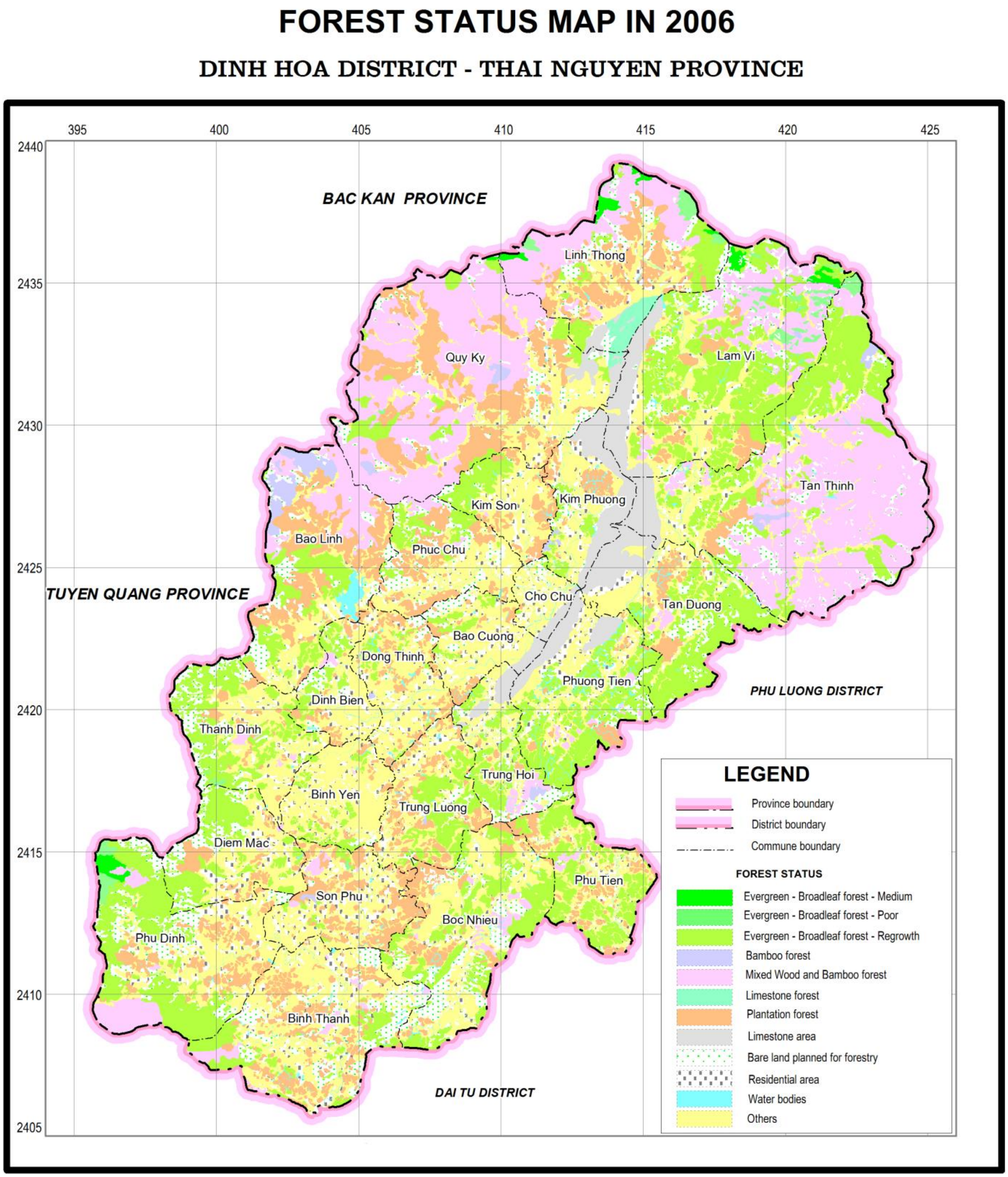


Figure 5.7 Forest status map (2006) of Dinh Hoa district, Vietnam.

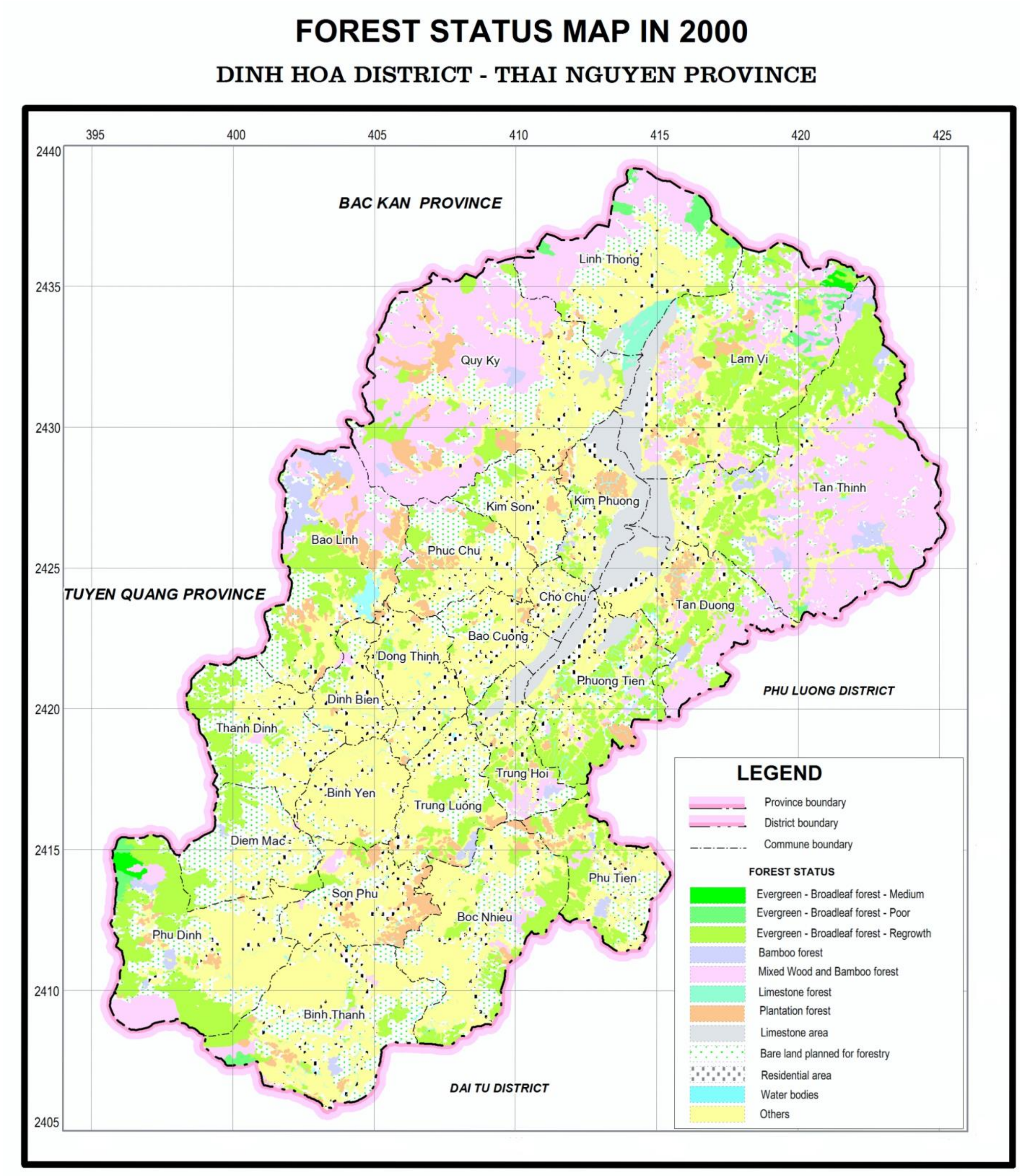


Figure 5.8 Forest status map (2000) of Dinh Hoa district, Vietnam.

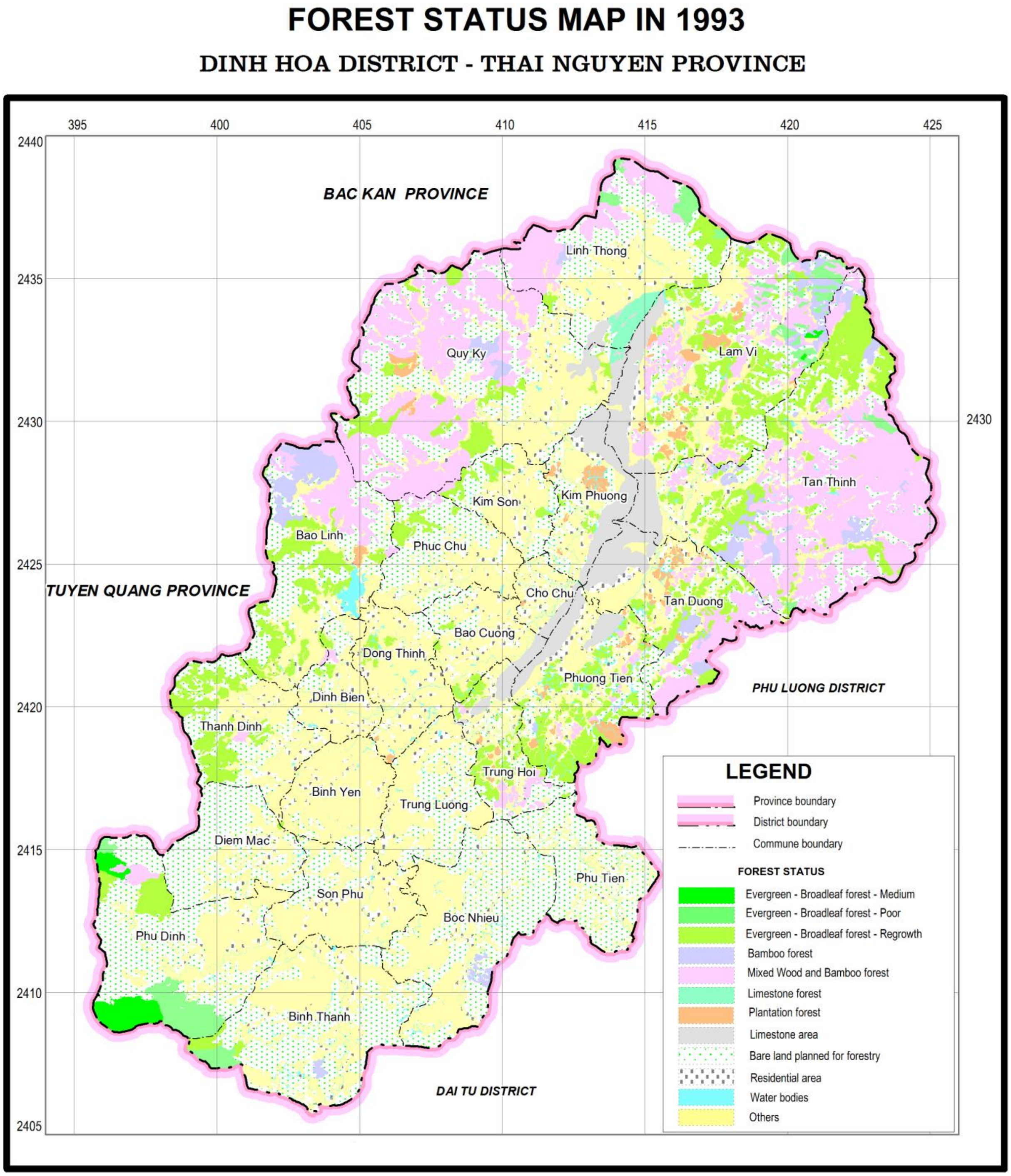


Figure 5.9 Forest status map (1993) of Dinh Hoa district, Vietnam.

5.8 Decline in non-forested land area

Decree 22/2007/QĐ-BTNMT specified that non-forested land refers to non-agricultural lands, bare lands (such as barren areas, Rocky Mountains without trees), and open water and coastal area including river bank. Non-agricultural lands includes residential area, land for special use (such as land for state owned institutions, military area, industrial area, public infrastructures and public services, markets, historical monuments, waste disposal), religious area, cemetery and other non-agricultural land (Other land). The study observed gradual but significant reductions in the area of bare lands and other lands (Figure 5.10) between 1993 and 2010.

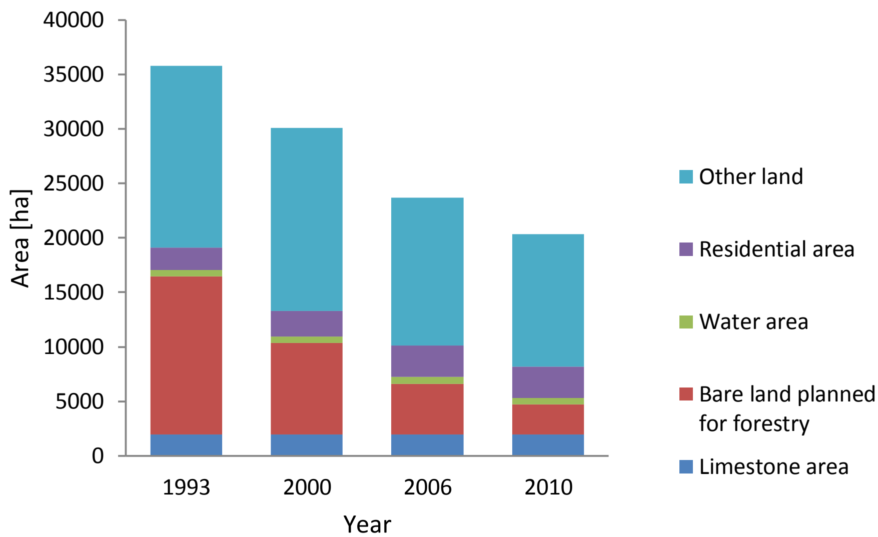


Figure 5.10 Changes in non-forested land area from 1993 to 2010. Non-forested land has shown a clear decreasing trend between 1993 and 2010.

Between 1993 and 2010, non-forested land decreased by 43%, with an average annual rate of 900 ha/year. Within the non-forested land, Bare land planned for forestry reduced drastically. The land decreased by 81%, with an average annual rate of nearly 700 ha/year. At the same time, forest plantation has increased by 820 ha/year (section 5.6) for the period of 1993-2010. The results indicated most of the bare lands and other non-agricultural lands; particularly Bare land planned for forestry, have been rehabilitated and afforested through assisted natural regeneration (ANR) and afforestation and reforestation (A/R) activities under the nation-wide forest reforestation programs such as Program 327 and Program 661 (5MHRP).

5.9 Forest dominated by low growing stock Evergreen Broadleaf Regrowth forest and Mixed Wood and Bamboo forest

Natural forest formations in Dinh Hoa district included Evergreen - Broadleaf forest – Medium (EBM) (101 < standing volume (V) ≤ 200 m^3/ha)) (MARD, 2009; Hai et al., 2015), Evergreen - Broadleaf forest – Poor (EBP) (10 m^3/ha < V ≤ 100 m^3/ha), Evergreen - Broadleaf forest – Regrowth/Restored (EBR), Bamboo forest (BF), Mixed wood and Bamboo forests (WBF), and limestone forests (forests over the rocky Limestone Mountains) (Table 5.1). EBR and WBF have been overwhelmingly dominated the natural forest formations since 1993 to 2010 (Figure 5.6, 5.7, 5.8, and 5.9). Well-stocked (standing volume >300 m^3/ha) Evergreen Broadleaf-rich forest was not recorded for the entire period. The complete absence of the Evergreen Broadleaf-rich forest indicated over exploitation of Dinh Hoa forest in the past.

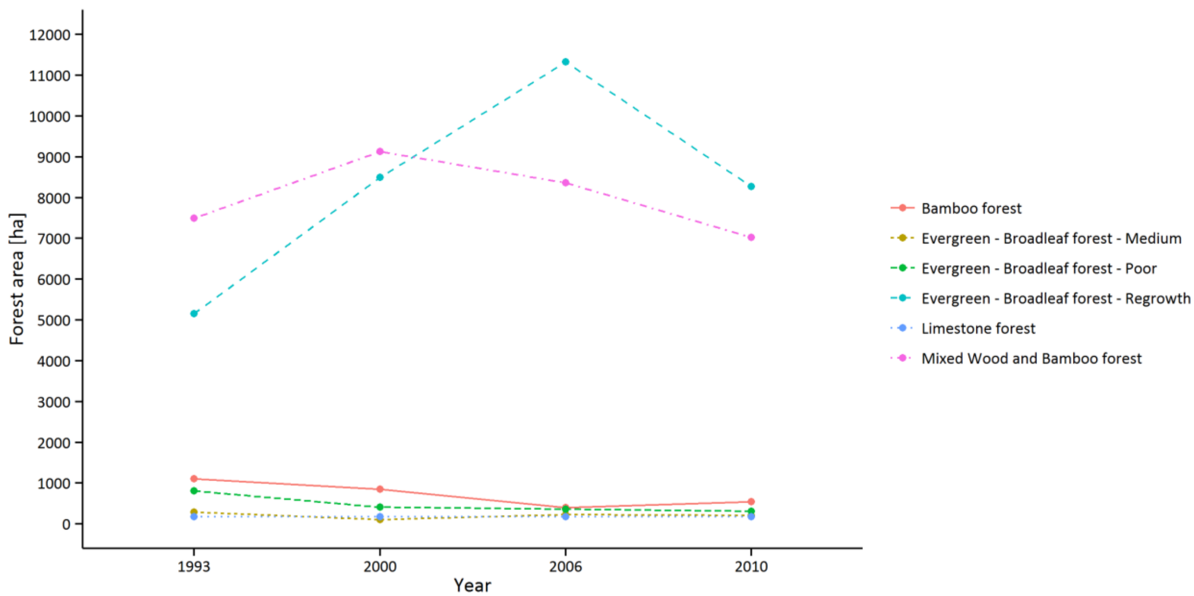


Figure 5.11 Forest cover trends of natural forest formations in Dinh Hoa district, Vietnam from 1993 to 2010. Decreasing trends of major forest formations after 2006 were observed.

In 2010, EBR accounted for 50% and WBF accounted for 42.5% of the total area of natural forests in the district. Despite the domination, both forest formations showed a sharp declining trend (Figure 5.11) in the last decade. WBF area was gradually increased from 1993 until 2000, but declined by 210 ha/year after 2000. Likewise, EBR area was increased until 2006, but has been decreasing by 766 ha annually after 2006.

5.10 Forest ecosystems are evenly distributed throughout the district; distribution of particular forest formations (types) are localized to particular geographic area of the district

Forest ecosystems are evenly distributed throughout the district in Dinh Hoa (Figure 5.6). The Evergreen - Broadleaf forest – Regrowth/Restored (EBR) was observed throughout the district. The distribution indicated forest rehabilitation programs such as Program 327 and Program 661 (5MHRP) have been effective to achieve their goal of forest rehabilitation/restoration. Most of the natural forest formations are found in higher elevation (more than 250 m) of the district. The EBR is highly concentrated in northeastern (Lam Vi and Tan Thinh communes) and southeastern (Phu Dinh, Thanh Dinh communes) parts of the district. While Mixed wood and Bamboo forest was concentrated on northern part (Quy Ky, Linh Thong and Tan Thinh communes). Planted forests occupied lowland of the entire district and mainly were concentrated in the central and southeastern parts (Figure 5.6).

5.11 Period of restoration of bare land and plantation initiation: 1993 - 2000

In 1993-2000 period, transition between forest and other land categories took place mainly in the Evergreen - Broadleaf forest – Regrowth/Restored (EBR), Mixed wood and Bamboo forests (WBF), and Bamboo forest (BF). Plantations in bare land and other land, and conversion of small amount of the EBR, WBF and BF, quadrupled the planted forest area.

Table 5.3 Land-use/land cover change matrix: 1993 - 2000

1993	2000												Total
	EBM	EBP	EBR	BF	WBF	LM	PL	LA	BL	WA	RA	OL	
EBM	61	14			217								292
EBP	39	327	366		81				2				815
EBR		48	4675		22		50		334			21	5150
BF			101	529	271		37		109			57	1105
WBF		27	173	6	7052		163		60			10	7491
LM						174							174
PL							530					1	531
LA								1.931					1931
BL			3117	316	1409		813		7788	1	55	1034	14533
WA										595			595
RA											2079		2079
OL			65		83		510		144	0	170	15675	16648
Total	101	415	8497	851	9134	174	2103	1931	8438	596	2304	16799	**51342**

EBM= Evergreen-Broadleaf forest–Medium; EBP= Evergreen-Broadleaf forest-Poor; EBR= Evergreen-Broadleaf forest–Regrowth/Restored; BF= Bamboo forest; WBF= Mixed Wood and Bamboo forest; LM= Limestone forest (forest over the Limestone Mountain); PL= Plantation (Planted) forest; LA= Limestone area; BL= Bare land planned for forestry; WA= Water area; RA= Residential area; and OL= Other land.

During the period, more than 3000 ha of bare land were converted to EBR. Similarly, 1400 ha of bare land was transformed to WBF. This showed a huge expansion of the natural forests in the bare land. The natural forest expansion suggested restoration activities, particularly in hilly region of the district, were effectively implemented in the period. Evergreen - Broadleaf forest – Medium (EBM) reduced to one-third. Out of 292 ha EBM in 1993, 217 ha was converted to WBF in 2010. Similarly, nearly half of area of Evergreen-Broadleaf forest- Poor (EBP) converted to EBR. The reductions in the area of EBM and EBP suggested forest degradation led by intensive selective cutting in the forests. Forest over the Limestone Mountains (LM) remained stable for the period.

5.12 Period of transformation of bare and other land to forest plantations, and restoration of natural forests: 2000 - 2006

For the period of 2000-2006, forest conversion mostly occurred in Evergreen - Broadleaf forest – Regrowth/Restored (EBR), and Mixed wood and Bamboo forests (WBF). The EBR was increased by 2832 ha and the WBF decreased by 774 ha. More than 850 ha of WBF converted to EBR. Bare land planned for forestry (BL) and Other land (OL) shrank by 3758 ha and 3219 ha respectively during the period.

Table 5.4 Land-use/land cover change matrix: 2000 - 2006

2000	2006												Total
	EBM	**EBP**	**EBR**	**BF**	**WBF**	**LM**	**PL**	**LA**	**BL**	**WA**	**RA**	**OL**	
EBM	101												101
EBP	29	300	57		29								415
EBR	39	14	7361		31		673		314	0		64	8497
BF			167	344	166		109		63			1	851
WBF	55	42	866		7572		383		201		1	14	9134
LM						174							174
PL			50		2		2023		16		0	12	2103
LA								1931					1931
BL			2372	52	434		1524		3461	1	153	441	8438
WA										596			596
RA											2304		2304
OL			456	5	125		2101		625	11	428	13047	16799
Total	223	356	11329	401	8359	174	6813	1931	4680	608	2887	13580	**51342**

EBM= Evergreen-Broadleaf forest–Medium; EBP= Evergreen-Broadleaf forest-Poor; EBR= Evergreen-Broadleaf forest–Regrowth/Restored; BF= Bamboo forest; WBF= Mixed Wood and Bamboo forest; LM= Limestone forest (forest over the Limestone Mountain); PL= Plantation (Planted) forest; LA= Limestone area; BL= Bare land planned for forestry; WA= Water area; RA= Residential area; and OL= Other land.

Forest restoration mostly occurred on Bare land planned for forestry (BL). More than 60% of the reduced area of the BL went under natural forest expansion (i.e., increased area of EBR). Planted forest area was more than three times greater in 2006 than the area was in 2000. Table 5.4 depicted most of plantations were established in Other land and Bare land planned for forestry during the period. However, few hundred ha of forest plantations were also established in EBR, WBF and BF. From 2000 to 2006, about 6500 ha of Bare land planned for forestry (BL) and Other land were converted to Evergreen - Broadleaf forest – Regrowth/Restored and forest plantations.

5.13 Period of escalating forest plantations and reducing natural forests: 2006 - 2010

In 2010, the study found that Evergreen - Broadleaf forest – Regrowth/Restored (EBR) shrank by 27% by area compared to its area in 2006. Similarly, Mixed wood and Bamboo forest (WBF) area was reduced by 16% during the period of 2006 to 2010. Other land was reduced by 1442 ha.

In the 2006-2010 period, area of planted forest was increased by 7660 ha. Table 5.5 suggested 3663 ha of EBR and 764 ha of WBF were converted to planted forests. This implies forest plantations mostly established by clearing the degraded natural forests. Nearly half of the plantation was established in the EBR. Most likely, the conversion, as mentioned earlier (chapter 5.4), was associated with the Circular 99/TT-BNN issued by the Ministry of Agriculture and Rural Development. The figures clearly indicated allocation of large amount of the Evergreen - Broadleaf forest – Regrowth and Mixed wood and Bamboo forest to establish forest plantations of high economic value after 2006. In the period, nearly 3200 ha of Bare land planned for forestry and Other land were gone under afforestation.

Table 5.5 Land-use/land cover change matrix: 2006 - 2010

2006	2010												Total
	EBM	**EBP**	**EBR**	**BF**	**WBF**	**LM**	**PL**	**LA**	**BL**	**WA**	**RA**	**OL**	
EBM	190		33										223
EBP		313	18				25						356
EBR		1	7335	19	208		3663		67	1	0	36	11329
BF				315	21		58		7				401
WBF	13		610	202	6703		764		51		1	16	8359
LM						174							174
PL							6796		8	0		9	6813
LA								1931					1931
BL			207	5	68		1703		2622	0	1	73	4680
WA										608			608
RA											2887		2887
OL			64		21		1463		8	3	18	12004	13580
Total	204	313	8266	540	7021	174	14473	1931	2763	612	2907	12138	**51342**

EBM= Evergreen-Broadleaf forest–Medium; EBP= Evergreen-Broadleaf forest-Poor; EBR= Evergreen-Broadleaf forest–Regrowth/Restored; BF= Bamboo forest; WBF= Mixed Wood and Bamboo forest; LM= Limestone forest (forest over the Limestone Mountain); PL= Plantation (Planted) forest; LA= Limestone area; BL= Bare land planned for forestry; WA= Water area; RA= Residential area; and OL= Other land.

5.14 Discussions

Dominant land use/land cover types of Dinh Hoa district were natural forests, planted forest, Bare land (planned for forestry), and Other land. Evergreen - Broadleaf forest – Regrowth, and Mixed Wood and Bamboo forest dominated natural forest formations. Over the period of 17 years (1993-2010), forest cover of the district increased approximately by 100%. The historical course of the forest cover of the district resembles with national trajectory of the forest area for the last two decades (chapter 2, Figure 2.4). Vietnam was 4th among the 10 countries with the largest annual net gain in forest area for the period of 1990-2010 (FAO, 2010b). In 1990, the total forest area of the country was 9.18 million ha, with a forest cover of 27.2% (De Jong et al., 2006). The forest cover increased to 13.17 million ha (excluding rubber plantation) in 2010 (FAO, 2010a; FAO, 2010b). In 2011, natural forests occupied 10.28 million ha and planted forests covered 3.23 million ha in Vietnam (VNFOREST, 2013).

Despite the increase in forest cover by double, natural forest area was increased only by 10% in the district. Increased area of planted forest, contributed 90% to total increment in the forest cover of Dinh Hoa for the period of 1993-2010. Similar trend was observed in national forest cover increase for the period of 1990-2010. During 1990-2010, average annual increase in forest area in Vietnam was approximately 0.2 million ha/year, while area of planted forest was increased by 0.134 million ha/year in the given period. Vietnam is 8th amongst the 10 countries with greatest annual increase in planted forest area for 1990-2010 period (FAO, 2010b).

During the period of 1993-2010, two main conversion types occurred: i) conversion of non-forested land to forested land through afforestation and reforestation (A/R) and assisted natural regeneration (ANR), and ii) mutual conversion within forested land, i.e., mutual conversion between different forest formations (types). Bare land and Other land were converted to Evergreen - Broadleaf forest – Regrowth, and forest plantations. Different types of mutual conversion between the forest formations were observed. Evergreen-Broadleaf forests- Poor were converted to Evergreen - Broadleaf forest – Regrowth. The conversion indicates forest degradation in the study area. On the contrary, Bamboo forests were converted to Evergreen - Broadleaf forest – Regrowth. This shows the trend of forest enrichment. More important, after 2006, Evergreen - Broadleaf forest – Regrowth and Mixed Wood and Bamboo forest were converted to short-rotation planted forests. This trend indicates the 'planned deforestation'.

Since 1986, government of Vietnam has formulated a series of forestry related policies and launched several initiatives to implement its people centered approach of forest management. Forest land allocation (FLA), aiming at improving livelihoods and well-beings of forest dependent people while protecting and rehabilitating forest resources, is one of the major policy initiatives. The government enacted several laws, regulations, decrees and decisions to legitimize and regulate the forest land allocation (chapter 2).

The study attempted to link the spatial and temporal land use/land cover change, and the observed different types of conversions with historical forest policy landmarks in Dinh Hoa and Vietnam. In pursuance of the development of forestry discourses and change in forest policies (chapter 2), scope of forest land allocation has been broadening: allocating only bare lands in early 1990s, included degraded forest land allocation around 2000 (Decree163/1999/ND-CP), and natural forest land allocation started after 2003 (Decision 178/2001/QD-TTg, circular 99/TT-BNN in 2006). In Dinh Hoa, forest land allocation was started in 1992. By 2010, about 21000 ha of forests and forest lands have been allocated and/or contracted to nearly 8000 households. After the Circular 99/TT-BNN issued by the MARD, several thousand hectares of natural forests, particularly of Evergreen - Broadleaf forest – Regrowth and Mixed Wood and Bamboo forest, were converted to forest plantations. The instances showed a strong linkage between policy interventions and land use/forest cover change over the last 17 years, and indicated policy factors as one of the major drivers of forest cover change in the district.

Policy initiatives initiated and implemented since early 1990s to 2008 in Vietnam and in Dinh Hoa, involved different policy and financial instruments relevant to forest and forest land management. They included legal frameworks (laws, decrees, decisions, circulars), governance (benefits to and obligations of households and individuals under Decision no 178/2001/QD-TTG, tenure security, and land entitlements), financial (compensation payment and subsidies under reforestation programs, tax exemption under the forest land allocation, cash and in-kind support through pro-poor program), and capacity building. The 'policy mix' approaches and outstanding achievements in the last 20 years: increase of forest cover by double, accumulation of livelihood assets (chapter 6), and economically viable forest management (chapter 7) in the district suggested complementary policy instruments can work together to achieve better overall performance against the objectives, due to increased synergy among the instruments, at a lower cost (financial, time, and other resource costs) than any one instrument implemented in isolation. Forest policies and instruments have been isolated and fragmented in action in many developing countries. Many drivers of deforestation and forest degradation lie outside the forest boundary. Results of the study indicated optimal forest management should combine several policy instruments into a set of policy package (‘policy mix’ approach) to address diverse and dynamic drivers of forest degradation and deforestation including the drivers outside forest boundary and forestry sector.

6 Result and discussions: perception and attitude of local residents towards forest management, forest land allocation and REDD+

Details of sample statistics of the survey are presented in Tables 6.1, 6.2, 6.3 and 6.4. In Table 6.1 frequency distribution of categorical variables are presented whereas in Table 6.2 mean, standard deviation (Std. dev.), minimum value (Min.), maximum value (Max.), confidence interval (CI) and number of observation (Obs.) of continuous variables are presented. Table 6.3 presents responses indicating agreement or disagreement with 92 statements regarding to forest management and forest land allocation program. The statements are grouped under five different livelihood capital assets. Table 6.4 demonstrates responses regarding people's awareness and attitude about REDD+. In all cases, sample statistics are presented for the entire study area.

6.1 Characteristics of sample households

During field study, 208 males (76%) and 66 females (24%) were interviewed. Of those, 83% were household head (Table 6.1). Average age of the respondents was 46 years (CI=1.43). Majority of the respondents (67%) went to junior high school, 19% went to high school, 13% went to primary school then dropped, 0.4% went to university, and only 0.7% of the respondents were illiterate. Sixty nine percent of the respondents were Tày people followed by Kinh (10%), Dao (10%) and Sắn chỉ (10%). The Tày people are the second largest ethnic group in Vietnam, and are generally farmers cultivating rice, maize and sweet potato. About 99% of the respondents were farmer. More than 97% of the farmers had their own agricultural land. Average agriculture land ownership was 0.23 ha (CI=0.02) varied from 0 ha to 1.3 ha/household. The small land holding resulted in weak food security in general. About 6% family produced food which supports their family only up to 3 months, and 27% produced sufficient food for 6 months. About 60% of the households produced food which was sufficient for 6-12 months to feed their family. Only 5.5% households had food production sufficient for their family for more than 12 months and were able to sell surplus food products.

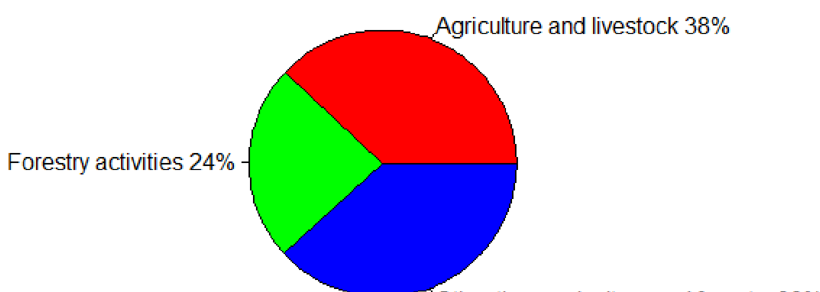


Figure 6.1 Income (cash) sources of households in Dinh Hoa district, Vietnam. Agriculture and forestry activities were major sources of income for the rural households in the district.

Table 6.1 Frequency distribution of categorical responses. Categorical variables, description (and responses) to the variables and frequency of the variables and responses are given.

Variable	Description	Frequency	%
Household head	No	46	16.8
	Yes	228	83.2
Gender	Female	66	24.1
	Male	208	75.9
Education	Illiterate	2	0.7
	Primary school (up to 5 grades)	36	13.1
	Junior high school (6-9 grades)	184	67.2
	High school (10-12 grades)	51	18.6
	College/University (>12 grades)	1	0.4
Ethnicity	Tày	189	69
	Kinh	28	10.2
	Dao	28	10.2
	Sắn chỉ	27	9.9
	Other	2	0.7
Occupation	Farmer	271	98.9
	Education/Extension agent	1	0.4
	Government service	1	0.4
	Other	1	0.4
Have own agricultural land	No	7	2.6
	Yes	267	97.4
Food security	≤3 months	16	5.8
	≤6 months	75	27.4
	≤ 12 months	168	61.3
	> 12 months	15	5.5
Food sold	No	258	94.2
	Yes	16	5.8
Have livestock	No	60	21.9
	Yes	214	78.1
Livestock sold	No	171	62.4
	Yes	103	37.6
Have allocated forest land	No	0	0
	Yes	274	100
Have bamboo in the forestland	No	187	68.2
	Yes	87	31.8
Bamboo product sold	No	233	85
	Yes	41	15
Earning sources other than agriculture, livestock and forestry?	No	180	65.7
	Yes	94	34.3
Fishery in forest land	No	268	97.8
	Yes	6	2.2
House made of	Only timber/thatch	155	56.6
	Brick masonry	87	31.7
	Timber/thatch and brick masonry	32	11.7
Firewood for cooking	No	5	1.8
	Yes	269	98.2
Charcoal for cooking	No	274	100

Variable	Description	Frequency	%
	Yes	0	0
Electricity for cooking	No	259	94.5
	Yes	15	5.5
LP gas for cooking	No	266	97.1
	Yes	8	2.9
Biogas for cooking	No	272	99.3
	Yes	2	0.7

Table 6.2 Descriptive statistics for continuous variables. Continuous variables and their sample statistics: mean, standard deviation (Std. dev.), minimum (Min.) and maximum (Max.) values, standard error of the mean (SE), confidence interval (CI) and total number of observation (Obs.) are given.

Variable	Mean	Std. dev.	Min.	Max.	SE	CI	Obs.
Age of respondent, year	45.82	12.04	22	86	0.73	1.43	274
Family size, number of individuals (no.)	4.12	1.27	1	8	0.08	0.15	274
Male members in family, no.	2.12	0.89	0	5	0.05	0.11	274
Female members in family, no.	2.00	0.94	0	5	0.06	0.11	274
Male members (age 15-60 years), no.	1.53	0.82	0	4	0.05	0.10	274
Female members (age 15-60 years), no.	1.44	0.76	0	4	0.05	0.09	274
Area of private land, ha	0.23	0.17	0	1.3	0.01	0.02	274
Area of rice land, ha	0.21	0.15	0	1.3	0.01	0.02	274
Area of maize land, ha	0.00	0.01	0	0.11	0.00	0.00	274
Area of cassava land, ha	0.02	0.09	0	1	0.01	0.01	274
Area of vegetable land, ha	0.00	0.01	0	0.05	0.00	0.00	274
Earning from food sale, 000 VND	417.88	2811.17	0	40000	169.83	332.86	274
Livestock unit	1.23	2.15	0	25	0.13	0.26	274
Earning from livestock sale, 000 VND	5560	15983.07	0	200000	965.57	1892.49	274
Area of allocated forest land, ha	2.81	5.94	0.02	80	0.36	0.70	274
Area of allocated natural forest land, ha	1.47	3.64	0	40	0.22	0.43	274
Area of allocated planted forest land, ha	1.33	2.82	0	40	0.17	0.33	274
Area of Special use forest, ha	0.30	0.83	0	6	0.05	0.10	274
Area of Protection forest, ha	1.36	5.66	0	80	0.34	0.67	274
Area of Production forest, ha	1.16	1.67	0	10	0.10	0.20	273
Acacia spp. planted Vietnamese đồng, ha	1.08	2.19	0	30	0.13	0.26	274
Magnolia spp. planted in forest land, ha	0.22	0.78	0	10	0.05	0.09	274
Cinnamomum spp. planted in forest land, ha	0.03	0.13	0	0.9	0.00	0.02	274
Earning from bamboo, 000 VND	441.06	1322.37	0	10000	79.89	156.58	274
Cassava cultivated in forest land, ha	0.03	0.20	0	3	0.012	0.02	274
Tea cultivated in forest land, ha	0.05	0.09	0	0.72	0.01	0.01	274
Compensation payment, 000 VND	7.68	38.68	0	360	2.34	4.59	273
Price of acacia timber, 000 VND per m^3	736.07	74.34	600	900	5.5	10.77	183
Price of magnolia timber, 000 VND per m^3	1040.00	225.09	650	1500	35.59	69.76	40

Variable	Mean	Std. dev.	Min.	Max.	SE	CI	Obs.
Price of cinnamon timber, 000 VND per m^3	570.83	261.92	400	1100	106.93	209.58	6
Price of cassava, 000 VND per ton	2841.46	2725.34	800	12000	425.63	834.21	41
Price of tea, 000 VND per Kg	31.66	6.30	25	60	0.62	1.21	105
Local wage rate per day, 000 VND	96.95	5.75	75	100	0.35	0.68	274
Quantity of acacia timber sold, m^3	0.04	0.60	0	10	0.04	0.07	274
Quantity of magnolia timber sold, m^3	0.02	0.30	0	5	0.02	0.04	274
Quantity of cinnamon timber sold, m^3	0.00	0.00	0	0	0	0.00	274
Quantity of cassava sold, ton	0.11	0.87	0	10	0.05	0.10	274
Income from cassava sold, 000 VND	345.73	3721.91	0	60000	224.85	440.70	274
Quantity of tea sold, kg	85.10	163.82	0	1200	9.90	19.40	274
Income from tea sold, 000 VND	2651.92	5282.09	0	42000	319.10	625.43	274
Total Income from other sources, 000 VND	6290.58	15077.22	0	114000	910.85	1785.23	274
Income from firewood sale, 000 VND	87.59	705.81	0	8800	42.64	83.57	274
Income from fishery, 000 VND	626.28	2600.49	0	30000	157.10	307.91	274
Income from NTFP sale, 000 VND	181.75	2545.76	0	42000	153.80	301.43	274
Income from pension, 000 VND	277.37	3245.13	0	40000	196.05	384.24	274
Income from remittance, 000 VND	164.23	2023.32	0	30000	122.23	239.57	274
Income from service, 000 VND	773.72	5310.84	0	60000	320.84	628.83	274
Income from skilled labor, 000 VND	1250.00	6349.74	0	63000	383.60	751.85	274
Income from local enterprise, 000 VND	1244.53	8669.05	0	96000	523.72	1026.47	274
Income from wage labor, 000 VND	1685.11	7046.02	0	60000	425.67	834.29	274
Age of acacia harvesting, year	7.59	0.65	7	9	0.049	0.10	177
Age of magnolia harvesting, year	13.56	1.20	10	15.5	0.18	0.35	45
Age of cinnamon harvesting. year	6.15	1.49	5	10	0.41	0.81	13
Income from fishery, 000 VND	0.00	0.00	0	0	0	0.00	274
Market price of timber, 000 VND per m^3	775.88	204.21	200	1650	12.50	24.49	267
Market price of firewood, 000 VND per m^3	295.56	120.84	200	800	7.40	14.50	267
Valuation NTFP, average score	5.83	0.40	4	6	0.024	0.05	273
Valuation carbon sequestration/storage, average score	2.70	0.50	1	4	0.0305	0.06	273
Valuation biodiversity, average score	2.29	0.47	1	4	0.0286	0.06	273
Valuation water, average score	4.85	0.60	3	6	0.0362	0.07	273
Valuation protection function, average score	4.31	0.60	2	6	0.0364	0.07	273
Valuation ecotourism, average score	1.02	0.19	1	3	0.0115	0.02	273
Gross (cash) income in 2012, 000 VND	15715.14	23351.07	0	200000	1410.69	2764.90	274

Note: VND = Vietnamese đồng, US$1 = 21,000 VND.

Sixty two percent of the cash income of the surveyed household was drawn from subsistence agriculture and forestry practices (Figure 6.1). Of this, agriculture and livestock products (food, livestock) shared 38%, and forestry based activities (compensation payment, firewood, NTFPs, cassava and tea cultivated in forest land, bamboo products) contributed 24%. Majority (78%) of the households had livestock (buffalo, pig, goat, horse, cattle, poultry) farming. The average livestock unit per household was 1.23 (CI=0.26). Livestock sale represented 35% of the total cash income. Of the total livestock farming households, 48% households sold livestock in 2012. In addition, the households had other considerable sources of income such as wage labor, skilled labor, store ownership and business, public profession (service), fishery (in private land), pension and remittance. The sources contributed 38% to the income. Trading of surplus tea cultivated in the forest land was the second largest (17%) income source. Wage labor mostly in forestry activities, skilled labor and enterprise were other income sources ranked on the top five in 2012 (Figure 6.2).

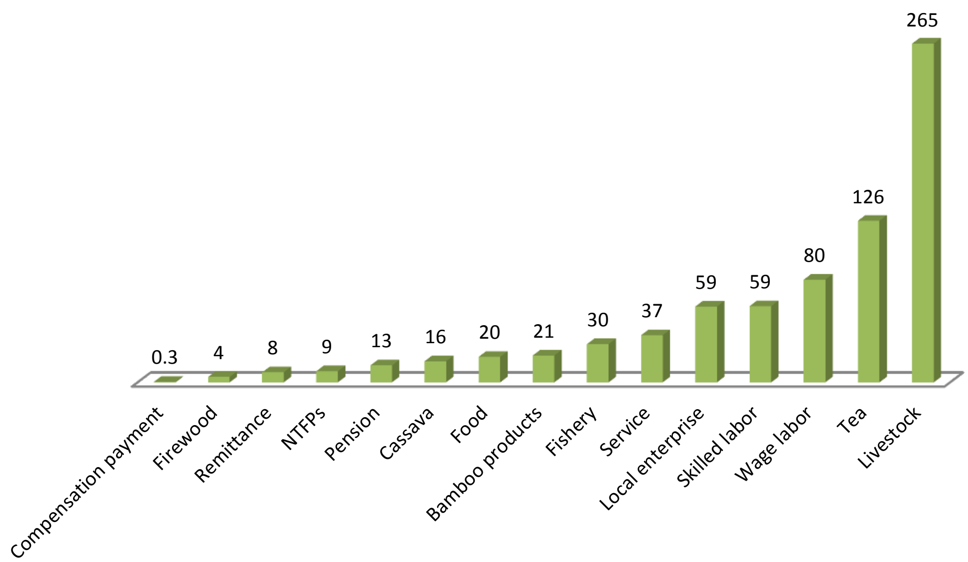


Figure 6.2 Household income (cash) and their sources in 2012, Dinh Hoa, Vietnam. Income sources and corresponding gross (cash) income (US$) are shown.

Average allocated/contracted forest land was 2.81 ha/household in the study area. The forest land holding was higher than the district average of 1.26 ha per household. Of the 2.81 ha, Special use forest was 0.30 ha/household, Protection forest 1.36 and Production forest 1.16 ha/household. Natural forests was 1.47 and planted forest was 1.33 ha/household. *Acacia* plantations (1.08 ha/household) dominated planted forest, followed by *Magnolia* (0.22 ha/household), and *Cinnamomum* (0.03 ha/household). Average areas of cassava and tea cultivation in the contracted forest land were 0.03 and 0.05 ha per household respectively.

Table 6.3 Households' perception towards forest management and forest land allocation (FLA) and their perception towards impacts of the forest management and FLA on their livelihoods. Livelihood capitals, statements related to each capital, and households' agreement or disagreement to the statements (in percent) are shown.

Livelihood capital	Code	Statements	Agreements (in %, n = 274)		
			Agree	Disagree	NA
Natural	N1	Forest cover (area) has increased	97.1	2.9	
	N2	There is enough forest land for resource utilization (subsistence demand)	99.6	0.4	
	N3	Allocated/contracted forest land is suitable for forestry	98.2	1.8	
	N4	Standing tree-volume has increased	97.4	2.6	
	N5	Natural forest (NF) provides timber	97.1	2.9	
	N6	Quantity of timber in NF has increased	92.7	0.7	6.6
	N7	Planted forest (PF) provides firewood	91.6		8.4
	N8	NF provides firewood	100		
	N9	Quantity of firewood in NF has increased	100		
	N10	PF provides fodder for cattle	92		8
	N11	NF provides fodder for cattle	96.4	2.6	1.1
	N12	Quantity of fodder in NF has increased	96.4	2.6	1.1
	N13	PF provides NTFPs (bamboo, bamboo shoots, palm tree leaves, fruits, seed, bark, mushroom etc.)	87.6	4	8.4
	N14	NF provides NTFPs	98.5	1.5	
	N15	Quantity of the NTFPs in NF has increased	95.3	4.7	
	N16	Soil erosion situation has improved by PF (afforestation)	91.6		8.4
	N17	Soil erosion situation has improved by NF protection	100		
	N18	Forest fire situation has improved by PF (afforestation)	91.6		8.4
	N19	Forest fire situation has improved by NF protection	99.3	0.7	
	N20	Water quality has improved with NF protection	98.9	1.1	
	N21	Water quality has improved with PF (afforestation)	90.1	1.5	8.4
	N22	Water quantity has improved with NF protection	94.5	5.5	
	N23	Water quantity has improved with PF (afforestation)	89.8	1.8	8.4
	N24	Air quality has improved by forest protection	99.3	0.7	
	N25	Air quality has improved by afforestation	98.5	1.5	
	N26	Total number of plant species in NF has increased	96.4	3.6	
	N27	Total number of animal species in NF has increased	94.2	5.8	
	N28	Protecting NF increased number of plants per ha	95.6	4.4	
	N29	Protecting NF increased number of wild animals including birds and amphibians	94.9	5.1	
	N30	New plant species in PF has appeared (except planted species)	74.1	17.5	8.4
	N31	New plant species in NF has appeared	89.1	10.9	
	N32	Plant species in PF has reappeared[32]	74.5	17.2	8.4
	N33	Plant species in NF has reappeared	90.1	9.9	

[32] Plant species were lost in the (recent) past from the study area, but again appeared naturally because of forest protection.

Livelihood capital	Code	Statements	Agreements (in %, n = 274)		
			Agree	Disagree	NA
	N34	New animal species in PF has appeared	88.7	3.3	8
	N35	New animal species in NF has appeared	91.2	8.8	
	N36	Animal species in PF has reappeared	73.4	18.2	8.4
	N37	Animal species in NF has reappeared	86.1	13.9	
	N38	Availability of tree wildings increased in NF	91.6	8.4	
	N39	Number of trees planted in private land increased (using those seedlings and wildings)	94.2	5.8	
	N40	Illegal logging in NF decreased	97.8	2.2	
	N41	Lopping and *lathra* (sapling) cutting in NF decreased	98.2	1.8	
	N42	Illegal hunting in NF decreased	95.6	4.4	
	N43	Overgrazing and pre-mature grazing in NF decreased	94.5	5.5	
	N44	Trend of stall feeding for livestock increased	92.7	7.3	
	N45	Ecological sensitive areas (e.g. stream buffer zones, steep slopes) are protected	96.7	3.3	
	N46	Rare or endemic species are protected	91.6	8.4	
Human	H1	Women have more time for other household and social activities than before	94.2	5.8	
	H2	Labor opportunities are diversified through NF protection activities	88.7	11.3	
	H3	Labor opportunities are diversified through PF management activities	83.2	8.4	8.4
	H4	Labor opportunities are improved through NF protection activities	93.4	6.6	
	H5	Labor opportunities are improved through PF management activities	90.9	0.7	8.4
	H6	Awareness about importance of forest services (control of soil erosion, water quality and quantity, biodiversity protection etc.) has improved (by trainings, field based learning process, group discussions, TV, radio, newspaper etc.)	96	4	
	H7	NF forest management skills are improved (trainings, field based learning process, group discussions, TV, radio, newspaper etc.)	99.6	0.4	
	H8	PF forest management skills improved	90.1	1.5	8.4
	H9	There are possibilities to attain trainings about NF management	97.1	2.9	
	H10	There are possibilities to attain trainings about PF management	88	3.6	8.4
Social	S1	Communication with local authorities is good	96.7	3.3	
	S2	Group meetings improved forest management skills	97.4	2.6	
	S3	Access to forest resources is fair	100		
	S4	Household feel secure about access to forest resources	98.5	1.5	
	S5	Land-use conflicts minimized	96	4	
	S6	Households' access to local (commune and district) forest authorities increased	100		
	S7	The trust between local communities and the forest authorities improved	95.6	4.4	

Livelihood capital	Code	Statements	Agreements (in %, n = 274)		
			Agree	Disagree	NA
	S8	Ownership of and use rights to NF are more clear	99.3	0.7	
	S9	The ownership and use rights are respected from both local communities and local authorities	93.1	6.9	
	S10	Ownership of and use rights to PF are more clear	91.6		8.4
	S11	Distribution/ownership of NF is considered as being fair/equitable	94.2	5.8	
	S12	Distribution/ownership of PF is considered as being fair/equitable	89.1	2.6	8.4
	S13	Mechanisms for sharing benefits of NF are fair, and are in place	97.4	2.6	
	S14	Mechanisms for sharing benefits for management of PF are fair, and are in place	89.1	2.6	8.4
	S15	Mechanisms for sharing work-obligations for protection of NF are fair and are in place	96	4	
	S16	Mechanisms for sharing work-obligations for management of PF are fair and are in place	90.5	1.5	8
	S17	Involvement of local people in decision making on land use planning increased	92	8	
	S18	Woman and disadvantaged people take part in the meetings	97.4	2.6	
	S19	Degree of participatory decision making increased	94.9	5.1	
	S20	Confidence to talk, to put own views and opinions, in the decision making increased	94.9	5.1	
Physical	P1	Fertilizers and pesticides are easy to buy (quantity/quality)	87.2	4.4	8.4
	P2	Availability of tree seedlings increased (due to forest nurseries)	93.1	6.9	
	P3	Seeds/seedlings are easy to buy (quantity/quality)	85	6.6	8.4
	P4	Equipment (machines and tools) for forest management activities are available	92	8	
	P5	Forest product processing facilities are available	95.6	4.4	
	P6	Easy access to information about new land development methods	93.4	6.6	
	P7	Increased access to information of recent policies, decrees, and decisions	97.4	2.6	
Financial	F1	Market for timber products has improved	98.2	1.8	
	F2	Market for NTFPs has improved	100		
	F3	Adequate funding for forest management available	94.5	5.5	
	F4	Credit facilities increased investments in NF management	91.6	8.4	
	F5	Credit facilities increased investments in PF management	90.1	1.5	8.4
	F6	Subsidies are available for forest planation management	94.9	5.1	
	F7	Provision of mortgage of NF (production) and PF for loans exists	95.6	4.4	
	F8	NF management activities provide net economic benefits	96.7	3.3	
	F9	PF management activities provide net economic benefits	86.5	5.1	8.4

6.2 Perception of local people towards forest management and forest land allocation

6.2.1 Increased forest cover, forest lands meet subsistence demand and are suitable for forestry activities

Statements N1, N2 and N3 (Table 6.3) examined households' opinions about allocated/contracted forest land: forest cover, quantity, and land suitability for forestry activities. Nearly all (97%) of the respondents expressed forest area has been increased in their vicinity. The local perception verified earlier findings about LULC change of the study (chapter 5). More than 98% of the households agreed allocated forest land was suitable for forestry activities.

Among others, one of the criteria to determine area of forest land to be allocated/contracted to households was family size and working members (age 15-60 years) in the family. Average Dinh Hoa households in 2012 consisted around four people- two males and two females (Table 6.2). Working males were 1.53, and working females were 1.44/family. The figure suggested 72% of family members belonged to working age. Average area of allocated forest was 2.81 ha/household, which was considerably higher than average area of private agricultural landholding of 0.23 ha/household. The ratio of forest land (ha) to working member is nearly 1:1. With the self-evident quantitative background, almost all of the respondents agreed that quantity of forest and forest land allocated to the households was enough to meet their subsistence demands of forest products.

6.2.2 Provision of forest products considerably increased and forest services improved

Statements N4-N15 (Table 6.3) dealt with trend of forest products (timber, firewood, fodder, and NTFPs) after FLA implementation. Nearly all of the respondents agreed availability of the forest products, in terms of quality and quantity, has been increased. Standing tree-volume has been improved. Respondents claimed forest services (N16-N25) such as control of soil erosion, water quality and quantity, and air quality have been remarkably improved due to protection of natural forests and afforestation. Irrespective of households' socioeconomic conditions, firewood was used by 98% of the households as the main energy source for cooking. In addition, 57% of the total houses were made up of timber and thatch, which came from forest (Table 6.1). In the situation, increased availability of forest products (such as timber, firewood, thatch, palm leaf) contributed considerably for housing and energy use of the study area.

6.2.3 Floral and faunal diversity increased and ecologically sensitive areas protected

Agreements provided by the local people suggested that the number of species and densities of flora and wild fauna have increased in the study area. The locals observed new plant and animal species in natural forests, and noticed the appearance of plant and animal species which had disappeared from the area long ago. Appearance of native tree species in monoculture (protective) plantations was noticed by the majority of the interviewees. This indicates a gradual transformation of the monoculture plantation to multispecies plantations consisting native tree species which might bring much economic and ecological benefits. The respondents experienced, number and species of trees in private lands including home gardens have increased due to availability of seedlings from forest nurseries and of increasing wildings in forests. Furthermore, the respondents realized a greater level of protection of rare or endemic species than in the past. Ecological sensitive areas such as critical watershed, stream buffer zones, and steep slopes were protected under management of Special use and Protection forest.

6.2.4 Illegal logging reduced, premature and uncontrolled felling and grazing decreased

Timber extraction and logging activities account for 70% of the total forest degradation and, to a lesser extent, fuelwood collection, charcoal production and livestock grazing are the most important drivers of forest degradation in (sub)tropical Asia (Kissinger et al., 2012). Contrary to this finding, according to the local agreements, illegal logging and sapling cutting (for fuelwood) in natural forests have been substantially decreased within the last two decades in the district. Over grazing and premature grazing were decreased in natural forests, and practice of stall feeding was found nearly everywhere in the district.

6.2.5 More time available for other household activities

Increased availability of forest products (section 6.2.2) shortened time needed for collection of the products in the study area. Neupane (2003) compared forest product collection time before and after community forestry implementation in a (Raniban) community forest (CF) in Nepal. Due to increased availability of fodder and firewood in the community forest, collection time of the products was reduced by 56% and 50% respectively under the community forest management. The study estimated reduced time for firewood was 4.6 working days/household/year. The children and women were the one who involved in collection of firewood and fodder. In line to the finding, locals in the study area experienced that women had more time available for household activities (H1, Table 6.3) than before, due to reduced time spend for collection of the forest products.

6.2.6 Increased and additional green and local jobs

Respondents assured that natural forest management and plantation activities have generated increased and additional job (labor) opportunities locally in the district (H2-H5, Table 6.3). In Dinh Hoa, people have been engaged in forestry plantation activities (land preparation, planting, weeding, harvesting, and transportation) as a wage labor. Similarly, timber harvesting, firewood collection, bamboo and rattan products and NTFP collection in natural forests have created several jobs, and increased food security. Veneer mills, saw mills, wood craft industries, furniture and other small and family-run wood processing enterprises employed as many as 1000 people. In 2012, Wage labor was the third largest cash income source for the households (Figure 6.2) in the district.

6.2.7 Increased awareness and improved knowledge and skills for forest management

Ministry of Agriculture and Rural Development (MARD) is responsible for agriculture and forestry extension and training in Vietnam. Research, Education, Training and Extension (RETE) is one of the five programs of National Forestry Development Strategy (GSRV, 2007). In 1993, an integrated agriculture and forestry extension system was established in the country. Since then, the MARD through its national level organization (Department of Agriculture and Forestry Extension, Forest Protection Department), province level agriculture and forestry extension centers, and extension stations at district and commune levels, has been providing demand-driven extension and training regarding forest land allocation and forest land development. To strengthen local knowledge on forest and forest land management, several capacity building have been initiated and implemented in Dinh Hoa. The capacity building included training on sustainable management of forest, forest enrichment, forest nursery, planting, thinning and timber harvesting, training for agricultural improvement and training on income generating activities. Farmers have been engaged in land use planning, multi-stakeholder forest management planning and monitoring processes.

Nearly all the respondents have experienced their enhanced access to such trainings, and improved awareness about importance of forest services (for instance, control of soil erosion, purification of water, biodiversity protection) through the trainings and field-based learning process, group meetings and discussions, and programs on television, radio and newspaper. They realized their improved skills to manage forests through the trainings and field-based learning process (H6-H10, Table 6.3).

6.2.8 Participation on forest management and trust among stakeholders increased

Communication is a fundamental component of an extension program. Two-way communication is the backbone of and a prerequisite for field-based/adult learning process. At the same time, such trainings and effective extension programs establish better communication and trust, which are key to ensure that the relationships are constructive and sustainable. This phenomenon is very evident in participatory forest management models in Nepal and elsewhere (Gauli, 2003; Neupane, 2003).

Local forest owners realized improved communication and interaction with local forestry authorities (S1). Their access to commune and district forestry authorities and processes has been enhanced (S6). The locals claimed trust between them and the state actors has been improved. This might have led to increased inclusive and meaningful participation of women, marginalized people and ethnic minorities in forest management and land use planning, and respective decision making processes (S17-19) in the district. The local residents realized their confidence to speak, and to put their own views and opinions in the decision making process has improved (S20).

6.2.9 Mechanisms for benefits sharing and work-obligations have become fair and equitable

Phuong (2000) described a long list of problems still existing, despite the success of forest land allocation. Among them, two problems are related to use rights and benefit sharing mechanism. He indicated that the rights and benefits of households are not well defined and regulations on benefits and responsibilities of households are not fully clarified. This study examined these two issues and observed the findings that contradicts with Phuong (2000). Of the interviewed local inhabitants, almost all of them felt secure about their access to forest resources (S2). They assured ownership of and use rights on planted and natural forests were clearer than ever (S8, S10-S12). They recognized that mechanism for sharing benefits and sharing work-obligations were in practice, and were fair and equitable (S13-S16). Importantly, all of the respondents accepted that ownership and use rights were mutually respected from both local communities and state actors (S9, Table 6.3). The difference in observations could be due to time difference between the two studies. The study Phuong conducted was back in 2000, so the situation might have changed since then.

6.2.10 Increased availability of materials and methods for forest management activities

Since its inception, one of the objectives of forest land allocation has been to facilitate the development of mountain regions characterized by poor physical infrastructure, remote areas, and poor socio-economic condition coupled with a high poverty rate. The difficult and remote terrain in the region, in general, contributed to a high price of fuel, seed, seedlings, fertilizer and other equipment needed for forest and agriculture management. Majority of the respondents expressed the situation has been gradually improved after implementation of forest land allocation in the district. They indicated availability of fertilizer and pesticides has increased (P1). The locals were benefitted by increased availability of high quality tree seedlings (P2-P3). They suggested equipment and means for forest management (harvesting, transportation) were locally available (P4). Wood processing could be done locally (P5). Furthermore, the local residents assured, timely and enhanced access to information about recent policies, decrees, decisions and circulars, as well as improved forest/land development techniques (P6-P7, Table 6.3).

6.2.11 Enhanced access to external finance and improved forest product market contributed financially to forest management

Forest land allocation is considered as the first step towards poverty eradication in mountainous areas. In line to the objective, the local agreement suggested that natural forest and planted forest management have been economically beneficial for the rural households (F8, F9). The study presents similar results derived from benefit cost analysis of forest management in subsequent chapter. The study found that benefit cost ratios of both natural forest and plantation forest management were greater than one.

The households suggested market for acacia and magnolia timber has been dramatically improved with increasing demand for the products in the last few years (F1). They have been selling bamboo and other NTFPs at a better price (F2). They suggested provision of mortgage for natural forest (production) and planted forest for loan, enhanced their capacity to borrow loans from rural financial institution. Land title (the RED Book), as prerequisite collateral, enhanced farmers' credibility and access to formal credit with low interest rate. All of them recognized such credits increased investments in forest management substantially. Phuong (2000) raised a concern that state investment capital is deficient to support livelihoods. However, the respondents in the study area assured there was adequate funding available in terms of external finance (loans) and government subsidies for forest plantations.

6.2.12 Valuation agreed forest management and forest land allocation have desirable impacts on local livelihood

The participatory household-based forest management (HBFM) and forest land allocation were found to be effective in improving livelihood assets of forest-adjacent and forest-dependent households (Figure 6.3). The study grouped the 92 statements discussed with the respondents under five capital assets (Table 6.3). Local agreements (Figure 6.3) showed the forest management practices and forest land allocation have strong and desirable impacts on livelihood assets accumulation in the study area at least for the period of 1993-2012.

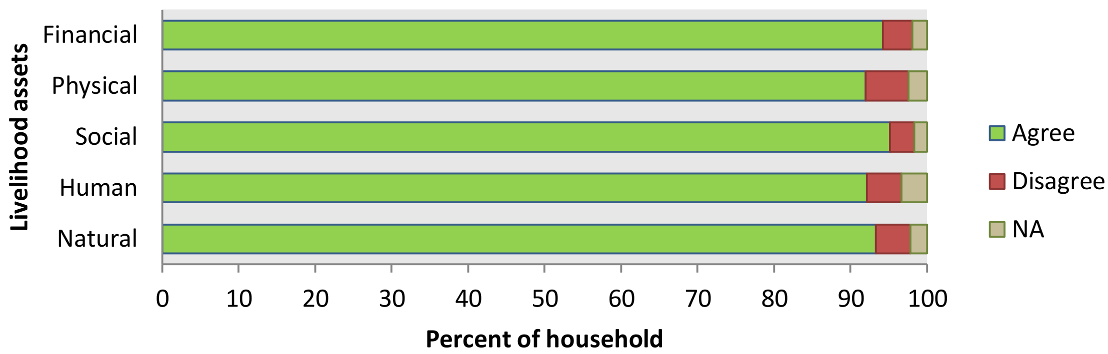


Figure 6.3 Households' response to impacts of forest management and forest land allocation (FLA) on local livelihood. Five capital assets, percent of interviewed households who 'agree' and 'disagree' to the statements related to the five livelihood assets are shown. Robust and desirable impacts of forest management practices and the FLA on livelihood assets accumulation in the study area were observed.

6.3 Local awareness and willingness to participate in REDD+ in Dinh Hoa

The study investigated local awareness of and willingness to participate in REDD+ and payment for ecosystem services (PES) programs. Table 6.5 shows results of interviews associated with awareness among the local people about REDD+ and PES program.

Table 6.4 Local awareness on REDD+ and payment for ecosystem services program. Statements on the awareness, local responses and their frequencies are shown.

Statements	Description	Frequency	Percentage
Do you know trees store carbon?	No	84	30.7
	Yes	190	69.3
Have you heard about REDD+ program?	No	274	100
	Yes	0	0
Do you know you can earn payment if your forest area is eligible for REDD+?	No	274	100
	Yes	0	0
Would you like to participate in REDD+?	No	0	0
	Yes	274	100
Would you like to receive payment instead of harvesting trees for timber?	No	0	0
	Yes	274	100
Does forest have value other than timber, firewood, fodder, and leaf-litter?	No	1	0.4
	Yes	273	99.6
Do you want to protect wildlife in forestland?	No	1	0.4
	Yes	273	99.6
Are you aware about multiple services provided by forests?	No	247	90.1
	Yes	27	9.9
Do you think that ecosystem service produced by your forest can benefit downstream neighbors?	No	0	0
	Yes	274	100
Have you heard about PES?	No	274	100
	Yes	0	0
Do you want to participate in PES scheme?	No	6	2.2
	Yes	268	97.8

Statements	Description	Frequency	Percentage
Do you prefer REDD+ program extended in your area?	No	1	0.4
	Yes	273	99.6
Do you prefer government develop PES scheme in your area?	No	1	0.4
	Yes	273	99.6

Though majority (70%) of the participants knew that trees store carbon, none of them were aware about REDD+ and its potentials. Almost all participants knew forest provides environmental services other than tangible forest products such as timber, firewood, fodder and litter. While all locals thought the environmental services produced by their forest can benefit downstream neighbors, none of them heard about payment for ecosystem services.

Before assessing their willingness to participate in REDD+ and PES programs, we explained briefly about REDD+ and PES schemes in Vietnam, policies and pilot projects, potentials and constraints of, and eligibility for the schemes. Although local people did not fully recognize the meaning of REDD+, carbon credits and PES, they were enthusiastic about it and showed their strong willingness to participate in the schemes. Similarly, when they were informed that PES and REDD+ schemes have already been piloted in their vicinity (Bac Kan Province[33]) and other parts of the countries, all of them preferred the government to implement the schemes in the study area.

6.4 Discussions

Form the findings, it was learned that household-based forest management, and forest land allocation have positive impacts on resource base (state of forest and forestland) and have a definite impact on increasing natural, human, social, financial and physical assets of the participant households. Local inhabitants were satisfied with the people-centered forest management approach embedded with allocation of adequate and suitable land for forestry activities, well-defined forest/land use-rights and obligations, and financial incentives. Forest and forestlands were healthier than before. The forest and land management practices improved forest conditions and vitality, such as: forest cover doubled through forest protection, afforestation and reforestation, and assisted natural regeneration activities; availability of timber and NTFPs increased; floral, faunal and landscape diversities increased; ecologically sensitive areas were protected. At the same time, illegal logging and premature felling were reduced, and forest fire and over-grazing were controlled. The participatory forest management and the forest land allocation also (i) promoted awareness about forests and their provisional and regulatory services, (ii) capacitated local households for forest and land management, and associated policy and institutional arrangements and processes; increased access to local forestry authorities, and improved communication and interaction between them; that increased local peoples' participation in forest management, collective planning and action, and assisted regulated forest use, and iii) contributed towards social equity in terms of minority ethnic groups, socially marginalized and deprived groups and

[33] Viet Nam Administration for Forestry (VNFOREST) of the MARD implementing REDD+ (pilot) programs in 6 provinces: Lao Cai, Bac Kan, Ha Thinh, Binh Thuan, Lam Dong and Ca Mau under the UN-REDD Vietnam Phase II Program. Bac Kan province bordered to the North-west of the district.

gender. The regimes helped to diversify income sources, increased household income level through additional jobs and forest products, and household assets. Issuance of land entitlement (the RED Book), provisions subsidies, cash and in-kind compensation and soft-loan schemes, enhanced financial capacity of the households, and credibility of the households to access to external finance, that increased investments on and returns from forest and land management and development. When accompanied with complementary infrastructure and development activities, the forest management and the forest land allocation contributed substantially on local physical assets. Land tenure, effective land use planning, recognition and respect for rights, and strong and accessible institutions and process are the factors need to be addressed by REDD+ framework (ISU, 2015).

Ratsimbazafy (2012) observed that for local residents, to cooperate with a reduction of deforestation and forest degradation, they must have a positive perception toward the forest conservation system and positive attitude toward forest conservation initiatives. The study showed that all locals interviewed in Dinh Hoa have developed positive perception towards forest management regime and positive attitudes forest land allocation mechanism. To this point, it is very important that such positive attitudes are considered and fostered by the program and the responsible state authorities through accommodating legitimate demands of, and perceived problems by the local households.

Majority of the respondents understood trees store carbon, while they were totally unaware of REDD+ and carbon credit. They were completely unknown about what, and to what extent they need to contribute and sacrifice to get monetary benefit from forest carbon credits under REDD+ mechanism. Fundamental reason behind locals lacking understanding about REDD+ was lack of opportunities to obtain information. Perceiver acquires information, processes it and understands, and the understanding leads to an action (Gibson, 2002; Sutta and Silayo, 2014). REDD+ initiative as an action to be undertaken, is highly dependent on how it has been perceived by the community implementing it thus assuring its sustainability (Sutta and Silayo, 2014). Despite the complete lack of knowledge of REDD+, the locals in Dinh Hoa showed their strong willingness to participate in the initiative. The study observed a possibility that the swooned '100% willingness' or '100% preference' of the respondents might be induced by false expectation of 'sky money' from REDD+.

Vietnam is preparing Emission Reductions Program Document (ER-PD) (chapter 2). One of the issues, identified by Carbon Fund Participants (FCPF Carbon Fund Tenth Meeting in Bonn), for Vietnam to take into consideration during development of their ER-PIN into ER-PD, is '*Building on established practice, the capacity of ethnic minority groups in the program area should be strengthened to enhance their full and effective participation in program design and implementation, benefit sharing, as well as safeguards design and monitoring*' (FCPF, 2014). Efforts should be directed towards educating and sensitizing local households about objectives and potential benefits of REDD+ activities. In addition to traditional approach of forestry extension and trainings, new approaches are needed to provide information about all relevant aspects of REDD+, in appropriate language and forms in accordance with intellectual and physical ability of the ethnic minorities, and forest-adjacent and forest-dependent households.

7 Results and discussions: economics of forest management in Dinh Hoa

7.1 Forest landholding and forest products demand and collection

Among 155 households surveyed, 95 households were managing both natural and planted forests, while 21 households were managing natural forests only and 39 households managing planted forest only. Altogether, 116 were managing 597 ha natural forests and 134 households were managing 277.65 ha planted forests. The average size of natural forest was 5.15±1.75 ha per household ranging from 0.2 ha to 90 ha. Planted forest averaged 2.07±0.4 ha per household ranging from 0.072 ha to 20 ha.

Table 7.1 Yearly demand of forest products and collection of forest products (in 2012) by individual households in Dinh Hoa. Types of forest products and sample statistics: mean, standard deviation (Std. dev.), minimum (Min.) and maximum (Max.) values, standard error of the mean (SE), confidence interval (CI) and total number of observation (Obs.) are given.

Variable	Mean	Std. Dev.	Min.	Max.	SE	CI	Obs.
Demand of forest products per year							
Timber, m^3	0.44	0.83	0	6	0.07	0.13	155
Small round wood, m^3	0.54	1.53	0	15	0.12	0.24	155
Firewood, load (25 Kg)	307.00	172.32	0	1095	13.84	27.34	155
Bamboo culm, number	59.35	55.82	0	300	4.48	8.86	155
Fodder, load (20 Kg)	72.97	140.56	0	730	11.29	22.3	155
Grass, load (20 Kg)	59.54	138.38	0	730	11.12	21.96	155
Palm leaf, load (20 Kg)	10.07	27.98	0	200	2.25	4.44	155
Collection of forest products in 2012 from natural forest							
Timber, m^3	0.75	2.46	0	22	0.23	0.45	116
Small round wood, m^3	1.30	6.91	0	70	0.64	1.27	116
Firewood, load (25 Kg)	267.55	175.38	0	750	16.28	32.25	116
Bamboo shoot, Kg	22.59	34.09	0	180	3.17	6.27	116
Bamboo culm, number	197.30	356.00	0	2000	33.03	65.43	116
Fodder, load (20 Kg)	37.09	95.69	0	480	8.88	17.6	116
Grass, load (20 Kg)	32.08	103.05	0	480	9.57	18.95	116
MAPs, Kg	5.85	46.71	0	500	4.33	8.6	116
Palm leaf, load (20 Kg)	57.17	141.88	0	1000	13.17	26.1	116
Cassava, Kg	752.41	1850.16	0	12000	171.78	340.27	116
Tea, Kg	156.81	641.30	0	5000	59.54	117.94	116

Most of the forest products were collected from natural forests for self-consumption. However, surplus amount of the products were traded to neighbors or local traders. In 2012, collection of timber, small round wood, bamboo culms and palm leaf exceeded the annual demand of the products (Table 7.1). Natural forests supplied nearly 90% of the firewood demanded in 2012. Bamboo shoot, rattan, fodder, grass, medicinal and aromatic plants, mushroom, honey, small wild animals (squirrel, hare) were other non-wood forest products harvested from natural forests in 2012. Cultivating cassava and tea in bare lands inside natural forests was a common practice. Farmers harnessed a handsome amount from cassava and tea in 2012.

7.2 Benefits and costs of natural forest management

Recurrent costs and benefits of natural forest management indicated that costs of collecting forest products dominated incurred total costs. Almost all of the benefits were accrued from forest products (Table 7.2). During household survey, only 25 households expressed that they received subsidies. The subsidy amount constituted only half percent of the total benefits.

Table 7.2 Recurrent costs and benefits of natural forest management in Dinh Hoa. Types of costs and benefits and amounts (US$) are given.

Costs	US$	Benefits	US$
Equipment cost (EC)	28651	Forest products	101780
Repair cost (RC)	1098	Subsidy	550
Forest development cost (FDC)	22665		
Tending operations cost (TOC) (Forest management cost)	20141		
Harvesting cost (HC) (Forest products collection cost)	31809		
Total costs	104364	Total benefits	102330

Forest products collection cost shared 31% of the total costs followed by equipment cost and forest development cost. In the first year, household spent substantial amount (27 %) in buying equipment. In the subsequent years, this cost was supposed to be substantially reduced. They spent around 1% of the total cost for maintaining those equipment.

7.2.1 Benefit-cost ratio

In the analysis, forest management plan was assumed to be for 10 years (Table 7.3). Considering the duration of the management plan, present value (PV) was estimated for the period of 10 years using 10% discount rate. Here, the study assumed most associated costs and benefits flow to be consistent throughout the management plan period, though, some costs and benefits may vary. For instance, equipment having life span less than 10 years need to be purchased more than once during the implementation of the plan. According to the respondents, lifespan of bicycle and knife was three years, and of axe, hand saw and grass cutter was four years. Similarly, the study assumed that government provides subsidy only for 25 households per year, so 25 households receive subsidy for the first four years and 16 households in the fifth year.

Estimated total costs per ha was US$907 for the entire period of the management plan. Similarly, the benefit accrued was US$1156/ha. Benefit-cost ratio of 1.27 indicated present management strategy of natural forest management was cost effective to the households. In the first year household invested more than benefits received. This was mainly due to purchasing of equipment used in forest products harvesting and transportation. From the second year, benefits took over the households' cost of managing natural forest.

Table 7.3 Present values of costs and benefits of natural forest management in Dinh Hoa. Types of costs and benefits, associated years and present values (US$) are given.

Costs	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	PV
Equipment	28651	0	0	1045	87	0	1045	87	0	1045	30572
Repair	0	1098	1098	1098	1098	1098	1098	1098	1098	1098	6324
Forest development	22665	22665	22665	22665	22665	22665	22665	22665	22665	22665	153195
Tending operations	20141	20141	20141	20141	20141	20141	20141	20141	20141	20141	136133
Harvesting	31809	31809	31809	31809	31809	31809	31809	31809	31809	31809	215001
Total	103266	75714	75714	76758	75800	75714	76758	75800	75714	76758	541224
Cost/ha	173	127	127	129	127	127	129	127	127	129	907
Benefits	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**	**PV**
Forest products	101780	101780	101780	101780	101780	101780	101780	101780	101780	101780	687936
Subsidy	550	550	550	550	358	0	0	0	0	0	2161
Total	102330	102330	102330	102330	102138	101780	101780	101780	101780	101780	690113
Benefits/ha	171	171	171	171	171	170	170	170	170	170	1156

7.2.2 Sensitivity analysis

Table 7.4 reports results of sensitivity analysis in different scenarios (see Annex 2 for details). The results showed that natural forest management was economically viable without subsidy situation as well. If farmers concentrated only on major forest products including timber, small round wood, firewood and fodder, then economic benefits would be decreased. Existing practice of natural forest management could not be endured if the households would not contribute in forestry activities or if forestry activities would have been carried out by hired labor.

Table 7.4 Benefits and costs of natural forest management under different scenarios in Dinh Hoa. Scenarios and their description, present values of benefits and costs (US$) and benefit-cost ratio of each scenario are given.

Scenario	Description	PV of Benefits (US$)	PV of costs (US$)	BCR
Scenario I	No subsidy	1152	907	1.27
Scenario II	No NTFPs	933	802	1.16
Scenario III	Forest products collection by hired labor	1156	1353	0.85
Scenario IV	No NTFPs + forest product collected by hired labor	900	1130	0.80

7.3 Benefits and costs of planted forest management

Table 7.5 reports required costs and benefits associated with planted forest management. Households receive benefits in the beginning as subsidy, and at the harvesting age from the forest products. The subsidy shared merely 6% of the total benefits. However, cost of planted forest management starts from year one in terms of land preparation, seedling purchasing, plantation, and purchasing of equipment and fertilizer. Equipment cost shared 52% of the total costs in the first year. Forest management cost was far-seconded the equipment costs. The costs of forest development and forest management vary with rotation period of plantation.

Table 7.5 Recurrent costs and benefits of planted forest management (per ha) in Dinh Hoa. Types of costs and benefits and amounts (US$) are given.

Costs	US$	Benefits	US$
Equipment cost (EC)	127	Forest products (7th year)	1553
Repair cost (RC)	6	Subsidy	92
Forest development cost (FDC)	18		
Tending operations cost (TOC) (Forest management cost)	72		
Harvesting cost (HC)	23		
Total costs	246	Total benefits	1645

7.3.1 Benefit-cost ratio

Benefit-cost ratio (BCR) of the present values of benefits and costs of planted forest management was 3.19 (Table 7.6). The benefit-cost ratio of greater than one indicated planted forest management was financially attractive. However, farmers receive benefits only after seven years (i.e., harvesting age of planted trees), and have to be prepared to invest for the period. In this analysis, we considered seven years rotation period as most of the households preferred this age (chapter 6) to harvest acacia, the dominant planted species in the study area. We assumed households received subsidy when they planted trees. Equipment had different lifespan and farmers purchased it accordingly. They selected forestry activities according to the age of the plantation. Forest patrolling was a regular task till harvesting.

Table 7.6 Present value of costs and benefits of planted forest management in Dinh Hoa. Types of costs and benefits, associated years and present values (US$) are given.

Costs	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	PV
Equipment	127	0	0	6	4	0	0	136
Repair	0	6	6	6	6	6	6	24
Forest development	18	5	5	5	5	5	5	39
Tending operations	72	11	6	0	5	0	0	91
Harvesting	0	0	0	0	0	0	23	13
Total	217	22	16	17	19	11	34	303
Benefits	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**PV**
Forest products	0	0	0	0	0	0	1553	877
Subsidy	92	0	0	0	0	0	0	92
Total	92	0	0	0	0	0	1553	968

7.3.2 Sensitivity analysis

In order to examine effects of various parameters on costs and benefits of planted forest management, sensitivity analysis was carried out. Four scenarios were developed for this analysis (Table 7.7, Annex 3). The analysis showed that in all four conditions, planted forest management was economically efficient. The subsidy was considered because subsistence farmers need initial investment funds. Estimating the monetary value of time required for forest management in terms of market wage provides insight into whether existing forest management practices can be extended beyond subsistence level. Rotation age is the age at the time of harvest, and is the planned number of years between establishment of plantation and the time when the planted trees are felled.

Table 7.7 Benefits and costs of planted forest management under different scenarios in Dinh Hoa. Scenarios and their description, present values (US$) of benefits and costs and benefit-cost ratio of each scenario are given.

Scenario	Description	PV of benefits (US$)	PV of costs (US$)	BCR
Scenario I	No subsidy	877	303	2.89
Scenario II	Monetary value of household time converted using market wage	968	366	2.65
Scenario III	Rotation period of 10 years	797	324	2.46
Scenario IV	Rotation period of 10 years and monetary value of household time converted using market wage	797	470	1.69

The result showed that rotation period of seven years was more profitable than a ten-year rotation period. Most of the households in the district were survival-oriented households. The households need immediate returns on their investments. As in the natural forest management, it was learned that plantation forest management can survive financially even without subsidy.

7.4 Discussions

Assessment of economic viability revealed household-based forest management (HBFM) in Dinh Hoa district is economically beneficial for participating households. Financial benefit-cost analysis at the household level, estimated benefit-cost ratios (BCRs) of greater than one for both, natural forest management as well as planted forest management. Resultant BCRs indicated that the HBFM is economically efficient in Vietnam given the present socio-economic context. Net benefit from natural forest management was estimated to be US$250 for the period of ten years. Planted forest contributed US$665 for seven-year rotation period.

Results revealed planted forests were economically more attractive than natural forests. This is rational, since plantations often produce more usable biomass than that available from natural forests (Stanturf et al., 2003). Despite the higher returns from planted forests, subsistence households might prefer natural forest management. Natural forests produce immediate and continuous flow of benefits over the years. In case of planted forests, the small-holders have to wait till the rotation age. In the district, most of the households harvested acacia between 5 and 8 years, which can be referred as medium rotation period for the species (Sikor, 2011). Few patches were managed at a rotation period of more than 15 years. The longer the rotation period, the higher the financial requirements are. Most of the households in Dinh Hoa districts were survival-oriented households (see Sikor, 2011). The higher financial requirements for the long-rotation plantations: initial investments, managing silvicultural treatments (labor and experts), and hiring labor for harvesting and transportation, exceed financial capacity of the households. In general, poor people have short-term horizons as they struggle to managing day-to-day living, hence they expect immediate returns on their investment (Woodburn, 1982).

Benefits from natural forest would further increase if forest environmental services, such as, conservation, and enhancement of forest carbon stocks, were considered as benefits. Natural forests often contain rich communities of plants and animals, and market value of forest resources constitutes only small portion of the total biodiversity value (Gowdy, 1997). However, this doesn't imply plantation stands have less importance. Their role in rehabilitating degraded tropical ecosystem has widely recognized (Parrotta, 1992). Results showed NTFPs influence the benefit-cost ratio of natural forest management considerably. These products may have significant contribution in livelihoods of farmers, and their extraction was less destructive (Arnold and Pérez, 2001). Besides, the study learned existing natural forest management was economically viable only in subsistence economy, where households can contribute to forest management activities.

Result showed a significant portion of the total forest management costs, particularly in the first year, was drawn by equipment used in forest product harvesting, and transportation. This cost was a financial burden to the small-holders managing small patches of forest. Therefore, forming cooperatives of the small-holders, and purchasing common equipment such as tractor and power chain saw would be beneficial for them. This may also enhance overall benefit of forest management by reducing the equipment costs. Additionally, the cooperatives might enhance their bargaining power while trading forest products, for instance, acacia timber or bamboo.

The study recognized rotation age was one of the major determinants of financial returns from plantation forest. Rotation age has different effects on financial returns based on the species planted. Results revealed short-rotation period tends to produce higher returns than longer rotations. This contradicts with a study in Lobolly pine plantations (Taylor and Fortson, 1991), where longer-rotation yielded higher economic returns. In the study area, seven-year rotation period was preferred and practiced by the small-holders. In addition to the poor economic condition of the households, another determinant to encourage the short-rotation period was market- a high demand for small round wood of *Acacia* spp., particularly for pulp. Moreover, the households perceived a risk of insect attacks beyond this age. This corroborates that short rotations are less risky compared to long rotations (ibid).

Subsidies, grants and taxation incentives are common in developing countries to promote conservation measures, and to encourage reforestation and afforestation program. My results showed subsidy has no influence on benefit-cost ratio in natural forest, but has substantial effects in planted forest management. In general, studies have shown subsidy structure favors plantation forestry relative to natural forest management (Kishor and Constantino, 1993). Increasing subsidies might further encourage the survival-oriented households to be involved in reforestation program, and enrichment planting of native tree species – of long-rotation period - in their planted, as well as degraded natural forest.

8 Discussions

8.1 Technical feasibility

The study classified and compared land cover maps from 1993, 2000, 2006 and 2010 to assess 1993-2010 land cover changes. Forest land and non-forest land were classified under several sub-categories which are consistent with national land use/land cover classification systems. Natural forests constitute Evergreen-Broadleaf forest-Medium, Evergreen-Broadleaf forest-Poor, Evergreen-Broadleaf forest-Regrowth, Bamboo forest, Mixed Wood and Bamboo forest and Limestone forest. Non-forested lands constitute Limestone area, Bare land planned for forestry, Residential area, Water area and Other land.

According to forest cover change analysis, forest area has been increasing steadily since 1993 in Dinh Hoa district. Between 1993 and 2010, forest area increased at a rate of 5.5%, which is equivalent to 900 ha/year. Between 2005 and 2013, average forest cover increase in Thai Nguyen province was 2040 ha/year (Thai Nguyen Statistics Office, 2014). This shows the district contributed significantly to the annual increment of forest cover of the province. Expansion of natural forests and gradual increase in afforestation and reforestation in bare lands contributed to the forest cover increase in Dinh Hoa.

The study estimated distribution of carbon stock across five carbon pools and different forest types. Estimated average total carbon stock was 54.01±2.82 t/ha. The carbon stock differs significantly from average carbon stock estimated for the country (124 t/ha) (FAO, 2010a; FAO, 2010b). Likewise, the country average of carbon in above ground biomass was enormously higher (61.6 t/ha) than Dinh Hoa average of 12.65 t/ha. The country estimates were based mostly on default values as suggested in IPCC guidelines (IPCC, 2006). This suggests policy makers to be cautious when using global models and values while designing jurisdictional/sub-national REDD+ scheme.

In Dinh Hoa, natural forests were dominated by Evergreen-Broadleaf forest-Regrowth (50%) and Mixed Wood and Bamboo forest (42%). Those forests were thriving with natural regeneration either after heavy exploitation in the past, or rehabilitating on abandoned agricultural and bare lands. The natural forest expansion has contributed to low average growing stock (and eventually to low carbon stock), and small stand diameter (12 cm) in natural forests. The small stand diameter indicates early development stage and low timber harvesting potential of the forests.

Results showed designated ecological functions, i.e., special use, protection and production imposed significant effects on above ground tree biomass of the forests. Protection forests had the highest above ground tree biomass followed by Special use and Production forests. Canopy cover and forest structure showed significant impacts on the above ground tree biomass. Special use forests had the highest carbon density followed by Protection and Production forests. Soil organic carbon contributed 73% of the total forest carbon stock and was the largest carbon pool in Dinh Hoa forests. The ecological forest functions showed highly significant impact on the soil organic carbon pool. Besides, the pool was affected significantly by soil types, altitude and mean slope gradient. Impact of slope aspects was non-significant on the soil organic carbon pool. In the district, most of Special use forests and Protection forests were located in higher altitude and were multi-layered forests. The evidence of strong association of the carbon stocks with the forest types, and with particular carbon pool provides valuable information for policy makers to make informed choice of forest management regime, forest types and carbon pool for the landscape.

Area of Evergreen-Broadleaf forest-Regrowth substantially increased between 1993 and 2010, while no significant change was observed in area of Mixed Wood and Bamboo forest during that period. Evergreen-Broadleaf forest-Regrowth and Mixed Wood and Bamboo forest share more than 92% of the total natural forest area. This suggests, *conservation of carbon stocks through the protection of existing/regrowth forests*, and *enhancement of carbon stocks by restoration of degraded forest lands through assisted natural regeneration* might be potential REDD+ activities.

Natural forest area was soaring upwards until 2006, but showed backsliding for the period of 2006-2010. Area of Evergreen-Broadleaf forest-Regrowth was reduced by 3000 ha over the four year period. The LULC matrix 2006-2010 (chapter 5) clearly demonstrates the forest area was converted to forest plantations, which was further confirmed by Thai Nguyen Statistical Office (2014). More than 4500 ha of plantations were established in the district between 2005 and 2013 (Thai Nguyen Statistics Office, 2014). Area of Bamboo forest was reduced by 50% between 1993 and 2010. The results indicated potential of *reducing emissions from deforestation through avoided planned deforestation*-as a REDD+ activity.

The study observed forest degradation was not a serious threat in the district. However, reduction in areas of Evergreen-Broadleaf forest-Medium by 89 ha and of Evergreen-Broadleaf forest-Poor by 458 ha from 1993-2010 indicated forest degradation is definitely taking place. More than 4500 ha of forests have been fully (non-extractable) protected under the Scheme of Forest Protection and Development in Dinh Hoa Safety Zone (ATK Scheme). The forests are considered as a part of Dinh Hoa Safety Zone- a relic complex of the Vietnamese revolutionary history (GSRV, 2008b). Estimated household demand/year of timber (0.44 m^3), small round wood (0.54 m^3) and fuelwood (7.6 tonnes) are potential threats for the remnants (chapter 7). In 2012, each household collected 0.75m^3, 1.3m^3 and 6.5 tonnes of the forest products respectively. Considering the low annual increment of the forests, the harvest might have exceeded annual available cut. There is potential to increase forest productivity through enrichment planting on degraded forests. However, there are other financial implications for the activity. Though, *reducing emissions from forest degradation* is a potential activity, but not promising from REDD+ perspective in the district.

In Dinh Hoa, planted forest area was increased from 531 ha in 1993 to 14473 ha in 2010. Annual increment was 820 ha. For the same period, the area of non-forest land decreased by 900 ha annually. In 1993, ratio of non-forested land area: natural forest area: planted forest area was 67.4: 28.3: 1. In 2010, the ratio was 1.4: 1.1: 1. This is now obvious that plantations were installed mostly on the non-forested land. The results suggest *enhancement of forest carbon stocks through conversion* of barren and unused land to forest land is practically achievable in Dinh Hoa. The conversion was mainly achieved through afforestation, reforestation and restoration activities. There are nearly 3000 ha of bare land planned for forestry activities and 12000 ha of other non-agricultural land potential for afforestation, reforestation and restoration.

In the district, majority of the planted forests have been established on lands- with low carbon and biodiversity values (low in carbon and low in conservation value), and without significant forest recovery potential (or where forest recovery is infeasible). Plantations bear potentials of producing substantial quantity of timber and avoiding need to source from natural forests. However, most of the plantations in the district were comprised of exotic species, and therefore, might not be attractive for volunteer market. Tropical exotic fastwood species, such as, acacia and eucalypts constitute larger area of the plantations compared to native tree species, such as, *Magnleitia glauca*, *Melia azedarach* and *Cinnamomum cassia*.

Most of the households in the study area are harvesting acacia at the age of 8 years. The native tree species have longer rotation period than acacia. With the longer rotation period, financial requirements are higher. In the study area, most of households were survival-oriented households (Sikor, 2011). The households have difficulties to meet food requirements for the entire year and are highly vulnerable to unexpected expenditure. Such households have short-term horizon and they need immediate returns on their investments (Woodburn, 1982). Management of the long-rotation native tree plantations is beyond the financial capacity of the survival-oriented households. The government encourages the households for enrichment plantation of *Chukrasia tabularis* and *Erythrophleum fordii* (native and high quality timber species) in Protection forests, while the financial situation of the households hinders them to implement such activity. Hence, *improved forest management with extended rotation age* might be a potential activity from REDD+ standpoint, but affordability of such activity is still a question at given point of time. We observed similar situation throughout Vietnam. Jurisdictional REDD+ with upfront and/or additional financial support might be a potential convincing factor for long-rotation plantation management.

8.2 Operational feasibility

8.2.1 Existing forest management practices and forest land allocation program contributed to conversion of non-forest land to forest land and enhanced protection of regrowth forests

Forest protection and development practices and forest land allocation in the district are inherently guided by national policies and measures. Pursuant to the Law on Land, and to the Law on Forest Protection and Development, the Thai Nguyen Provincial People's Committee implemented forest land allocation in 1992 in Dinh Hoa. Besides allocation of forests and forest lands to local households, the forest land allocation included small cash payments (US$5/ha/year) for forest protection contracts, and subsidies in terms of cash and in-kind such as seedlings and fertilizer for tree planting.

In 2013, local households owned more than 21,000 ha of forests in the district. Forest area even at the household ownership (or management) in 2013 was significantly higher than the total forest area which the district had in 1993 (15,556 ha). Between 1993 and 2010, natural forest area was increased by 1500 ha and planted forest area was increased by 14000 ha. Area of Evergreen-Broadleaf forest-Regrowth was increased by 3100 ha for the same period. It is apparent that the forest land allocation and forest protection contracts caused households to protect and restore natural forests, to establish plantation forests, and use those forests for long-term purpose; and consequently led to the substantial increase in forest cover. The findings suggest the forest expansion not only coincides with the forest management policies and practices that mandated decentralization and devolution of forest management authority, but also is the resultant of the national policies and measures. The result resonates the findings of several other studies suggesting the drivers of increased forest area in Vietnam are government policies and measures, notably forest allocation policy and protection contracts under the 5MHRP (To et al., 2012; Thiha, 2007a; Thiha, 2007b; Phuc, 2013; Heimo, 2010).

8.2.2 Long-term land tenure and secured forest use-rights encouraged households for the conversion

Secure rights in forest land are essential for the implementation of REDD+ (Chagas et al., 2011). Stern (2007) recognizes the needs to address issues of tenure, property rights and traditional rights. In Vietnam, forest land allocation entitled land users to use the allocated land for 50 years, enjoy its benefits, transfer use rights to other entities, and use allocated rights as collateral (Sikor, 2001). The land-use rights are secured by means of land-use certificate (the Red Book).

The study examined households' perception towards forest management practices and attitude towards forest land allocation and associated forest/land use-rights. A questionnaire survey was carried out amongst the households residing in 12 villages of the district. Respondents from 274 households were interviewed. Of the interviewed local inhabitants, almost all of them felt secure about their forest-use rights. They assured ownership of and use rights on planted and natural forests were more explicit than ever before.

Griffiths (2007) suggested the need for more solid guarantees that human and customary rights of forest peoples will be respected in any future avoided deforestation policies and programs. The local agreements in the study area showed that the use-rights and obligations were mutually respected by local households and state authorities. They expressed land-use conflicts are minimized. All respondents confirmed provision of mortgage of natural (production) forests and planted forests enhanced their capacity and credibility to borrow loans from rural financial institutions and formal credit markets.

Vietnamese Constitution states all lands are state property, and owned and administered by the state. The state grants forest use-rights through one of three arrangements: forest land allocation, contract or lease. The use-rights and obligations differ according to the arrangements, user groups and forest types. Forest users receiving forest or forestland allocated to them benefit the largest scope of use-rights compared to those granted under contracting and leasing arrangements (To et al., 2012; Dang et al., 2012). Forest owners of Special use and Protection forests have limited autonomy over their forests, especially in case of natural forests (Dang et al., 2012). The natural forest owners cannot sale, exchange, lease, donate and mortgage their use-rights. The land-use rights: tenure (land title), use, residual income, inherit and invest over natural forests are much restricted compared to productive forest plantations. Thus, households are not real 'forest owners' but are forest users. This ambiguity should be clearly specified in Laws and sub-law regulations. Several studies suggest local and indigenous communities are managing and protecting forests effectively, and arguing that further significant advances in carbon and ecosystem maintenance could be achieved if resolution of tenure issues and greater finance were to be expedited (ISU, 2015).

Carbon rights which may be affected by or effect implementation of REDD+ policies and programs, are cross-cutting issues not only for REDD+ implementing countries, but also for carbon credit buyers particularly from private sector. The sector is being increasingly involved in jurisdictional REDD+. It is very unlikely that the UNFCCC negotiations would create detailed rules defining substantive issues of carbon rights (To et al., 2012). As long as different national and local circumstances (forest management practices, forest ownerships) prevail, much of this would likely be left to national governments to address under domestic legislations. Including Vietnam, most of the REDD+ implementing countries are yet to define 'carbon rights' in their domestic legislation. Moreover, the carbon rights attached to different carbon pools should be explicitly defined. In Dinh Hoa, carbon in soil (soil organic carbon pool) contributed more than seventy percent of the total carbon stocks in the forest.

To et al. (2012) express that state granted land/forest use-rights presumably extend to include carbon. The Law on Forest Protection and Development (Article 64) recognizes in principle that buyers may purchase forest goods and services (potentially including reducing carbon emissions from sources and removals by sink), with payments delivered to those responsible for generating the goods and services. Section 4 of the Law describes right and obligations of forest owner being a household and individuals. Articles (69, 70 and 71) under the sections allow the users to exploit and use of forest products and enjoy added values.[34] Policy on Payment for Forest Environment Services (Decree 99) (Article 4) recognizes a bunch of forest environmental services including conservation and enhancement of forest carbon stocks, and conservation of biodiversity. Article 8 of the Decree recognized households and individuals as entities to enjoy payments for the services. The Law on Protection of the Environment (Article 84)[35] states the provision of transfer, buying, and selling of GHG emissions quotas between Vietnam and foreign countries (GSRV, 2005).

Though there is no law that specifically addresses carbon ownership in Vietnam, the laws, decrees and programs effective in Vietnam appear to support legal land users owning carbon rights (To et al., 2012). National REDD+ Action Program intends to review, amend and supplement legal frameworks and formulate legal documents on forest carbon rights, benefit sharing and safeguard measures for REDD+ implementation (GSRV, 2012c).

8.2.3 Willingness of local households to engage in forest protection and development practices

Several studies highlighted needs of understanding of perceptions and attitudes of rural communities towards conservation of forest and forest management programs. Infield (1988) emphasized that attitudes of rural communities towards conservation must be studied and their perceived needs and aspirations should be taken into account for effective conservation outside of protected area. Due to differences in abilities, attitudes and perceptions of forest community, securing active and equitable

[34] Article 69- to exploit, use forests and fully tap forest products (Protection forests); Article 70 (2)- to exploit planted production forests, (3)- to exploit added value on natural production forests; 71 (2)- to enjoy the added value of leased production forests

[35] Article 84 (2) - The transfer, buying and selling of greenhouse gas emission quotas between Vietnam and foreign countries shall be as stipulated by the Prime Minister of the Government.

participation from all social layers remains a challenge for all forest conservation projects (Ratsimbazafy et al., 2012). On the contrary, the present study found exceptionally positive perceptions of local households towards forest protection and development practices, and positive attitudes towards forest land allocation and state forest authorities. Since the households have favorable and positive attitudes towards the regimes, the likelihood that they will continue involving in implementation of the regimes is guaranteed. Positive perceptions and attitude on conservation initiatives are good indicators for sustainability of REDD+ initiative (Sutta and Silayo, 2014). Increased households' access to forest authorities, and improved trust between local households and the authorities have built strong confidence among the households. This has led to the inclusive participation of the households including women and ethnic minorities in land use planning and forest management, and decision-making related to forest management in the study area (chapter 6).

The study estimated present value of costs of and benefits from natural forest and planted forest management to understand whether the household contributions to the forest managements are economically viable for the households (chapter 7). The costs were described as equipment cost, repair cost, forest development cost, tending operation cost (forest management cost) and harvesting cost. The forest development cost, forest management cost and harvesting cost together contributed 72% of the total costs incurred for natural forest management. Most of the costs were generated in terms of labor from household members. The enormous contributions in terms of household labor demonstrated a strong willingness of households to participate in forest protection and development activities.

8.2.4 Willingness and capacity of local households to participate in REDD+ mechanism

The study attempted to explore local understanding of and willingness to participate in REDD+, and found low level of knowledge among the households and public understanding about the scheme. Majority of the households understood trees store carbon, while they were totally unaware of REDD+ and carbon credit. In Vietnam, knowledge of REDD+ issues is very strong at national level (WWF, 2013b). Vietnam is the first country to pilot free, prior and informed consent (*ibid.*). However, awareness among administration at all levels and among population of all strata on climate change and disaster is not deep enough and associated closely with highly practical actions (GSRV, 2012b). REDD+ is highly technical and hard to understand for low capacity countries, political leaders and other constituencies (ISU, 2015). Use of carbon standards could reduce risks for buyers and sellers of REDD+, bearing in mind that there can be trade-offs between high standards and ability of certain groups to meet these standards (Peskett and Harkin, 2007).

Despite the dearth of knowledge and awareness in the study area, the locals expressed a strong interest to participate in REDD+ and preferred the government to implement the scheme in the study area. Jeremiah (2014) found local peoples' willingness to participate in REDD+ activities was influenced by attitude, land size and income; but to the greatest extent by awareness. Community participation is one of the critical components of REDD+ implementation success, and is seen to be the building block for the efficiency of REDD+ project (Ratsimbazafy et al., 2012). Therefore, prior to and during the implementation of jurisdictional REDD+ program, proper and continued awareness and capacitation on REDD+ of participating households, local political leaders, local government, field-level forestry officials and civil society groups and non-governmental organizations working in forest management are highly needed. The awareness and capacity-building support them to understand climate change and its impacts; REDD+ processes, and its' potential benefits and risks; and help to benefit from REDD+ and to manage REDD+ activities; and to monitor the results of the activities. REDD+ capacity-building contributes to developing expertise on community rights and livelihoods aspects of REDD+, and links to broader processes (like, sustainable development) and networks focused on them (WWF, 2013a).

Most of the jurisdictional programs currently implemented around the world are facing important gaps in human and technical capacity and finance (Fishbein and Lee, 2015). A significant investment is needed to build subnational government capacity so that they can adequately adapt REDD+ design to local realities (Larson and Petkova, 2011).

8.3 Financial viability

Costs associated with REDD+ mechanism can broadly be grouped into two types: i) opportunity cost of compromising forest use, and ii) implementation, institutional and transaction costs. In Vietnam, land use change from forest to other forms (agriculture, pasture etc.) is restricted by law for contracted or leased household forestry. Opportunity costs of forest conservation in the context of household forestry could arise due to compromises that households would make in harvesting forest products or restricting their access to such products. Opportunity costs of conserving forest for the purpose of GHG emissions reductions underpin economic sustainability of REDD+, and are essential to ascertain before embarking into REDD+ mechanism (Gurung, 2014).

The study estimated present value of net benefit from natural forests to be US$25 per ha per year (chapter 7). The households accrued the benefit from forest products such as timber, small round wood, fuelwood, and other NTFPs. Benefit cost ratio was greater than one (1.27). In this context, REDD+ would be financially attractive to the households if the mechanism generates additional income, i.e. income additional to the current income from the forest management. In other words, it is based on an assumption that storing carbon in the household forests is a part of conservative forest management practice of the households, which would not necessarily compromise the forest use pattern of the households. However, several challenges and uncertainties are related to this assumption, for instance, how carbon-focused forest management will fulfill households' forest product needs and what trade-offs might exist between contemporary practice and carbon-focused forestry. These challenges are not predictable at this point of time. Implementation of REDD+ might impose more restrictions on land and forest use-rights, and might change the access to the forest products. Mertz (2009) argued one of the key implementation challenges in REDD+ scheme is to ensure that poor farmers have access to forest products and they perceive such program as beneficial one to their livelihood.

In the study area, smallholders derive significant share of their total household (cash) income from livestock, tea and cassava cultivated in the allocated forest land, forest based activities and non-timber forest products including wild-foods (bamboo shoot, honey). Forestry based activities including skilled labor and wage labor and forest products contributed 24% of the total household (cash) incomes. The income from forest based enterprise is not included in the contribution. This result resonates with the findings of Vedeld et al. (2004) and Nguyen et al. (in press). Vedeld et al. (2004) found 22% of the total income of households studied in eastern and southern Africa was contributed by fuelwood, wild foods, and fodder for animals. Nguyen et al. (in press) found forest products collected from natural forests contributed 21% of the total household incomes each year. Although agriculture and off-farm incomes had higher share of the total household incomes in Dinh Hoa, forest based income is of particular importance to households living close to poverty line (survival-oriented households). We observed the forest products are providing an essential source of income during poor agricultural harvest in the district. Such income from forest products has a strong and significant equalizing effect on local income distribution (Vedeld et al., 2004). Since REDD+ is a performance/result-based payment mechanism, important concern arises on whether REDD+ would maintain benefit flows in terms of time (temporal distribution) and distribution among households. Support for upfront costs is required in order for national/local governments, companies, communities and individuals to access REDD benefit flows (Peskett and Harkin, 2007). In this context, jurisdictional implementation of REDD+ might attract upfront payment from private sector.

Grieg-Gran (2006) summarizes factors affecting opportunity costs including methodological issues (type of activities) and various economic, social, and geographical/physical factors. In examining opportunity costs of REDD in Brazil and Indonesia, Olsen and Bishop (2009) observed significant variation in per hectare opportunity costs between countries reflecting differences in local conditions, land use and proximity to transport infrastructure and markets. Nguyen et al. (in press) assessed 'willingness to accept' of compensation payment for natural forest (non-extractable) protection by conducting in-person interviews involving the households (of the same study area as this study). The study showed the acceptance of compensation level differs between the forest types. Mean willingness to accept of households contracted/allocated Production forest, Special use forest and Protection forest were US$28, US$16 and US$14 per ha per year. This further suggests the need of estimating both opportunity costs and carbon content on forests locally, indicating a high applicability of jurisdictional REDD+ implementation.

The second major cost component – implementation, institutional and transaction costs - are costs associated with search, negotiation, certification, insurance, implementation, enforcement, monitoring, measurement, reporting and verification. There is a significant economies of scale that large projects have lower implementation costs per unit of emissions avoided (Olsen and Bishop, 2009). Transaction costs, on the other hand, are likely to be fixed and will be greater for smaller projects than for larger projects and also greater for a large number of small transactions than smaller number of larger transactions (Börner and Wunder, 2008). Transaction cost has direct relevance to jurisdictional implementation of REDD+ in household-based forest management in Vietnam. This is particularly important in present situation as areas of allocated/contracted forests to households in the district are small (<5 ha/household) and fragmented, while for REDD+ project to be economically attractive allocation of comparatively large forest area is required. In such scenario, formation of cooperatives and/or group certification might be a good option to reduce transaction costs. Vietnam has developed a benefit sharing mechanism for payment for forest environmental services including carbon sequestration. Decree 99 (Article 6) states, payment for forest environmental services can be made directly to providers of the services. Under jurisdictional approach, this provision allows households to receive REDD+ benefits directly from buyers. Implication of this might reduce transaction and institutional costs.

Form of REDD transactions from international to national levels, and benefit distributions within the country, are yet to be decided. Chagas et al. (2011) suggested three models for distribution of REDD+ incentives from international REDD+ mechanisms: direct distribution to state, jurisdictions and projects; direct distribution to state and jurisdictions, and jurisdictions pass to projects; and direct distribution to state only, and state passes to jurisdictions and projects. Jurisdictional REDD+ implementation adopting the second model reduces transition costs. In addition, jurisdictional and nested REDD+ requirements issued by Verified Carbon Standard proposed similar models (Verified Carbon Standard, 2014). REDD+ funds could lie within the pockets of a few individuals, place additional burdens on rural poor and/or fail to diminish carbon emissions (Larson and Petkova, 2011). Therefore, less centralized systems may be preferred for efficiency, administration costs reduction and avoiding state capture (Peskett and Harkin, 2007).

Since 2006, Vietnam has secured nearly US$100 million of funding (multilateral and bilateral) for REDD+ and other forestry related activities. However, financial support for result-based payments is not secured and predictable. National REDD+ Action Plan (2011-2020) supports formation of carbon credit markets and encourages private sector participation in REDD+ (To et al., 2012). Vietnam is also involved in discussions with international development partners, including FCPF Carbon Fund and German REDD+ Early Movers Programs for additional support for REDD+ readiness and for provision of positive incentives for REDD+ performance (WWF, 2013b). Jurisdictional and nested REDD+ implementation contain a high potential to harness much-needed and secured finance for the country until 2020.

8.4 Political feasibility

The study analyzed political feasibility of jurisdictional REDD+ implementation (JRI) in three perspectives: i) whether the legal frameworks of the country allow JRI; iii) whether institutional arrangement for REDD+ implementation established in Vietnam is supportive to JRI; and iii) if JRI could be integrated to the forest protection and development, and land use practices at jurisdictional level.

REDD+ is considered as a key component of National Target Program to Respond to Climate Change (NTP-RCC); and a key instrument to achieve the country's aims to reduce emissions from agricultural and rural development sector (including forestry) by 20 percent by 2020, and to increase overall forest cover to 45 percent by 2020. Vietnam has several laws to support REDD+ activities: Law on Land, Law on Forest Protection and Development, Law on Protection on Environment, and Law on Biodiversity. The overall goal of REDD+ and activities conducted in order to achieve the goal, are coherent with several national strategies and plan related to climate change and forest development: National Strategy on Climate Change, National Strategy on Green Growth, National Forest Development Strategy, and National Action Plan on Forest Protection and Development.

In accordance with the agreed consent of 16th UNFCCC Conference of the Parties (COP 16) in Cancun, Vietnam approved a National REDD+ Action Program 2011-2020 (NRAP) with ambitious, time-bound and nation-wide objectives. REDD readiness preparation and piloting are key tasks for the period of 2011-

2015, and completion of formulation of relevant mechanisms and policies, finalizing reference emission levels/forest reference levels (RELs/FRLs), MRV, benefits distribution system (BDS), safeguards are major tasks for 2016-2020.

Institutional arrangement for REDD+ implementation in Vietnam constitutes a network of institutions at scales of REDD+ implementation from national to commune level. The institutional arrangement is vertically arranged undertaking a nested or a jurisdictional approach (partially decentralized or partially centralized approach). The arrangement sets a clear division of responsibilities and authorities between national and subnational (Provincial, District) levels; and establishes mechanisms for coordination and interaction both vertically and horizontally. This is particularly important for MRV and financial functions because these functions play huge roles in distribution of benefits among REDD+ participants.

Province level actors (Province-level Peoples' Committee, Provincial REDD+ Steering Committee, and Provincial REDD+ Taskforce) can implement REDD+ functions with some degree of independence from a higher-level authority ensuring compliance with nationally and internationally agreed-upon financial, fiduciary and reporting standards.[36] The National REDD+ Action Program explicitly assigned to the Province level actors several mandates and tasks related to REDD+ implementation, MRV and finance:

Implementation and MRV:

- Prepare and implement provincial-level REDD+ program in accordance with REDD+ national strategies and policies, MRV standards, and social and environmental safeguards
- Develop provincial-level reference emission levels
- Oversee implementation of District REDD+ activities, programs and projects

Finance:

- Establish provincial-level Forest Protection and Development Fund, and provincial-level REDD+ Fund
- Collect and manage Provincial-level Forest Protection and Development Fund and REDD+ Fund
- Allocate and distribute benefits among REDD+ participants

Furthermore, the arrangement sets District REDD+ Taskforce for REDD+ implementation. The Taskforce involves forest managers, local communities and other stakeholders while implementing REDD+ activities in respective district.

Province is second administrative level below national level. In accordance with the National REDD+ Action Program, Vietnam is piloting REDD+ implementation in eight provinces. The provincial administrative level fits to the Verified Carbon Standard requirements for jurisdictional or nested REDD+ implementation (Verified Carbon Standard, 2014).

Vietnam's REDD+ Readiness Preparation Proposal also explicitly refers to subnational implementation of REDD+. The proposal states, subnational RELs/RLs will be developed based on stratification of national

[36] The action of providing the results of the estimation of emissions and removals to the UNFCCC in a standardized manner (UNFCCC, 2003)

territory into more homogenous eco-regions (GSRV, 2011). Decree 99 recognizes forest carbon as one of the forest environmental services, where households are beneficiaries of the service (GSRV, 2010). The decree also recognized the Forest Protection and Development Fund. Vietnam is preparing REDD+ benefit distribution system closely linked with the decree.

In sum, the country's legal frameworks legitimate jurisdictional REDD+ implementation which is one of the key tasks under the National REDD+ Action Plan. The institutional arrangement constituting a network of institutions at scales of REDD+ implementation is in principle highly supportive to jurisdictional REDD+ approach.

The study found concurrent forest policies, forest land allocation and long-term tenure have collectively contributed to substantial increase in forest cover in the district. Households perceived forest protection and development, and forest land allocation had positive impacts on their livelihood (chapter 6). Positive perceptions of the households have increased their investments and meaningful participation in forest and forest land management, and enhanced inclusive decision-making process regarding forest protection and development, and forest land allocation. The study showed forest protection and development (natural forest and planted forest) practices are financially beneficial for the households. All the stakeholders have embraced protecting natural forests and rehabilitating degraded (forest) and unused lands as routes to achieve economic and political goals. More importantly, the study observed their strong willingness to participate in REDD+ program. Increased access of the households to forestry authorities and commune officials; and enhanced communication and trust between them indicate a favorable bureaucratic environment for REDD+ program. Meanwhile political and bureaucratic turnover was widely cited as an ongoing problem on the jurisdictions studied by Fishbein and Lee (2015). Coherent forest development policies and practices enhancing local livelihoods; forest and household friendly land-use planning; households' positive perception towards forest protection and development, households' positive attitudes towards forest land allocation and REDD+; and households' strong desire to participate in REDD+ program point to a high political acceptance of REDD+ at the local level. This implies that REDD+ activities should be coherent to and should embrace the concomitant policies, programs and practices related to forest protection and development, and the forest land allocation policy and program.

Lesson learned from REDD+ pilot projects suggested the need for REDD+ project to be firmly embedded into on-going sectoral and/or land use and forest management plans at national and sub-national levels for the successful implementation of the projects (To et al., 2012). This is even more pertinent for countries like Vietnam with strong top-down planning systems, and where forests are predominantly owned by the state. Working through on-going policy and planning structure is critical to ensure government buy-in, to allow replication and to reduce risks if any, associated with impermanence. Dinh Hoa District People's Committee has been managing ATK Scheme for sustainable management of forests in the district. Besides sustainable forest management, the scheme aims to create more jobs and contribute to increasing living standards for ethnic minority people in the district. Local political acceptability and local legitimacy of REDD+ mechanism might be increased substantially if implementation of REDD+ is integrated into the scheme.

Optimal forest management policy is not one instrument, but 'mix' of several. Complementary policy instruments can work together to achieve better overall performance against objectives, due to increased synergy among the instruments, at a lower cost (financial, time and other resource costs) than any one instrument implemented in isolation. Nevertheless, some instruments can interact in unexpected ways, if the instruments are not complementary, that may actually reduce performance. Aligning REDD+ with current practice of household forestry might have different levels of costs and benefits to the households, since some level of compromise or trade-off on current practice (particularly of forest products use) is inevitable. Reasons of such compromise among households could vary depending on numerous factors: level of dependency on forest products for livelihood, socio-cultural contexts, household economies, availability of close substitutes for forest products, opportunity costs of forgone forest use, and economic benefits accrue from practicing REDD+. Sensitiveness of the trade-offs depending on forest types, forest area, household needs and use of forest products, household's dependence on forests, and potential risks to households by engaging in REDD+ is an area that needs further exploration.

9 Conclusion

The study has advanced our knowledge and understanding of viability of jurisdictional REDD+ implementation in Vietnam. The viability was assessed in terms of technical, operational, financial and political feasibility. From technical perspective, there is scope of both reducing emissions from sources and removals by sinks. The study identified following REDD+ activities which are grouped under two sub-categories of managed forest lands specified by the 2006 IPCC Guidelines (IPCC, 2006):

Conversion of non-forest to forest

1. Enhancement of forest carbon stocks through restoration of degraded forest lands through assisted natural regeneration;
2. Enhancement of forest carbon stocks through increasing conversion of barren and unused land to forest through reforestation and afforestation of native tree species;

Forests remaining as forests

3. Reducing emissions from deforestation through avoided planned deforestation;
4. Conservation of forest carbon stocks through protection of existing/regrowth forests;
5. Sustainable management of forests through enrichment planting; and
6. Enhancement of forest carbon stocks through extended rotation age.

Among the potential activities, *conservation of forest carbon stocks through protection of existing/regrowth forests* and *enhancement of forest carbon stocks through restoration of degraded forest lands with assisted natural regeneration* would be the most promising REDD+ activities for the study area. Special use forests and Protection forests are major natural forest categories for the REDD+ activities. Evidences showed Evergreen-Broadleaf forest-Regrowth, Bamboo forest, and Mixed Wood and Bamboo forest have been converted to planted forests, particularly, after 2006. Thus, *reducing emissions from deforestation through avoided planned deforestation* might be further REDD+ activity to be considered.

The government encourages local households for forest enrichment through enrichment planting of native tree species of high quality timber in order to improve quality of poor and degraded natural forests and to meet households' demand for timber. The government also encourages establishment of forest plantations of the native tree species into barren and unused lands. From technical point of view, *sustainable management of forests through enrichment planting* and *enhancement of forest carbon stocks through increasing conversion of barren and unused land to forest through reforestation and afforestation of native tree species* might be potential REDD+ activities. However, longer rotation period of the native tree species compared with tropical fastwood species (such as, acacia, eucalypts) needs higher financial investment; which is beyond the financial capacity of the survival-oriented households in the study area at given point of time. The limited financial capacity of the households also restricts the potentials of *enhancement of forest carbon stocks through extended rotation age*.

The study suggests estimation of emission factors and preparation of reference emission levels for each activity; and calculation of corresponding financial values using different carbon price scenarios for explicit determination of REDD+ activities. The work could be built upon using historical land use and land cover data and thematic maps, and carbon stock distribution data provided by the study.

Concomitant land-use and forest policies and measures have contributed to conversion of non-forest land to forest land. Long-term land tenure and secured and explicit forest-use rights have encouraged households for natural forest protection, establishment of forest plantations, and long-term use of the forests and forest lands. Mutually understood and respected roles and responsibilities regarding forest management and improved trust among local stakeholders have led to an inclusive and meaningful participation in land use planning and decision-making related to forest management. In addition, increased households' access to forest authorities has contributed to build a strong confidence among the households. Collectively this has led to the development of exceptionally positive local perception towards forest protection and development practices, and positive attitudes towards forest land allocation and state forest authorities. Since the households have favorable and positive attitudes towards the regimes, the likelihood that they will continue involving in implementation of the regimes is guaranteed. Positive perceptions and attitude on forest conservation regimes and initiatives are good indicators for the sustainability of a REDD+ mechanism. Enhanced feeling of a sense of ownership in forest management has further motivated the small-holders for their enormous contributions in terms of household labor for forest protection and development. The contributions demonstrate a strong willingness of households to participate in forest protection and development activities. The households expressed a strong interest to participate in REDD+ scheme and preferred the government to implement the scheme in the study area. In this context, jurisdictional implementation of REDD+ is conceptually feasible from an operational perspective, because the forest management activities shaped by the policies and measures have conserved and enhanced forest carbon stocks through protection and development of existing and regrowth forests. However, low level of knowledge and understanding about REDD+ among local stakeholders is an impediment for REDD+ implementation and thus urged capacity-building. A significant investment is needed to build capacity of local households and jurisdictional governments so that they can understand complete aspects of REDD+ mechanism and adequately adapt REDD+ design to local realities.

Present value of net benefit of US$25 per ha per year and benefit cost ratio of greater than one revealed that household-based natural forest management is economically beneficial for the households in the study area. The net present value of the benefit indicates opportunity costs of forest conservation under REDD+ to the households. The opportunity costs appear to be high compared with current carbon price on international market. Benefits from natural forest would further increase if forest environmental services were considered as benefits. This implies that carbon market under REDD+ mechanism may entail high opportunity costs. It is now apparent that jurisdictional REDD+ implementation might be financially attractive to the households, if the mechanism accrues incomes additional to the current income from the forest management under the household-based forest management regime. This is in consistent with the core percept of REDD+ mechanism: the REDD+ actions must be additional-assumption of this study.

The additionality percept is based on an assumption that storing carbon in the household managed forests is a part of conservative forest management practice, which would not necessarily compromise existing forest use pattern of the households. However, implementation of REDD+ might impose restrictions on land and forest use-rights, and access to forest products, which in turn will violate the assumption. Further studies are needed to address challenges and uncertainties related to this assumption. The challenges and uncertainties, for instance, include: how carbon-focused forest management under REDD+ mechanism will fulfill households' forest product needs; to what extent REDD+ implementation affects forest and forest product use pattern of the households; and what trade-offs might exist between contemporary forestry practice and carbon-focused forestry under REDD+, while these uncertainties are not predictable at this point of time.

For the survival-oriented households, one of the major concerns of REDD+ implementation is: whether financial benefits from REDD+ would maintain benefit flows in terms of temporal distribution. This is very unlikely as REDD+ is a performance-based payment mechanism. Jurisdictional implementation of REDD+ with private sector engagement is likely to provide upfront payments and operational investments, and hence, might maintain the financial flows over the years of a commitment period.

At this stage of REDD+ development, there are still numerous financial and policy uncertainties. Since there are several unknowns about implementation, institutional and transaction costs of REDD+, it is challenging to conduct financial analysis for each of the REDD+ activity suggested by this study. This seriously hinders our ability to rank the activities based on the financial benefits in return, which would help to prioritize the activities for the jurisdictional implementation.

Based on review of national and international REDD+ policy documents, jurisdictional REDD+ implementation is politically acceptable and compliant with requirements of national policy, the UNFCCC REDD+ process, and other relevant processes outside the UNFCCC, such as Verified Carbon Standard. The country's institutional arrangements for REDD+ implementation, undertaking a jurisdictional approach and constituting a network of institutions at scales of REDD+ implementation, is in principle highly supportive to jurisdictional REDD+ approach. The assignment of several mandates related to REDD+ implementation; measurement, monitoring, reporting and verification; and management of REDD+ funds and finance enables Province level actors (Province-level Peoples' Committee, Provincial REDD+ Steering Committee, and Provincial REDD+ Taskforce) to develop, implement and administer jurisdictional REDD+ program.

Concomitant forestry and land use policies and management practices contributing forest protection and development with significant livelihood outcomes; highly positive local perceptions and attitudes towards the policies and practices, forest land allocation and REDD+; and strong local desire to participate in REDD+ program; indicate towards a high local legitimacy and political acceptance of jurisdictional REDD+ at the local level. This emphasizes that REDD+ activities should be coherent to and should embrace the existing well-functioning policies, programs and practices - a precondition for legitimacy of jurisdictional REDD+ assumed by the study.

In conclusion, the study suggested that jurisdictional REDD+ implementation is technically feasible, operationally achievable, financially viable and politically acceptable. To integrate jurisdictional REDD+ activities into national REDD+ schemes, jurisdictional REDD+ activities are to be firmly embedded into on-going sectoral and/or land use and forest management plans at jurisdictional levels. This is even more pertinent for countries like Vietnam with strong top-down planning systems, and where forests are predominantly owned by the state. Working through on-going policy and well-functioning structure is critical to ensure government buy-in, to allow replication and to reduce risks associated with impermanence. When aligning jurisdictional REDD+ implementation with the current practice of household based forestry, some level of compromise or trade-off on current practice is inevitable, this needs further exploration.

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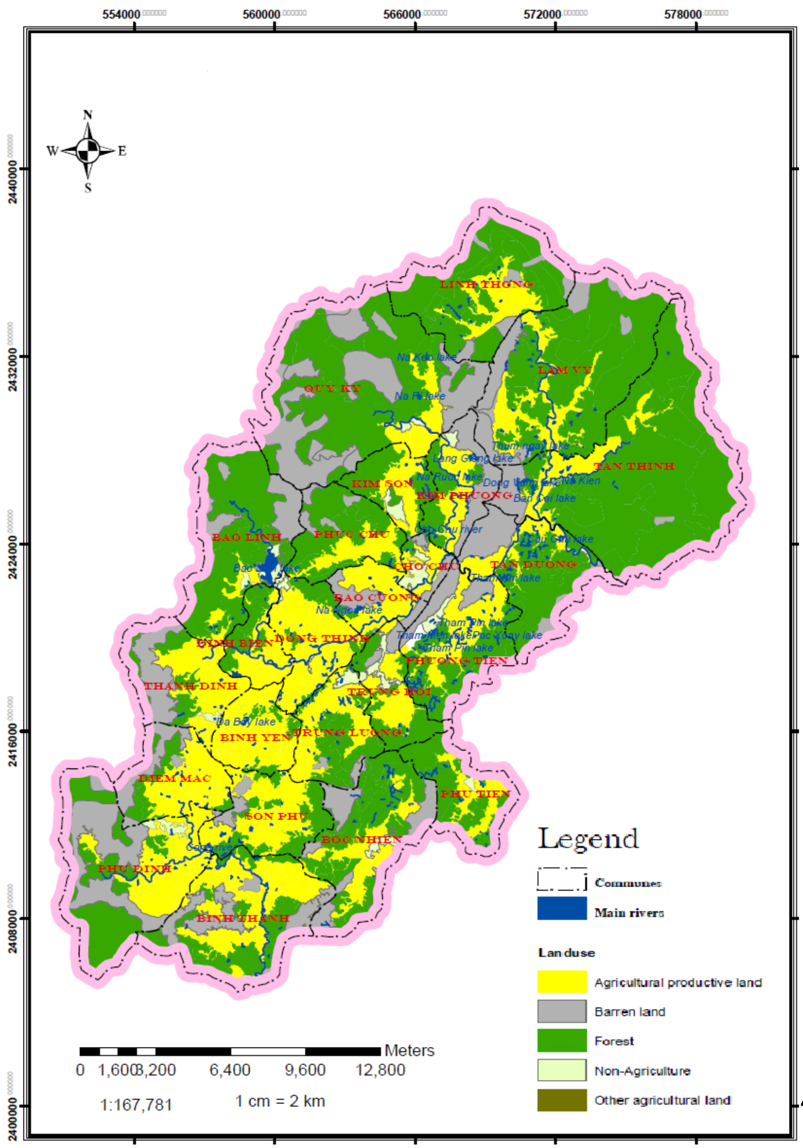
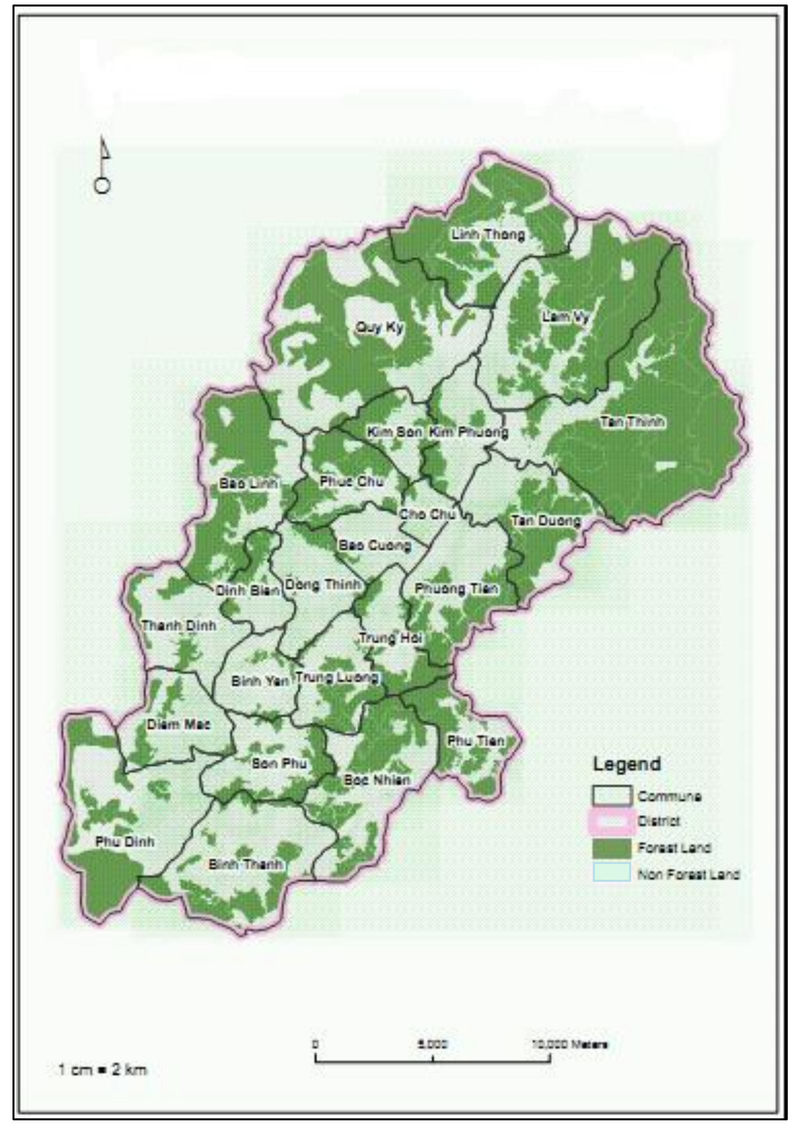
Annexes

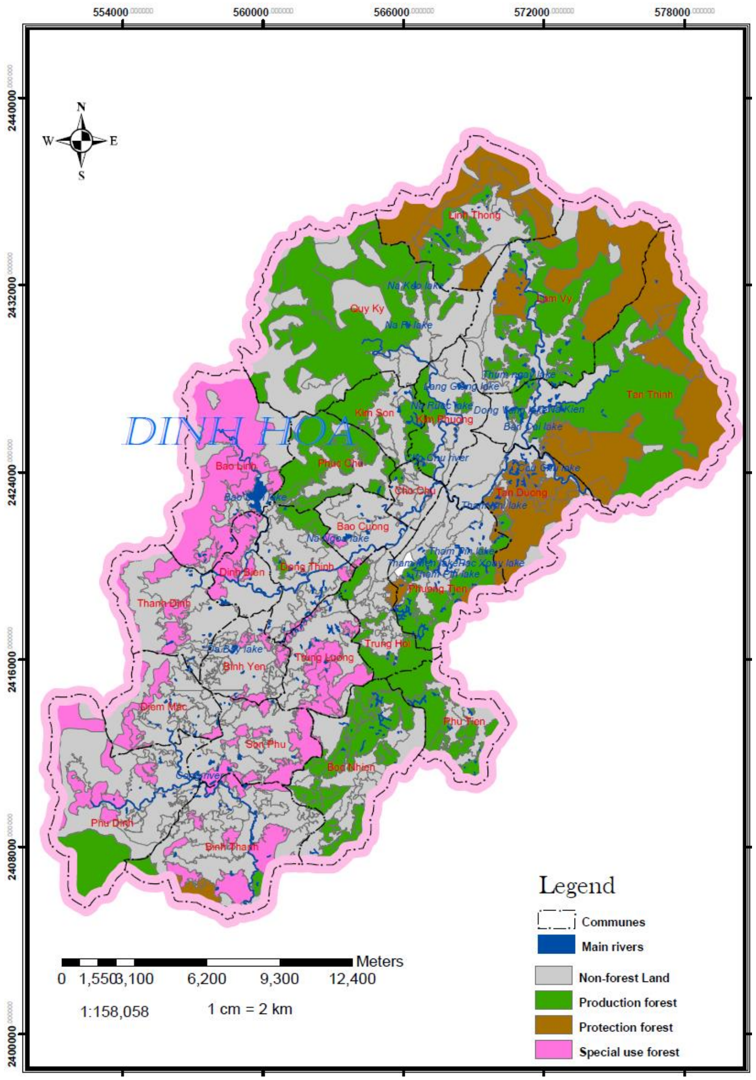
Annex 1 Maps showing land use, forest and non-forest land, forest types, soil types and elevation of Dinh Hoa district.

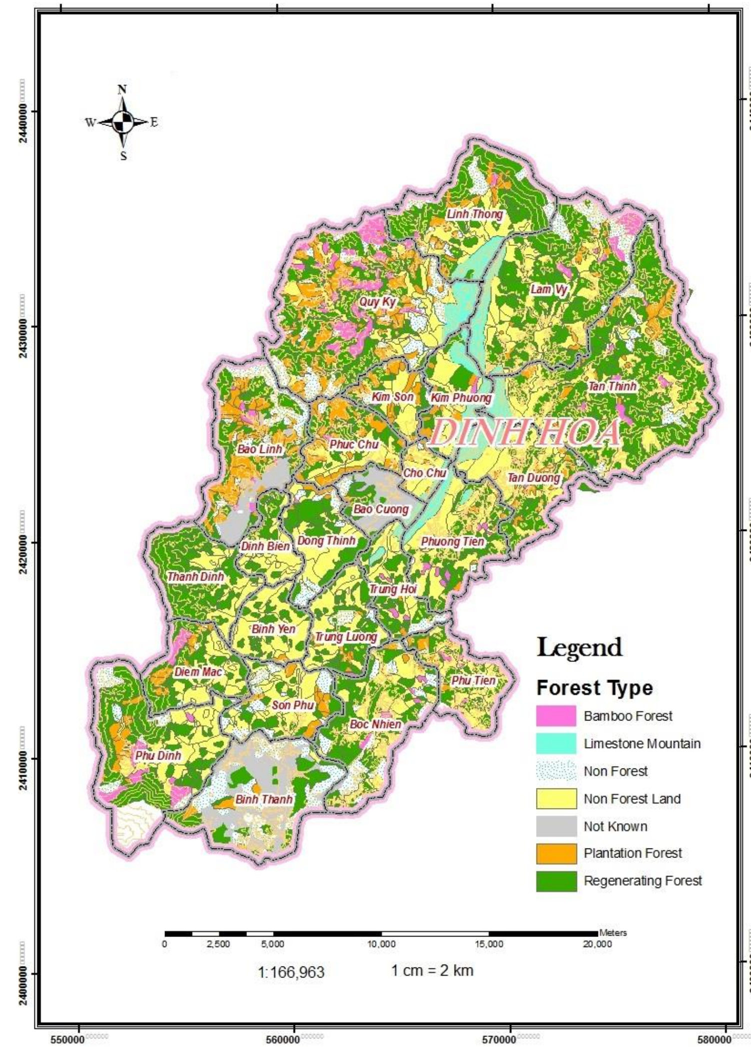
Annex 1.1 Land use (left) and forest and non-forest land (right)



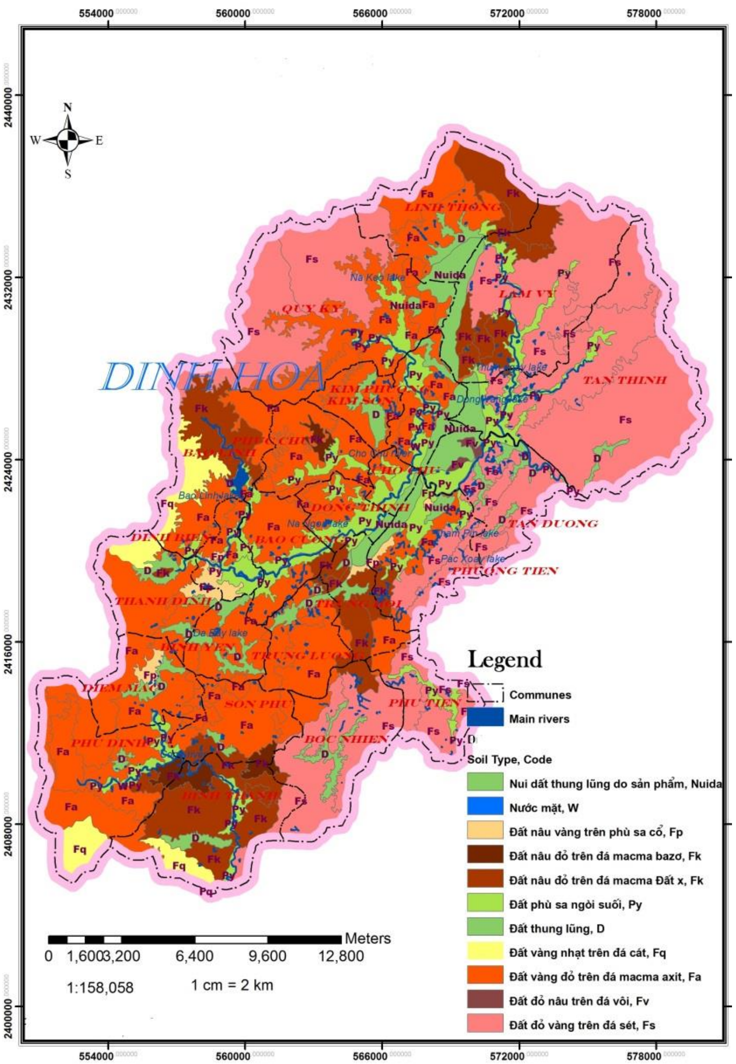


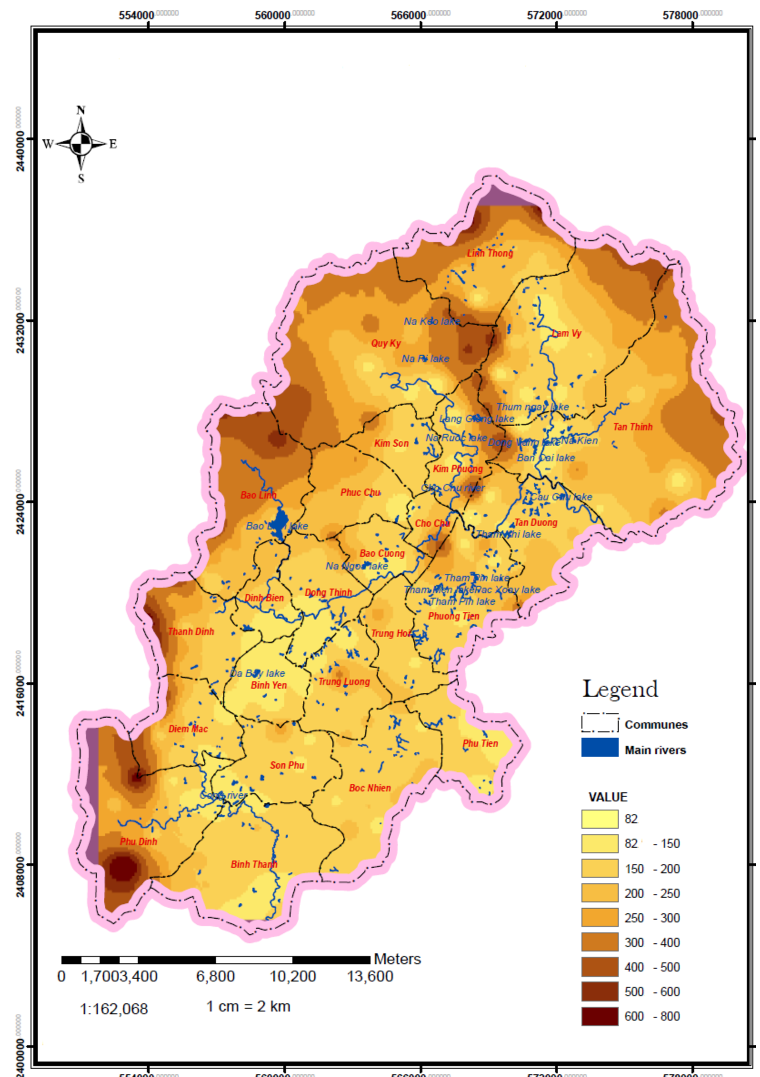
Annex 1.2 Forest types by designated ecological functions (left) and forest types by mode of forest origin (right)





Annex 1.3 Soil types (left) and elevation (m) (right)





Annex 2 Sensitivity analysis of natural forest management

Annex 2.1 No subsidy

Costs	**year 1**	**year 2**	**year 3**	**year 4**	**year 5**	**year 6**	**year 7**	**year 8**	**year 9**	**year 10**	**PV**
Equipment cost	28651	0	0	1045	87	0	1045	87	0	1045	31165
Repair cost	0	1098	1098	1098	1098	1098	1098	1098	1098	1098	6324
Forest development	22665	22665	22665	22665	22665	22665	22665	22665	22665	22665	153195
Forest management	20141	20141	20141	20141	20141	20141	20141	20141	20141	20141	136133
Forest products collection	31809	31809	31809	31809	31809	31809	31809	31809	31809	31809	215001
Total	103266	75714	75714	76759	75800	75714	76759	75800	75714	76759	541224
Per ha	173	127	127	129	127	127	129	127	127	129	907
Benefits	**year 1**	**year 2**	**year 3**	**year 4**	**year 5**	**year 6**	**year 7**	**year 8**	**year 9**	**year 10**	**PV**
Forest products	101780	101780	101780	101780	101780	101780	101780	101780	101780	101780	687936
Subsidy	0	0	0	0	0	0	0	0	0	0	0
Total	101780	101780	101780	101780	101780	101780	101780	101780	101780	101780	687936
Per ha	170	170	170	170	170	170	170	170	170	170	1152

Annex 2.2 No NTFPs

Costs	year 1	year 2	year 3	year 4	year 5	year 6	year 7	year 8	year 9	year 10	PV
Equipment cost	28651	0	0	1045	87	0	1045	87	0	1045	31165
Repair cost	0	1098	1098	1098	1098	1098	1098	1098	1098	1098	6324
Forest development	22665	22665	22665	22665	22665	22665	22665	22665	22665	22665	153195
Forest management	20141	20141	20141	20141	20141	20141	20141	20141	20141	20141	136133
Forest products collection	22543	22543	22543	22543	22543	22543	22543	22543	22543	22543	152368
Total	94000	66447	66447	67492	66534	66447	67492	66534	66447	67492	478592
Per ha	157	111	111	113	111	111	113	111	111	113	802
Benefits	**year 1**	**year 2**	**year 3**	**year 4**	**year 5**	**year 6**	**year 7**	**year 8**	**year 9**	**year 10**	**PV**
Forest products	82064	82064	82064	82064	82064	82064	82064	82064	82064	82064	554675
Subsidy	550	550	550	550	358	0	0	0	0	0	2161
Total	82614	82614	82614	82614	82422	82064	82064	82064	82064	82064	556836
Per ha	138	138	138	138	138	137	137	137	137	137	933

Annex 2.3 Forest products collected by hired labor

Costs	year 1	year 2	year 3	year 4	year 5	year 6	year 7	year 8	year 9	year 10	PV
Equipment cost	28651	0	0	1045	87	0	1045	87	0	1045	31165
Repair cost	0	1098	1098	1098	1098	1098	1098	1098	1098	1098	6324
Forest development	22665	22665	22665	22665	22665	22665	22665	22665	22665	22665	153195
Forest management	20141	20141	20141	20141	20141	20141	20141	20141	20141	20141	136133
Forest products collection	71231	71231	71231	71231	71231	71231	71231	71231	71231	71231	481455
Total	142688	115135	115135	116180	115222	115135	116180	115222	115135	116180	807678
Per ha	239	193	193	195	193	193	195	193	193	195	1353
Benefits	**year 1**	**year 2**	**year 3**	**year 4**	**year 5**	**year 6**	**year 7**	**year 8**	**year 9**	**year 10**	**PV**
Forest products	101780	101780	101780	101780	101780	101780	101780	101780	101780	101780	687936
Subsidy	550	550	550	550	358	0	0	0	0	0	2161
Total	102330	102330	102330	102330	102138	101780	101780	101780	101780	101780	690097
Per ha	171	171	171	171	171	170	170	170	170	170	1156

Annex 2.4 No NTFPs and forest products collected by hired labor

Costs	year 1	year 2	year 3	year 4	year 5	year 6	year 7	year 8	year 9	year 10	PV
Equipment cost	28651	0	0	1045	87	0	1045	87	0	1045	31165
Repair cost	0	1098	1098	1098	1098	1098	1098	1098	1098	1098	6324
Forest development	22665	22665	22665	22665	22665	22665	22665	22665	22665	22665	153195
Forest management	20141	20141	20141	20141	20141	20141	20141	20141	20141	20141	136133
Forest products collection	51515	51515	51515	51515	51515	51515	51515	51515	51515	51515	348194
Total	122972	95419	95419	96464	95506	95419	96464	95506	95419	96464	674417
Per ha	206	160	160	162	160	160	162	160	160	162	1130
Benefits	**year 1**	**year 2**	**year 3**	**year 4**	**year 5**	**year 6**	**year 7**	**year 8**	**year 9**	**year 10**	**PV**
Forest products	62348	82064	82064	82064	82064	82064	82064	82064	82064	82064	534959
Subsidy	550	550	550	550	358	0	0	0	0	0	2161
Total	62898	82614	82614	82614	82422	82064	82064	82064	82064	82064	537120
Per ha	105	138	138	138	138	137	137	137	137	137	900

Annex 3 Sensitivity analysis of planted forest management

Annex 3.1 No subsidy

Costs	year 1	year 2	year 3	year 4	year 5	year 6	year 7	PV
Equipment cost	127	0	0	6	4	0	0	136
Repair cost	0	6	6	6	6	6	6	24
Forest development	18	5	5	5	5	5	5	39
Forest management	72	11	6	0	5	0	0	91
Harvesting	0	0	0	0	0	0	23	13
Total	217	22	16	17	19	11	34	303
Benefits	**year 1**	**year 2**	**year 3**	**year 4**	**year 5**	**year 6**	**year 7**	**PV**
Forest products	0	0	0	0	0	0	1553	877
Subsidy	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	1553	877

Annex 3.2 Household time value converted based on market wage

Costs	year 1	year 2	year 3	year 4	year 5	year 6	year 7	PV
Equipment cost	127	0	0	6	4	0	0	136
Repair cost	0	6	6	6	6	6	6	24
Forest development	32	11	11	11	11	11	11	79
Forest management	75	22	12	0	4	0	0	109
Harvesting	0	0	0	0	0	0	32	18
Total	297	35	29	30	32	24	47	366
Benefits	**year 1**	**year 2**	**year 3**	**year 4**	**year 5**	**year 6**	**year 7**	**PV**
Forest products	0	0	0	0	0	0	1553	877
Subsidy	92	0	0	0	0	0	0	92
Total	92	0	0	0	0	0	1553	968

Annex 3.3 Rotation period of 10 years

Costs	year 1	year 2	year 3	year 4	year 5	year 6	year 7	year 8	year 9	year 10	PV
Equipment cost	127	0	0	6	4	0	6	4	0	6	142
Repair cost	0	6	6	6	6	6	6	6	6	6	32
Forest development	18	5	5	5	5	5	5	5	5	5	47
Forest management	72	11	6	0	5	0	5	0	0	0	94
Harvesting	0	0	0	0	0	0	0	0	0	23	10
Total	217	22	16	17				14	11	40	324
Benefits	**year 1**	**year 2**	**year 3**	**year 4**	**year 5**	**year 6**	**year 7**	**year 8**	**year 9**	**year 10**	**PV**
Forest products	0	0	0	0	0	0	0	0	0	1663	705
Subsidy	92	0	0	0	0	0	0	0	0	0	92
Total	92	0	0	0	0	0	0	0	0	1663	797

Annex 3.4 Rotation period of 10 years and household time value converted based on market wage

Costs	year 1	year 2	year 3	year 4	year 5	year 6	year 7	year 8	year 9	year 10	PV
Equipment cost	127	0	0	6	4	0	0	4	0	6	222
Repair cost	0	6	6	6	6	6	6	6	6	6	107
Forest development	32	11	11	11	11	11	11	11	11	11	40
Forest management	75	22	12	0	4	0	0	0	0	0	91
Harvesting	0	0	0	0	0	0	32	0	0	23	10
Total	297	35	29	30	32	24	27	24	20	50	470
Benefits	**year 1**	**year 2**	**year 3**	**year 4**	**year 5**	**year 6**	**year 7**	**year 8**	**year 9**	**year 10**	**PV**
Forest products	0	0	0	0	0	0	0	0	0	1663	705
Subsidy	92	0	0	0	0	0	0	0	0	0	92
Total	92	0	0	0	0	0	0	0	0	1663	797

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