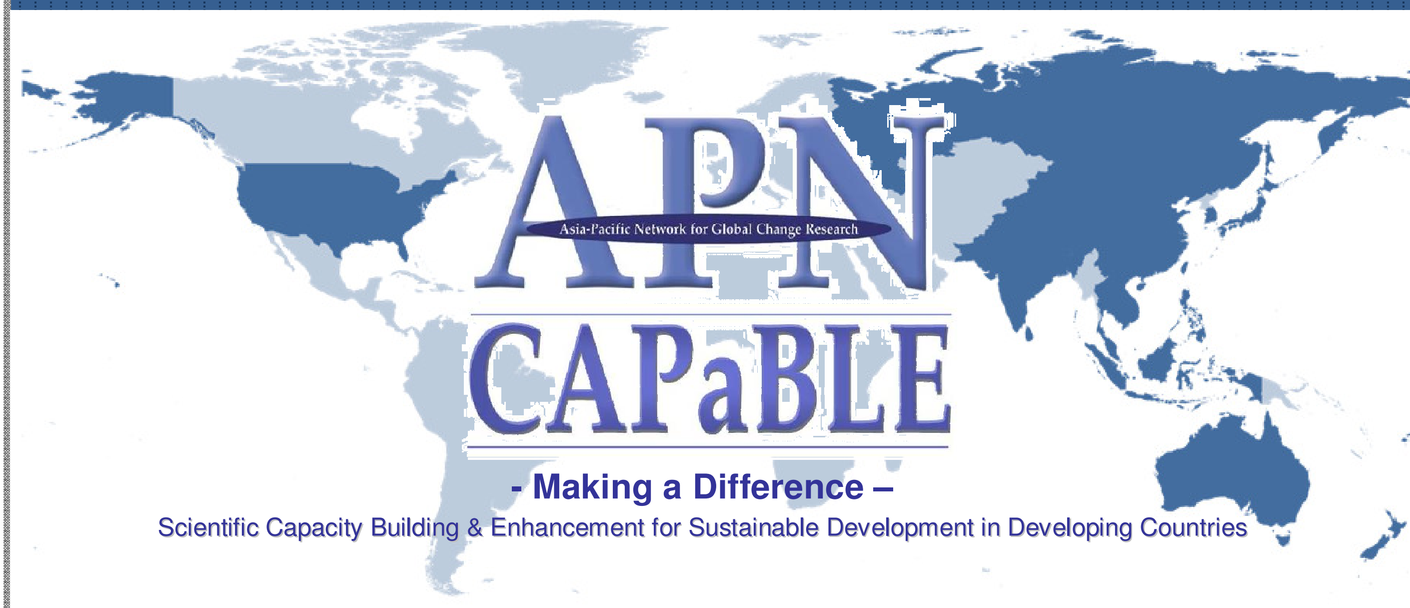
FINAL REPORT for APN PROJECT

Project Reference Number: EBLU2012-02NMY(R)-Takeuchi

Critical Analysis of Effectiveness of REDD+ for Forest Communities and Shifting Cultivation, based on Lessons Learnt from Conservation Efforts in Laos and Thailand



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NAFRI

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OVERVIEW OF PROJECT WORK AND OUTCOMES

1. Introduction and background

Covering about 30 percent of the world's land area, forests are home to around 300 million people around the world, including many indigenous people. More than 1.6 billion people depend, to varying degrees, on forests for their livelihoods, e.g. fuelwood, timber, medicinal plants, forest foods, income and fodder, and for their cultural and spiritual identify. Forests sustain critical environmental services such as conservation of biodiversity, water and soil, and climate regulation. In spite of the importance of forests, around 13 million hectares of natural forests were lost between 2000 and 2010. Deforestation is estimated to account for almost 18% of global greenhouse gas emissions, as well as unimaginable losses in biodiversity, human and environmental well-being. Thus, the new global initiative for reduction of deforestation and degradation, including the role of conservation, sustainable management of forests and enhancement of forest carbon stocks or REDD Plus (+) has substantial potential to deliver co-benefits for climate change mitigation/adaptation, biodiversity conservation and livelihoods.

Successful REDD+ strategies are those that not only justify economic rationale for forest conservation versus alternative uses, but also provide positive incentives to those who live around forests and are dependent on forests for their livelihoods. This requires integrating and complementing traditional forest management and agro-forestry practices of many local and indigenous communities, rather than handling the two land uses as independent land use systems.

Traditional shifting cultivation often practiced in the tropical forests integrates a short cropping phase and a long forest fallowing phase in rotation. In the cropping phase many cereals, root crops and vegetables are cultivated to ensure a balanced diet for shifting cultivators, while soil seed bank and tree stumps are conserved through zero tillage to facilitate subsequent forest regeneration. In the fallow phase, forests not only provide a range of products so crucial for livelihoods, but also contribute to soil fertility through transfer of nutrients from deeper horizons to surface soil, nitrogen fixation, carbon sequestration, control of weeds and soil conservation. Apart from forest fallows, natural forests are maintained at places by shifting cultivators for timber, honey, pollination, water supply and spiritual values. Over generation, shifting cultivators have created and accumulated profound knowledge on cropping as well as forest management. Nevertheless, traditional shifting is undergoing a variety of changes, driven by both internal and external factors, with implications for local livelihoods and ecosystem services.

2. Participating countries:

The UN University, in partnership with National Agriculture and Forest Research Institute (NAFRI), Laos, and Chiang Mai University (CMU), Thailand, with the support of the Asia-Pacific Network for Global Change Research (APN) undertook a 3-year project to address the knowledge gaps and potential opportunities and challenges of REDD+ in harmonizing co-benefits of carbon sequestration, biodiversity conservation and livelihood improvement in the shifting cultivation landscapes. As part of the UNU network, the research carried out by Jawaharlal Nehru University (JNU) land use, biodiversity, carbon and livelihood dynamics in the Himalayas contributed to sharing of experiences and success stories for sustainable development in marginal mountain regions. The nodal project collaborators were:

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3. Objectives:

The main objectives of the APN project were to (1) assess the potential social, economic and environmental challenges and opportunities of REDD+ for selected communities in Laos and Thailand by drawing lessons from past/ongoing forest conservation policies; (2) provide much-needed scientific evidence on the potential co-benefits of traditional forest management and agro-forestry practices by comparing it with alternative land-uses; and (3) develop participatory community-based MRV mechanisms for REDD+. Findings assisted the pro-poor design and implementation of REDD+, improved the well-being of forests dependent communities and integrated traditional agro-forestry as an approach to climate change mitigation.

Amount granted and number years supported

The Grant awarded to this project was: 3 years from 2011-2013
US$ 44,000 for Year 1:
US$ 38,000 for Year 2:
US$ 38,000 for Year 3:

Activities undertaken

The project activities in the Year 1 included (1) the inception workshop to finalize site selection, project implementation and monitoring framework and work plan; (2) the methodology training to develop national capacity for project implementation; (3) the field work to characterize project sites, classify and map land uses as a basis for carbon stock measurements, and (4) communication and advocacy strategy of reaching out to various stakeholders involved in policy making and implementation. The inception workshop held in Chiang Mai, Thailand in January 2011 re-confirmed the above work plan, and agreed to build on the land use survey to test the carbon stock measurement methodology in **Year 1** although carbon stock estimation was planned for Year 2 in the project.

In **Year 2**, the project activities included land use mapping, household surveys, field and laboratory work, and plot sampling for estimation of carbon storage intensity. The inventory of carbon stock and assessment of land use and carbon dynamics in project sites were successful. Two national workshops were organized: on December 25-27, 2011 in Jinghong, China and on July 19-21, 2012 in Chiang Mai, Thailand. The national workshop in Jinghong also promoted exchange of information and linkages with other relevant projects in China. A training course on “What are carbon stocks and how to monitor them” was organized in Tee Cha Village in Northern Thailand on 11-13 October 2012 for building the capacity of local farmers and forest officers to understand and manage forest carbon stocks as stipulated in the MRV mechanism of UN-REDD. A good practice of avoiding burning to enhance understory vegetation, carbon stock and biodiversity in teak plantation was demonstrated to local farmers and officials in Laksip Village in Northern Laos.

In **Year 3**, the project findings were compiled and presented to a wider group of local officials, communities, researchers, policymakers and international community in the international workshop in Tokyo, Japan on 8-12 October 2013. The training on “What are carbon stocks and how to monitor multiple functions of forest ecosystems” was organized in the Chang Khain Highland Research Station in Chiang Mai, Thailand on 1-4 November 2013 for local farmers, local forest officers and academic staffs of Chiang Mai University to disseminate the lessons learnt in community-based MRV.

Site selection

Three major land-use systems/landscapes in tropical mountains: shifting cultivation, transition from shifting to sedentary and sedentary cultivation and forest landscapes around Laksip Village, Luang Prabang. Lao PDR and Tee Cha Village (a Pwo Karen Village in Sop Moei District of Mae Hong Son Province), Thailand were selected based on a quick review of secondary data and supplementary field survey. Characterization of both sites is described in details in **Technical Report**.

In order to share experience across different countries in SLM-MMSEA, the project team discussed with the Indian partner to identify an associate project site in India with financial support from different sources. A research activity on the sedentary land use systems/landscape has been carried out in the Ratagad micro watershed, Indian Himalaya in Uttarakhand State of India. Land use/land cover changes were mapped using satellite data and carbon densities in above-ground and below-ground compartments within each land use/land cover type were estimated based on ground measurements. It was agreed to select the Ratagad micro watershed as associate study site for the APN project to exchange carbon stock estimation method and experience. The Chinese partner of SLM-MMSEA carried out a new Ford Foundation project to assess multiple ecosystem services of ancient tea forests in Mangjing Village in Southern Yunnan and to promote this system for the FAO's Globally Important Agricultural Heritage Systems (GIAHS) site. Inventory of high biodiversity and carbon stocks in the tea forests is a critical element of the Ford Foundation-funded project. It was agreed to select Mangjing village as an associate site for the new APN project to exchange information and experience with the Chinese partner. The project associate sites in India and China represent sedentary land use systems/landscapes in the mountainous regions.

Development of the project methodologies

The project evaluated different methods/models of estimating opportunity costs and carbon stocks under different land use and land cover types and their suitability for community based MRV. The project conducted both biophysical and socio-economic surveys. The biophysical survey included mapping of land use-land cover types, inventory of carbon stocks and biodiversity in different land use-land cover types, and analysis of carbon dynamics and biodiversity under different land use scenarios and reference level. The socio-economic survey analyzed the economic benefits of different land uses and opportunity cost of REDD+ for forest conservation versus alternative land uses. Good land use practices were identified to enhance co-benefits of carbon sequestration, biodiversity conservation and income generation. The project teams demonstrated good land use practices to local farmers and officials in Thailand and Laos. The project results were used to train local stakeholders to appreciate, manage, measure and monitor forest carbon pools as a process of community-based MRV. The project workshops were organized to develop methodology, exchange knowledge and review progress across different participating countries.

Project workshops and training

As planned over the period of 3 years, five project workshops were organized as follows:

- **Project Inception Workshop,** 17-19 January 2011, Chiang Mai, Thailand. Project members reviewed and discussed the project goals and expected outcomes, finalized the project framework, and confirmed selection of two project sites, one each in Laos and Thailand. Under the framework, project members discussed and agreed on the project work plan and responsibilities. The workshop proposed to review and develop a project methodology to guide land use survey and carbon stock inventory, and tested it this year. The methodology workshop was then planned to take place in Luang Prabang, Laos in June 2011. The workshop offered a good opportunity for the visiting project team members to appreciate different land uses and their ecosystem services, including rotational shifting cultivation practices in the Tee Cha Village, Northern Thailand, and details in **Annex 1**.

- **Project Methodology Workshop,** 19-21 June 2011, Luang Prabang, Laos. In this workshop, different methodologies for carbon stock measurement at landscape level, and the proposed methodology for each project site in India, Thailand and Laos were reviewed and harmonized as the project methodology. The results of the workshop were then summarized as a working manual to guide carbon stock measurement in all project sites. During the field trip to the Laksip Village, the project team discussed and advised the Lao team to develop land use/land cover classification for carbon stock measurement and laying sample plots in the Laksip Village. The workshop provided a training opportunity for young researchers to learn about the methodology for carbon stock measurement in the forested landscape, details in **Annex 2**.
- **Project Workshop**, 25-27 Dec 2011, Jinghong, China. Project members reviewed findings of carbon stocks measurement at the landscape-level across participating countries and compare the carbon stocks of different land uses in the village landscape, and reviewed relevant policies and propose a policy action plan. The project team visited and discussed on measurement of carbon stocks at the associated project site in Yunnan, China is part of the Ford Foundation-funded project "Demonstrate the use of World Agricultural Heritage Status to strengthen community rights over natural resources in marginal ethnic minority communities of western China".
- **Project International Workshop**, 19-21 July 2012, Chiang Mai, Thailand. Project members reviewed the project progress on carbon stock measurement, land use and carbon dynamics and future scenarios, reference levels and opportunity cost, and discussed operational guidelines for community based MRV and demonstration of good land use practices. The project teams visited Pah Poo Chom village and Pang Ma O village near Chiang Mai and discussed with local officials and farmers on land use management, and learned about the process of *Miang* tea including harvesting, streaming and fermenting.
- **Project Workshop,** 8-12 October 2013, Tokyo, Japan. Project members reviewed the final project reports of national teams on five aspects of the project: land use-land cover, biomass and soil organic carbon estimation; land use and carbon dynamics: scenarios and references levels; economic analysis-opportunity cost/benefit analysis; community based MRV process, and policy recommendations. The project teams visited the Globally Important Agricultural Heritage System (GIAHS) site of the "traditional integrated tea-grass system" in Higashiyama Area, Kakegawa City, Shizuoka Prefecture, and an area of ice terraces. Rice terraces were abandoned many years ago, but are being restored through an innovative system of memberships.
- **Project Training**: while above project workshops shared and enhanced expertise and capacity of project teams across different countries, training programmes were conducted to develop capacity of local farmers and local forest officers on topics of "What are carbon stock and how to measure it in forest": two in Chiang Mai Province, Thailand and one in Luangprabang Province, Laos. The training report is attached in **Annex 3.**

Relevance to the APN Goals, Science Agenda and to Policy Processes

In response to APN goals, the project promoted regional cooperation in global change research on conservation of tropical forests in Southeast Asia and South Asia, and further enhanced the UNU research network on sustainable land management in the mountainous region of mainland Southeast Asia (SLM-MMSEA), disseminated the project findings to other countries through SLM-

MMSEA, such as Yunnan Province of China and Myanmar. Project coordinators in Lao PDR, Thailand and India are based in national research institutions and have regular interactions with policy-making at national and local levels. In addition to regular discussions with policy makers, policy workshops were held at end of the project in Laos, Thailand and at UNU to present project findings to policy makers and researchers. Scientific knowledge from the project was also provided to local communities through training and field demonstration activities in Laos and Thailand. The regional cooperation, through the south to south (Laos, Thailand and India) and the north to south (Japan and other developing countries) linkages, the research capabilities of participating nations in the region have been strengthened. The research capacity of young project team members also benefited from the international programme "On-the-Job Research Capacity Building for Sustainable Agriculture/Forestry in Developing Countries (OJCB)" which is funded by Ministry of Agriculture, Forestry and Fisheries (MAFF). Postgraduate students benefited from their participation in the project. Through UNU coordination, the project contributed to the University Network for Climate Ecosystems and Change Adaptation Research (UN-CECAR). In particular, the project networking in Southeast Asia helped develop the new project on Sustainable Forest Rehabilitation and Management for the Conservation of Trans-boundary Ecological Security in Montane Mainland Southeast Asia– Pilot Demonstration Project of Lao PDR, Myanmar and China/Yunnan" (SFR-MMSEA), which is funded by the Asia-Pacific Network for Sustainable Forest Management and Rehabilitation (APFNet). The project team also shared relevant expertise and experience with members of the new project SFR-MMSEA at the final project workshop held in UNU in October, 2013.

The project directly contributed to APN's **Science Agenda** by deepening regional research on forest ecosystem, biodiversity and land-use change. More specifically, it explored the symbiotic relationship between communities, agricultural systems and forests, and the way in which policy interventions like REDD+ can affect it. The project brought together natural, socio-economic and political sciences and non-science stakeholders. The project involved science-policy-community partnerships as a key element of the MRV mechanism for REDD+. Regular policy discussions and workshops were held to develop strategies with policymakers and decision-makers, and mainstream outputs into policy processes. Project collaborators hold unique positions in their own right as a bridge between local people, academia, government, and UN and other international organizations/networks. Regular publications and presentations were used to disseminate scientific findings, and increase the regional visibility of the APN to policymakers, end-users and the public from local to national and international levels.

Self evaluation

The project selected two excellent study sites, one each in Northern Thailand (Tee Cha, a Pwo Karen village in Sop Moei District of Mae Hong Son Province), and Northern Laos (Laksip, a Khmu village in Luang Prabang Province). The rotational shifting cultivation remains the major livelihood in the study village in Northern Thailand while the shifting cultivation is converting to plantations in the study village in Northern Laos. Two villages offer a good comparison of traditional land use systems in transition with consequences on carbon stock, biodiversity and livelihoods. Two associate sites in India and China provided a contrast of sedentary agriculture in similar mountainous areas.

As planned, the project carried out successfully four major components: (1) biophysical survey mapped land use-land cover types, measured carbon stocks and biodiversity in different land use-land cover types, analyzed land use scenarios, carbon dynamics and reference level; (2) Socio-economic survey investigated economic benefits of different land use-land cover types, estimated opportunity cost of REDD+ (focusing on forest conservation versus alternative land uses); (3) good land use practices were identified to enhance co-benefits of carbon stocks, economic benefits as well as biodiversity through integration of biophysical and socio-economic assessments, and (4) community-based MRV, capacity building, networking and policy recommendation (5 workshops, training activities/field demonstrations). Good land use practices were demonstrated to local farmers and officials, and relevant training programmes organized for local farmers and officials to manage, measure and monitor forest carbon pools as a process of community-based MRV. These activities produced and disseminated relevant research findings on co-benefits of forests as well as enhanced regional cooperation and led to a new follow-up project SFR-MMSEA, and strengthened national and local capacity in sustainable forest management. In addition, the project developed a working manual for carbon stock measurement at a landscape level (see Appendix).

Potential for further work

Deforestation remains a global challenge in tropical regions. As an important watershed and hotspot of biocultural diversity, MMSEA suffers from severe deforestation with negative impacts on ecology, hydrology and local livelihoods, resulting from inappropriate land use change under internal and external pressures. Forest conservation often incurs the opportunity cost by forgoing more profitable alternative land uses, such as conversion to cropland. REDD+ is expected to mitigate the opportunity cost. However, the payment from REDD+ remains unpredictable, and could be too small in comparison with other forms of support for forest conservation. It is important to combine REDD+ with other measures for forest conservation. Moreover, carbon stocks exist in non-forest land uses (such as cropland, home garden, agro forest, or fallow fields), and should be managed at a landscape level. Agro-forestry system can also significantly increase income from components of cropping and NTFPs beyond carbon benefits. Past efforts to rehabilitate degraded land are often through mono-species plantations with limited contribution to restoration of environmental services. There is a critical need to further study multiple values or co-benefits of forests and develop practical models of forestry that combine production as well as environmental values.

Publications

1. Semwal, R.L., Nautiyal, S., Maikhuri, R.K., Rao, K.S. and Saxena, K.G. 2013. Growth and carbon stocks of multipurpose tree species plantations in degraded lands in Central Himalaya, India. **Forest Ecology and Management,** 310, 450-459.
2. Bhadauria, T., Kumar, P., Kumar, R., Maikhuri, R.K. and Saxena, K.G. 2012. Earthworm populations in a traditional village landscape in Central Himalaya, India. **Applied Soil Ecology**, 53, 83-93.
3. Takeuchi K., Takahashi S., Lim A., Kawasaki J., and Liang L. 2011. REDD+ for Forest Communities. APN Newsletter Vol. 7, Issue 3, Sep. 2011, ISSN 2185-6907.
4. Takeuchi, et al, 2012. Forest Carbon Stocks in Shifting Cultivation of Thailand and Lao PDR, APN Science Bulletin Issue 2, March 2012, ISSN 2185-761x

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TECHNICAL REPORT

Preface

With APN's financial support, UNU, CMU, NAFRI, and JNU undertook the 3-year project "Critical analysis of effectiveness of REDD+ for forest communities and shifting cultivation, based on lessons learnt from conservation efforts in Laos and Thailand" from 2011-2014. This report is an outcome of the joint project. The draft reports from participating countries were first reviewed at the final project workshop held in UNU in 9-11 October 2013. These reports have been then updated and presented to national policy makers and researchers for feedbacks, and finalized and synthesized according to the APN format. The contents are organized into five sections. Section I discusses project background, justification and objectives. Section II explains the project methodology, including biophysical and socio-economic survey and analysis. Section III provides a synthesis of project results and discussions. Section IV summarizes project findings. Section V identifies gaps in knowledge and areas of future research and development. Views expressed in this volume are of the authors and not necessarily of the organizations they are affiliated to.

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1.0 Introduction

1.1 Background

Forests are home to around 300 million people around the world, including people of indigenous and tribal groups, who are largely dependent on forests. More than 1.6 billion people depend to varying degrees on forests for their livelihoods, e.g. fuelwood, medicinal plants, forest foods and income, and for their cultural and spiritual identity. Forests sustain critical environmental services such as conservation of biodiversity, water and soil conservation, and climate regulation.

According to FAO's the Global Forest Resources Assessment 2010, the world's forests covered just over four billion hectares, or 31 per cent of total terrestrial area, and stored more than 650 Gt of carbon, presenting a significant global carbon stock. However, 13 million hectares of forests mainly in tropical regions was lost every year between 2000 and 2010. Deforestation is estimated to account for almost 20% of global greenhouse gas emissions, resulting in losses in biodiversity, environmental services and human well-being.

Forest carbon stocks can be increased through reforestation and afforestation. The Clean Development Mechanism of Kyoto Protocol (CDM) allows industrialized countries to meet a part of their carbon emission reduction commitments by carrying out afforestation and reforestation (AR) in developing countries. On the other hand, loss of forest carbon stocks as emission of greenhouse gases can be avoided through conservation of standing forests that would be otherwise lost and degraded, i.e. reducing deforestation and forest degradation. Nevertheless, avoided deforestation to reduce emission is not included under the Kyoto Protocol.

Reducing Emissions from Deforestation and Forest Degradation in Developing Countries (REDD) is an emerging international instrument initially proposed at the COP 11 of UNFCC in Montreal in 2005 to provide economic incentives to developing countries to undertake actions for protection and enhancement of standing forest carbon stocks. Discussion on REDD was focused first on 'reducing emissions from deforestation' or RED. 'Avoided degradation' – the second D in REDD – was officially added later at COP13 in Bali, 2007, when it was realized that for some countries, forest degradation was an even bigger problem than deforestation. There was further recognition that even greater climate benefits could be achieved if positive actions, such as conservation of forest carbon stocks, sustainable management of forest and enhancement of forest carbon stocks could be combined with avoided deforestation and degradation. The positive actions became the '+' in REDD+, and was officially endorsed one year later at COP14 in Poznan.

Similar to payments for environmental and ecosystem services (PES) mechanisms, REDD+ is expected to provide incentives to forest owners and users for not converting forests to other uses to prevent loss of forest carbon stocks, or for not overusing forests to avoid degradation of forest carbon stocks. The incentives or payments are based on the net change in carbon stocks for a specific period in comparison to a reference level. The net change in carbon stocks are measured and calculated into certified 'carbon credits' which can be eventually bought and sold on a carbon market or paid through a fund. However, the global architecture for REDD+ still remains under development.

The success of any REDD+ projects must consider the sustainability of forest communities whose livelihoods depend on forest ecosystem services. REDD+ strategies need to go *beyond carbon* benefits to promote co-benefits for environment and forest communities through the harmonious integration of multiple values of forests, including poverty reduction, food and livelihood security, biodiversity conservation, climate change mitigation and adaptation. In another words, REDD+ should promote the multiple values of forests, not only carbon benefits but also co-benefits of food and livelihoods, and biodiversity conservation. Any attempts that enforce a barrier between local people and their forests, without consideration of their needs or other conflicting policy priorities, may do little to alleviate poverty, and even fail to enhance carbon stocks and prevent biodiversity loss in the long term. Carbon benefits for global climate regulation should not be achieved at expense of forest functions to support local livelihoods and biodiversity. Furthermore, a whole landscapes approach is necessary to ensure against 'leakage' whereby the carbon benefits from areas protected under REDD+ are offset by severe reductions in carbon storage and biodiversity from inappropriate land use intensification and land degradation in surrounding areas.

Learning from the past

From a historical perspective, REDD+ is only one out of a long line of many other approaches that have been used for forest conservation. Past and ongoing forest efforts have had mixed results, they include forest regulations and laws, zoning of protected areas, projects to rehabilitate degraded forests and lands, relocation of forest communities, etc. While some may have achieved objectives for increased forest cover, it has often been at the expense of forest communities. In some cases, perverse and unintended consequences have emerged or even resulted in the worsening of deforestation rates. This raises many ethical, equitable and sustainability concerns that should not be repeated under REDD+.

One of the past efforts for forest conservation is to deal with shifting cultivation which includes a short period of cropping and a relatively long period of forest fallow. Many forest communities, including those in Southeast Asia rely on shifting cultivation as one of their main livelihoods. A wide-scale forest conservation policy has been implemented to restrict and stop shifting cultivation by promoting sedentary agriculture, allocating forest fallows for forest conservation and resulting in land shortage for shifting cultivation. Without providing alternative livelihoods and capacity development, forest communities have had to increase the cropping period of the shifting cultivation and decrease the fallow period to cope with the land shortage, but at the risk of accelerating land degradation (Liang, et al, 2010). Time-averaged aboveground carbon stocks could decline by about 90% if the long fallow periods of traditional swidden cultivation are reduced to 4 years short fallow system (Bruun, et al, 2009). REDD+ can be both a challenge and opportunity for shifting cultivators (Mertz, 2009).

Restrictions on forest access, reductions in available land for shifting cultivation, and then on top of that, increased population density, competing land-use pressures and conflicting policies have led to significant acceleration in land degradation and unsustainable agricultural intensification, as well as observed reductions in soil fertility and species and plant biodiversity. This in turn has caused increased hardship, food insecurity, and social tensions. It is likely that at the landscape level, the overall carbon-storage balance was also affected negatively, yet more scientific research is needed to determine this. Other perverse consequences include the loss of crop diversity embraced in the traditional shifting cultivation.

Learning the lessons from the past and how the experience will be translated into REDD+ are only partially considered in current mainstream debates on REDD+. The introduction of any additional forest conservation measures, even those like REDD+ with its carbon storage-focus, cannot be analysed in a vacuum separated from the past but as part of a continuum of one of many forest conservation efforts. Nor can it be developed in isolation from communities who not only depend on forests, but who are also critically needed and supported for the long-term and on-the-ground management, monitoring, reporting and verification (MRV) of forests within REDD+ so as to benefit from carbon finance as additional source of income from forests. The realities of forest conservation policies and its success in achieving stated goals and the socio-economic impacts (spatial and temporal) on local communities must be clearly evaluated. Without understanding why past forest conservation and rehabilitation efforts have failed and how to properly address the drivers of deforestation will only guarantee failure. As it stands, the development of REDD and REDD+ appears to follow similar paths taken by past forest conservation efforts, i.e. as stand-alone approaches that focus purely on carbon accounting and seek to erect barriers between local communities and forests. What could result is a fragmented mosaic where 'conservation islands' of protected forest areas exist next to poverty-ridden forest-agriculture frontiers.

Going beyond REDD+

The approach of REDD+ has so far mirrored present conservation approaches to treat 'nature' and human societies as separate entities. That is, exclude, even, expulse humans from protected forest areas (carbon sinks) as their intervention causes its degradation. This thinking devalues the role of local and indigenous communities in shaping and maintaining the surrounding landscapes and ecologies with which they live in, and ignores the positive impacts that their traditional (agri)cultural practices can have on the integrity, richness and resilience of ecosystems and landscapes (Takeuchi, et al, 2002; van Oudenhoven, et al, 2010).

With the uncertainty of future climate change, it is necessary to enhance the resilience and adaptability of these landscapes by enhancing diversity and flexibility of social-ecological systems. Because of the role socio-ecological landscapes play in soil fertility, carbon sequestration, biodiversity, food and water security, livelihoods and increased climate change resilience for the poor, they must be incorporated and supported by REDD+ mechanisms. Rerkasem (2003) and Hajjar *et al*, 2008 argue that the complex mosaic landscapes of traditional land-use systems, with well-managed forest fallows, provide a range of environmental and social services: hydrology, biodiversity, carbon storage, and livelihoods. They are socio-ecologically productive landscapes that maintain ecosystem functioning and support a rich repository of agricultural biodiversity through social mechanisms of exchange and use of many varieties and species. In addition, the indigenous knowledge and technology have been adapted to deal with the social and economic change (Rerkasem, et al, 2009; Liang, et al, 2009).

Presently, the objectives and scope of REDD+ remain narrow with its focus on carbon sequestration and 'officially-defined' forests areas. One of the difficulties is the complicated definitions of what a forest is and what to do with the many trees that exist outside areas officially defined as forests, such as on farms. In developing countries, around 1.2 billion people practice farming that combines both agriculture and forestry, or agroforestry (FAO, 2005). It is also at these agricultural-forest interfaces where much soil and land degradation can occur from land-use pressures should those trees be removed. Agricultural-forest interfaces, agroforests and tree-based land-use systems managed by farmers still remain at the fringes of the REDD+ debate. However there have been calls to include agriculture, agroforestry and other land use types (AFOLU) in the carbon accounting

(Smukler, S., and Palm, C., 2009). More recently, the 'reducing emissions from all land uses' (REALU) approach has been put forward for arguing that "a whole-landscape approach to reducing emissions and managing carbon stocks can help address the drivers of deforestation, reduce problems like leakage, and eliminate the need for precise forest definitions" (van Noordwijk, M. *et al*, 2009.)

REDD+ is about recognizing the multiple values of forests and should not narrowly emphasize forests as carbon sinks. The traditional forest and trees-based land-use systems and landscapes offer many models to integrate many values of forests and trees into REDD+. Systematic research and scientific data are needed to evaluate past/ongoing forest conservation efforts and assess their stated objectives to the actual realities on the ground, and then translate the lessons learned into improving future forestry schemes like REDD+.

1.2 Objectives of the current project

In order to address the knowledge gap on potential opportunities and challenges of REDD+ as discussed above, the UN University, in partnership with National Agriculture and Forestry Research Institute, Laos, Chiang Mai University, Thailand and Jawaharlal Nehru University, India, with the support of the Asia Pacific Network has undertaken the 3-year project that aims to:

- Assess the potential social, economic and environmental challenges and opportunities of REDD+ for forest communities in Laos and Thailand. Lessons will be drawn from past/ongoing forest conservation policies;
- provide much-needed scientific evidence on the potential co-benefits of traditional forest management practices and comparing it with alternative land-uses; and
- Develop participatory community-based MRV mechanisms for REDD+ to enable local communities to incorporate carbon stocks into their forest management.

Findings could assist the pro-poor design and implementation of REDD+, improve the well-being of forests dependent communities and integrate traditional agriculture and forestry as a climate change mitigation agenda. The project was launched in Chiang Mai University in Jan 2011 with identification of two study villages, one each in Northern Thailand and Northern Laos.

1.3 Location of main project sites

Two project sites, one each from Thailand and Laos, were selected. Tee Cha Village, the project site in Thailand and Laksip Village, the project site in Laos represent different forms of shifting cultivation and changes therein. The rotational shifting cultivation remains the major livelihood in the study village in Northern Thailand while the shifting cultivation is in transition to plantations in the study village in Northern Laos. Two villages offer a good comparison of traditional land use systems in transition. In addition, UNU research network members in India and China associated their study villages to the research project for a cross-region comparison. Location of both sites is indicated in the **Figure 1** at end of the annex. Details of each of these two project sites are characterized in the section three.

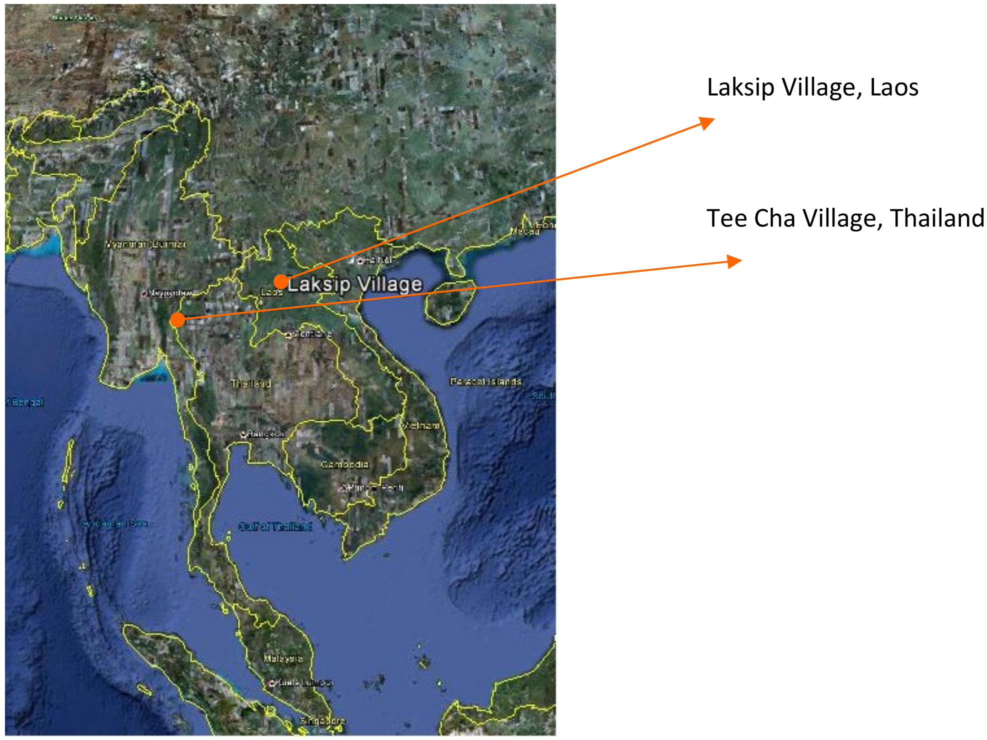


Figure 1 Location of Project Sites

2.0 Methodology

The project methodology was formulated to answer the questions: (i) which land uses encompass high levels of carbon stocks/biodiversity and what are the rates of losses or gains in carbon associated with different land use/management changes?; (ii) what are the factors driving conversion of high carbon stock/biodiversity land uses to low carbon stock/biodiversity land uses?; (iii) what opportunities and challenges are available for promoting conversion of low carbon stock/biodiversity land uses to high carbon stock /biodiversity land uses?; and (iv) what opportunities and challenges are available for promoting conservation of high carbon stock/biodiversity land uses?

The methodology is composed of four components: (1) biophysical survey and analysis mapped land use-land cover types, measured carbon stocks and biodiversity in different land use-land cover types, analyzed land use scenarios, carbon dynamics and reference level; (2) Socio-economic survey assessed economic benefits of different land use-land cover types, estimated opportunity cost of REDD+ (focusing on forest conservation versus alternative land uses); (3) Identification of good land use practices to enhance co-benefits of carbon stocks, economic benefits as well as biodiversity through integration of biophysical and socio-economic assessments, and (4) good land use practices were demonstrated to local farmers and officials, and relevant training programmes organized for local farmers and officials to appreciate, measure, monitor and manage forest carbon pools as a process of community-based MRV.

2.1 Land use and biodiversity survey

Each project site village represents a land use system and landscape with different land uses which support village livelihoods as well as provide ecosystem services. Tee Cha Village in Thailand represents the land use system of shifting cultivation; Laksip Village in Laos presents the land use system in transition from shifting cultivation to sedentary system. The associate sites in India and China represent sedentary land use systems. These land use systems create particular village landscapes and cover a mixture of land uses to detect and compare land use and carbon dynamics in MMSEA.

Land use survey determined different land uses, areas and their spatial distribution in the whole village landscape, and provided a basis for stratification of the village landscape into relatively homogenous units for sampling investigation of carbon stock and biodiversity in each major land use type in the village landscape, and for identification of good land use practices rich in these ecosystem services. While drawing the land use classification scheme, due attention was paid to the indigenous management systems so that local communities were able to better participate in the MRV process and appreciate impacts of their land management practices on carbon stocks and biodiversity.

Mapping of existing and historical land use-land cover types in each project site integrated satellite based and ground surveyed based information, including review of secondary data. All data were pooled in a digital data base and analyzed in a GIS system. Land use change analysis over a number of time series projected land use scenarios, carbon dynamics and reference level.

2.2 Carbon stock measurement in the forested landscape

The carbon storage estimation

Carbon density in vegetation in a given land use-land cover was estimated as 50% of the oven-dried biomass.

The biomass measurement

A. **In the Forest Areas**

A.1 The biomass of plant species (above ground biomass)

Measurement in each replication (4 Rep. in forest type)

- For plant height (>1.5 m) we used plot size as follows:
  - Plot size 40m X 40m for measuring diameter of mature trees with DBH ≥4.5 cm
  - Plot size 20m X 20m for measuring diameter of other trees and shrubs
- Biomass was calculated using allometric equation given by Tsutsumi et al. (1983):

Biomass of Stem (W_S) $= 0.0509*(D^2 H)^{0.919}$

Biomass of Branch (W_B) $= 0.00893*(D^2 H)^{0.977}$

Biomass of Leaf (W_L) $= 0.0140*(D^2 H)^{0.669}$

and by Ogawa et al. (1965) for Utility forest

Biomass of Stem (W_S) $= 0.0396*(D^2H)^{0.9326}$

Biomass of Branch (W_B) $= 0.003487*(D^2H)^{1.027}$

Biomass of Leaf (W_L) $= ((28.0/Ws+ W_B) +0.025)^{-1}$

A.2 The biomass of root trees (below ground biomass)

Root biomass was estimated by equation given by Cairns et al., (1997) and Jobbagy and Jackson (2000).

Root biomass = 24% of Aboveground biomass of trees

A.3 The biomass of the groundcover (groundcover/herbaceous plants and litter)

The biomass of the groundcover and litter was estimated by .

- Cutting off all standing plants at ground level in 2 m x 2 m plots and collection of litter on ground floor.

- Samples were weighed directly and sub-sample of 3 kg (groundcover plant) and 1 kg (litters) were taken for oven drying at 80 ^{o} c for 48 hours to calculated oven-dried biomass.

For the carbon storage in the soil

Measurement of soil organic matter

Soil organic carbon content (Cs) was estimated in soil collected from 0-30 cm layer using the equation of

Cs = 58% OM x Soil mass

Soil mass = D * A * H

OM = organic matter,

D = Soil bulk density (g/cm^3), A = Area (ha), H = soil depth (cm)

The carbon content

The carbon content in the biomass of the aboveground and belowground portions of the trees was calculated by summarizing total biomass, then conversion factor at 0.5 for carbon content estimation.

$$B_T = B_S+B_B+B_L+B_R$$

$$T_C = B_T \times 0.5$$

Whereas: B_T = Total biomass of tree (ton/ha)

B_S = Total biomass of stem (ton/ha)

B_B = Total biomass of branch (ton/ha)

B_L = Total biomass of leave (ton/ha)

B_R = Total biomass of root (ton/ha)

T_C = Total carbon content of tree (ton/ha)

The groundcover carbon content was estimated by the following equation

$$G_T = G_{CT} \times 0.5$$

Whereas: G_T = Total groundcover carbon content (ton/ha)

G_{CT} = Total biomass of groundcover (ton/ha)

The carbon content of top soil horizon (0-30cm.) will be calculated by the following equation:

$$S_T = \text{Soil mass X SOC concentration (\%)}$$

Soil mass (ton/ha) = [Area X Depth] X Bulk density

Whereas: S_T = Total soil carbon content in top soil horizon (ton/ha)

D = Bulk density (g/ cm^3)

H = Depth (cm)

SOC = Soil Organic Carbon = 58%OM

Total carbon content was estimated by the following equation:

$$C_T = T_C+G_T+S_T$$

Whereas: T_C = Total carbon content of tree (ton/ha)

G_T = Total carbon content of groundcover (ton/ha)

S_T = Total soil carbon content of soil (ton/ha)

2.3 Economic analysis- opportunity cost/benefit analysis

Based on farmers' interview, the monetary costs and benefits under different types of land use were used to estimate the opportunity costs of land use by using the Net Present Value (NPV) formula.

$$\text{NPV} = \sum_{t=0}^{n} \frac{(\text{Benefits} - \text{Costs})_t}{(1 + r)^t}$$

where:

r = discount rate

t = year

n = analytic horizon (in years)

- NPV is calculated to estimate the profitability of a land use over 20 years
- Discount rate used is 5 % for every year; there are no discount rate for the years where there is no profit
- NPV of each land use is an accumulation of every year profit (revenues minus costs of material and labor inputs) minus discount rate

3.0 Results & Discussion

3.1 Thailand

3.1.1 General background of project site in Thailand

The project site-Tee Cha village, Mae Hongson Province, saw over 5-fold increase in number of households/population and 2-fold reduction in the length of fallow phase between two successive croppings on the same site during 1950 —2011 period decline in length of fallow. The settlement patterns of farmers in Tee Cha Village (1934-2011) are showed in table 1 and figure 2.

Table 1 Settlement patterns of farmers in Tee Cha Village (1934-2011)

Year	Households	Fallow cycle (years)
<1950	5-9	>10-20
1950-1957	15	10
1958-1994	8-18	10
1994-2005	32-35	7
2011	48	7

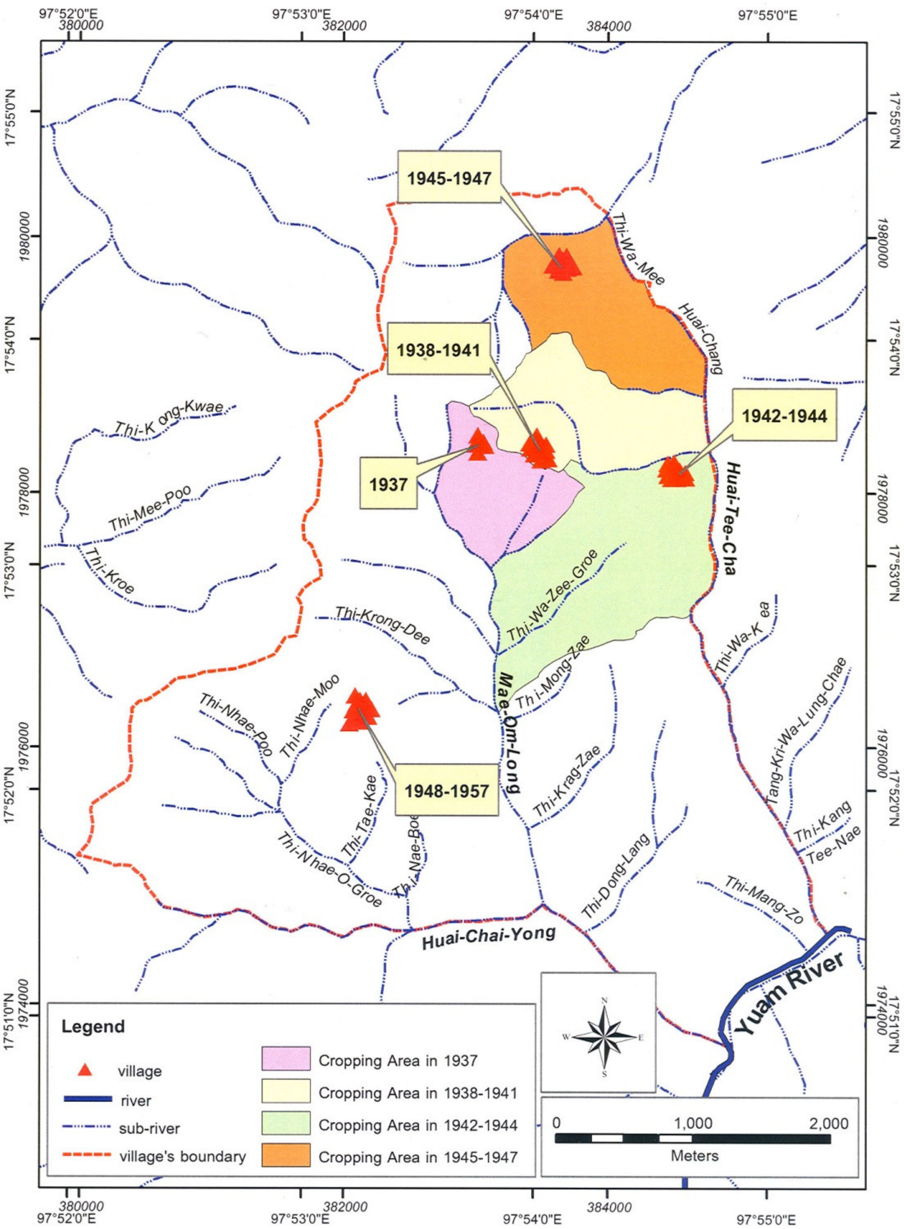


Figure 2 Expansion of cropping area in Tee Cha during 1937-1957

At present, Tee Cha village is Pwo Karen Village of Sop Moei in Mae Hong Son province (19°78 N, 93°84 E), in Northern Thailand. The village has 172 people in 48 households. The cycle of rotational shifting cultivation is 7 year rotation.

General characteristics of village site are the mountainous area of Pwo Karen ethnic group. The climate in Tee Cha (700-900 m MSL) is slightly more annual rainfall at 1,204 mm and 3 seasons, rain season in June-September, winter season in November-February and summer season in March-May. The average temperature is 24.4 ^{0}C (T max 41.2 ^{0}C, T min 9.5 ^{0}C). The soil in Tee Cha is sandy loam texture with good drainage property and generally poor with low pH (average 5.16 pH).

Table 2 The site description of Tee Cha Village, Thailand

Characteristic	Tee Cha
Demographic	
• Household	48
• Population	172
- Male	83
- Female	89
School	Primary school
Infrastructures	
• Electricity	90 %
• Road	Soil road
• Water supplied	60 %
Occupation	
• On-farm	48 HH
• Other	0 HH
Production system	Short rotational shifting cultivation system
Productivity	For subsistence
Location	
• Province	Mae Hon Son
• Altitude (MSL)	700-900
National context.	
• National policy relevance	Reduce fallow period for 10 to 7 years and promote sustainable farming practices
• Potential contribution from implementing Agencies	Tambon Administration Offices (TAOs)
Critical problems facing by government and implementing agencies	Reduce fallow period
Main problem of land degradation	Deforestation, soil erosion and soil degradation

Land allocation and tenure arrangement

In Tee Cha, land allocation and tenure arrangements are basically based on local tradition, customary rules and regulations. According to local rules and regulations, Karen community allows individual families to own paddy fields and permanent orchards. Shifting cultivation fields were originally managed on communal basis. Community made almost every decision from choosing land for opening up, time of slashing and burning, and allocation of land to individual household for upland rice production. Village leader (Ran Koo) plays a significant role in these decisions. With increasing pressures on land, the previous plot allocated for household production is allocated and fixed permanently to household members in the village. Rights to land ownerships are determined from families who open up the land first and big trees are often used as the land mark. After burning, the land may be lined up with bamboo or any tree stems to demarcate the plot. Demarcation of the plot would have to conduct jointly with owners of the adjacent fields in order to avoid any conflicts of interests. Inherited rights of land to the youngest daughter in family are common in Karen community. The reason for this relates to her duty to look after her parents when they are old. Land may be shared and exchanged with relatives in order to keep his or her rights. Sharing land with people outside kinship is a risk to losing land rights. This may happen with small family but occupy big piece of land. Every household has access to at least a piece of land for upland rice cultivation. The land has to be redistributed among the member households. Final decision has to be reached before agreement to opening up fallow field. The customary land tenure and ownerships of Pwo Karen community are shown in table 3.

Table 3 Activities of rotational shifting cultivation of farmers in Tee Cha Village

Activities	Timing(month)	Management Decision
1. Village meeting	-	-
• New year ceremonial	February	Communal
• Selection of field plot for cropping	February	Communal
• Land allocation to each household	February	Communal / Household
• To ask permission land spirit	February	Household
2. Slashing and looping big trees	March	Collection
3. Drying and burning		
• Firebreak construction	April	Communal
• Control burning	End of April	Communal
• Land spirit ceremonial (in the 7 days after burning)	April-May	Household
• Cleaning	May	Household
• Shelter	May	Household
• Fencing	May	Household
4. Preparing seeds		
(rice & swidden crops)	May	Household
• Planting pre-rice-swidden crops	May	Household
• Planting upland rice	May	Collection

• Planting seven-hole rice	May	Household
• Planting post-rice-swidden crops	May	Household
5. Rice establishment	June-July	Household
6. Weeding		
• First weeding	June	Household
• Second weeding	July	Collection
• Third weeding	August	Collection
7. Spirit ceremonial		
• Seven-hole rice spirit ceremonial	July	Family
• Land spirit ceremonial	July	Family
• Trees spirit ceremonial	July	Family
• Protection bad spirit ceremonial	July	Household
8. Animals protection	July	Household
9. Harvesting swiddens	July-January	Household
10. Harvesting and staking	End of Oct - Nov	Collection
11. Rice drying	November	Household
12. Threshing	December	Household
• Rice spirit ceremonial	December	Household
13. Transportation	December	Household / Collection
14. Storage	January	Household

Source: Yimyam (2006)

Sources of cash incomes and livelihood activities

According to Tambon and district statistics, average annual income of farmers in Tee Cha was 1,500 baht $person^{-1}$ $year^{-1}$. Chilli was the major source of cash income derived from selling chilli (table 4). Wage labours outside the village have significant contribution to household income. More than half of total households in the village have gone out to lowland village for Longan picking. Many households also harvest forest products, e.g., edible mushroom, bee honey, bamboo shoot and bamboo worm, for selling to outside markets. Cattle and buffaloes are sold out during emergencies. Almost all of household have own animals. Small animals, pigs and chickens are raised for own consumption and offered to please spirits and village deities.

So far, cash income earning activities are somewhat supplement to the overall livelihood of the household. Villagers in Tee Cha are concerning with rice production for subsistence of the farming household. It was said that surplus production from one year of swidden cycle could adequately support the family for at least the next 2 years of poor production.

Table 4 Livelihood activities of villagers in Tee Cha Village

Activity	Number of Households	% of total HH

Upland rice	48	100.00
Paddy	5	10.42
Chillies	35	72.92
Fruit trees	9	18.75
Sugar cane	1	2.08
Coffee	8	16.67
Swidden crops	48	100.00
Weaving	48	100.00
Basketry	34	70.83
Fishing	34	70.83
Livestock		
• Pigs/ chicken	48	100.00
• Cattle/ buffalo	33	68.75
Forest products collected		
• Mushroom	48	100.00
• Honey	5	10.42
• Fruit and vegetable	48	100.00
• Bamboo shoot	48	100.00
• Bamboo worm	48	100.00
Wage labour		
• Longan picking	25	52.08
• General wage labour	10	20.83
Small shops	5	10.42

Source: Household interview (2011)

In Thailand, the areas under protected forests in the North range from over 75% of national reserves and over 95% of total area of national parks and wildlife sanctuaries in the country (Suraswadi et. al. 2004). The Tee Cha is locating in reserved forest in Sop Moei District under control of the conserve office area 16 (Chiang Mai) of the local administrative control of forest area of Department of Natural Parks, Wildlife and Plant Conservation. At present, shifting cultivation represents the dominant agricultural land use covering 45.8% of total area. Natural forests cover 51.5% of total area in the village.

The year 1985 was the turning point when the forest area in the country was reduced to < 30% of total land area in the country. In Northern Thailand, even though recent rates of forest loss are declining, the percentage loss forest cover remains higher than national average (Suraswadi et. al. 2004). The principal proximate causes of deforestation in Northern Thailand are conversion of forest to agriculture and logging. While conversion of forests to agriculture and logging was basically due to lowland populations, traditional practice of shifting cultivation of highland population was blamed for deforestation to justify forest conservation by law enforcement. Importance of diversity and complexity of land use practiced by the diverse ethnic groups on the highlands is being realized but much more needs to be done, especially in the face of land use transition to sedentary agriculture, in order to improve policy process (Kunstadter et. al. 1978 and Yimyam et. al. 2005). Lack of understanding has led the government to increase the area and extent of protected sites, especially the National Parks and Wildlife Sanctuaries, in Northern Thailand enormously for the past two decades.

After the National Parks and Wildlife Sanctuaries declared the reserve forest areas above some areas of shifting cultivation of Tee Cha Village, restriction on existing land use reduced areas available for shifting cultivation and led to shorter cycle of 4-5 years for rotational shifting cultivation. Community forests are being transferred to local forestry offices responsible for reforestation.

Since 2002, local authorities have been trying to stop shifting cultivation with law enforcement. This has created tension between communities and local authorities. To avoid conflicts with communities, the authorities are currently trying to negotiate with local communities for shorter rotation, say a maximum of 4-5 years cycle under the restricted areas. Together with infrastructure improvement, traditional land use system is under a big threat with no direction and support for such the big change.

3.1.2 Land use-land cover mapping

Land use in Tee Cha village is the rotational shifting cultivation represents the dominant agricultural land use with an overall area of about 495.6 ha or 45.8% of total area. Area under forests remains 557.2 ha or 51.5% of total area in the village (table 5 and figure 3).

Table 5 Land use in Tee Cha Village

Type of Land Use	Area	
	Ha	%
Forests Area	557.17	51.48
• Conservation forest and head water	84.21	7.78
• Community forest	47.19	4.36
• Utility forest	422.30	38.01
• Cemetery forests	3.47	0.32
Village Site	5.50	0.51
Agriculture Lands	519.68	48.01
• Shifting Cultivation	495.6	45.79
Fallow since 2005	70.61	6.52
Fallow since 2006	57.71	5.33
Fallow since 2007	59.78	5.52
Fallow since 2008	104.43	9.65
Fallow since 2009	86.32	7.98
Fallow since 2010	69.94	6.46
Fields cropped in the year 2011	46.81	4.32
• Permanent Fields	16.08	1.49
• Wet Paddy fields and Fish ponds	8.00	0.74
Total Area	1082.35	100.00

Source: Field survey (2011)

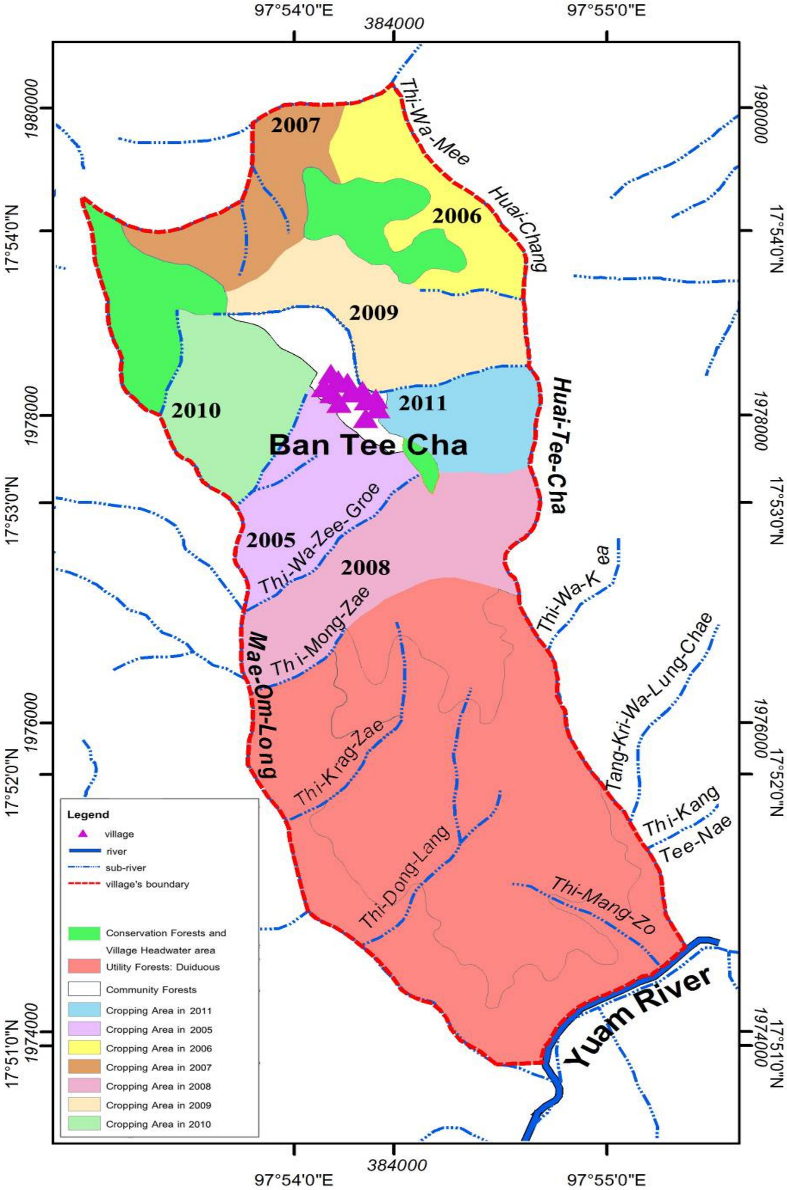


Figure 3 Map of existing land use in Tee Cha project site in 2012

3.1.3 Biodiversity in different land uses

Farmers in Tee Cha could maintain their shifting cultivation system with high diversity of upland rice and swidden crop species traditionally managed and conserved over generations (Yimyam 2006).

1. Genetic diversity of upland rice

In Tee Cha farmers are planting both glutinous and non-glutinous rice type. There are some 12 varieties of non-glutinous and 5 varieties of glutinous type. On average, a household would grow 3-5 varieties, depending upon the conditions of the field and their preference.

2. Species diversity of swidden crops

The total number of swidden crops grown in Tee Cha was found to be as high as 56 species. The average number of species grown by farmers in the whole village remained fairly constant 35 species.

3. Plant species in various land use stages and field types

In Tee Cha Village, farmers are managing *Macaranga denticulata* to sustain their traditional shifting cultivation for subsistent production of upland rice and a rich diversity of other swidden crops with fairly short rotation Rerkasem (2000) observed that species richness in the *Macaranga* dominant bush fallow is less than those of forests that were community-managed as well as unmanaged natural ecosystems (table 6).

Table 6 Number of plant species in various land use stages and field types of Tee Cha Village

Land Use Stags/Field Types	Number of Species	
	Total	Useful
Undisturbed Headwater	72	64
Community Forests (>200 years)	64	57
Utility Forests (Dry Dipterocarpus)	54	45
Bush Fallow with Reduced Cycle (7 years)	41	37
Cropping year in shifting cultivation	84	64
Mixed Perennial and Fruit trees garden (*Mr. Nopporn*)	49	40
Home gardens	85	nd
Total	308	nd

Source: Rerkasem (2000); nd= Not determined

3.1.4 Biomass and carbon storage estimation in different land uses

Carbon storage estimation

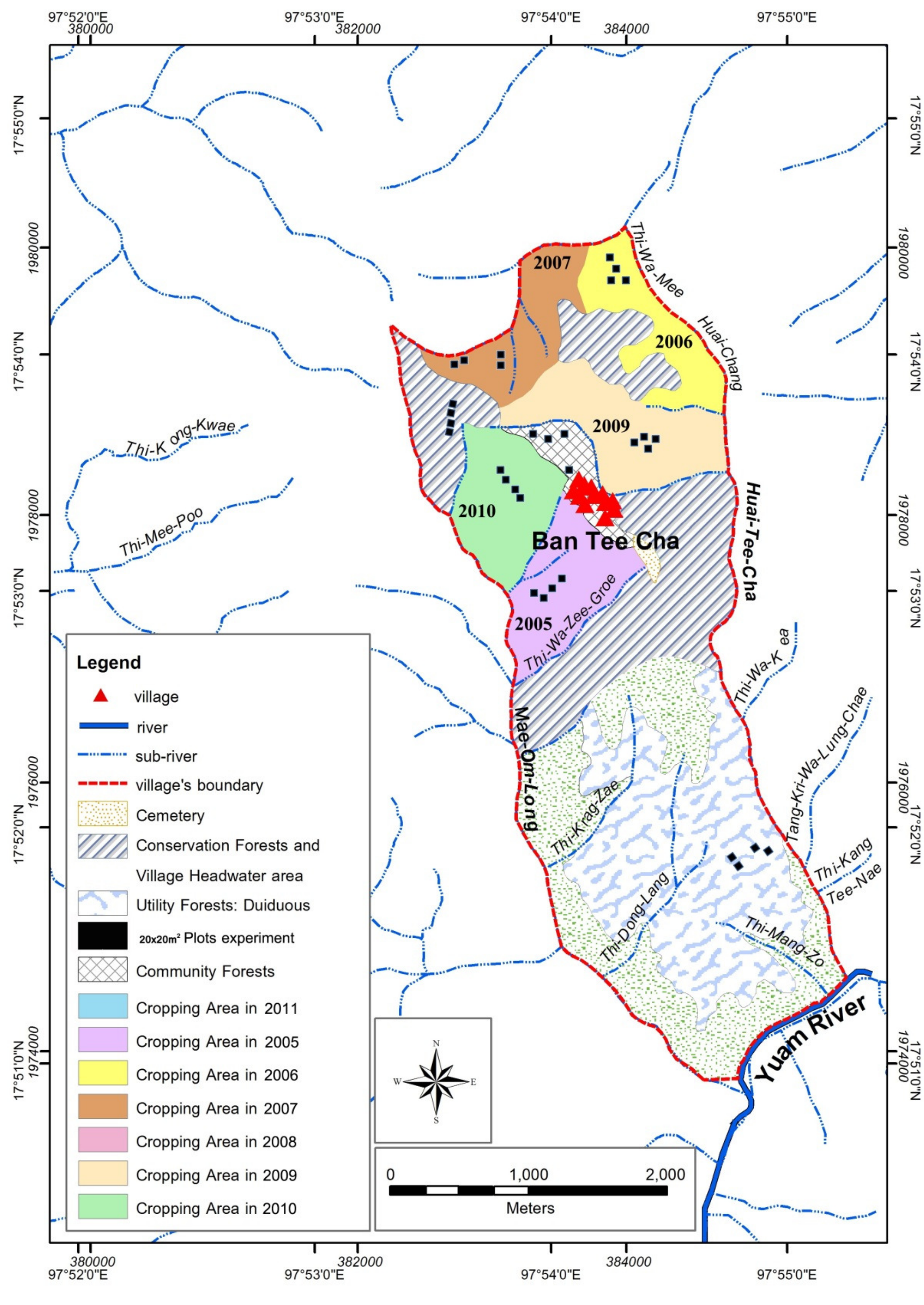


Figure 4 distributions of plots in conservation forest, community forests and fallow fields for carbon storage estimation in Tee Cha Village

Plant biomass estimates at landscape level in Tee Cha Village are given in table 7-10 and carbon stocks in table 11-12.

Table 7 Plant biomass (ton/ha) of different field type of forest land use

Forest type	Above ground biomass	Below ground biomass	Total biomass
Conservation forest	271.08	65.06	336.14
Community forest	91.58	21.98	113.55
Utility forest	157.99	37.92	195.91

(Above ground biomass = Plant biomass +Ground cover)

Table 8 Carbon stock (ton/ha) of different field type of forest land use

Forest type	Carbon in plant biomass	Carbon in soil organic matter	Total carbon stock
Conservation forest	168.07	104.58	272.65
Community forest	56.78	97.54	154.31
Utility forest	97.95	75.63	173.59

Table 9 Plant biomass (ton/ha) in different field type of agriculture land use

Agriculture type	Above ground biomass	Below ground biomass	Total biomass
Shifting cultivation	21.52	5.16	26.68
Cropping year	1.36	0.33	1.69
Fallow year 1	3.16	0.76	3.92
Fallow year 2	10.13	2.43	12.56
Fallow year 3	22.51	5.40	27.91
Fallow year 4	30.71	7.37	38.08
Fallow year 5	36.53	8.77	45.29
Fallow year 6	46.25	11.10	57.35
Permanent fields	21.55	6.27	27.82
Paddy fields	4.08	0.98	5.06

Table 10 Carbon stock (ton/ha) on different field type of agriculture land use

Agriculture type	Carbon from plant biomass	Carbon from OM	Total carbon stock
Shifting cultivation	13.34	83.61	96.95
Cropping year	0.84	70.33	71.17
Fallow year 1	1.96	94.41	96.37
Fallow year 2	6.28	90.10	96.38
Fallow year 3	13.95	93.01	106.97
Fallow year 4	19.04	89.79	108.83
Fallow year 5	22.65	77.70	100.35
Fallow year 6	28.67	69.93	98.61
Permanent fields	13.91	51.43	65.34
Paddy fields	2.53	46.91	49.44

Table 11 The carbon stock intensity (ton/ha) in each land use type in Tee Cha Village

Type of Land Use	Biomass (ton/ha)			Carbon Storage (ton/ha)			
	Above Ground	Below Ground	Carbon Soil OM	Above Ground	Below Ground	Carbon Soil OM	Total
Natural Forest							
· Conservation Forest and Head water	271.08	65.06	104.58	135.54	32.53	104.58	272.65
· Community Forest	91.58	21.98	97.54	45.79	10.99	97.54	154.31
· Utility Forest: Deciduous	157.99	37.92	75.63	78.99	18.96	75.63	173.59
Agriculture Lands							
· Shifting Cultivation	21.52	5.16	83.61	10.76	2.58	83.61	96.95
Fallow year 6 (2005)	46.25	11.10	69.93	23.12	5.55	69.93	98.61
Fallow year 5 (2006)	36.53	8.77	77.70	18.26	4.38	77.70	100.35
Fallow year 4 (2007)	30.71	7.37	89.79	15.36	3.69	89.79	108.83
Fallow year 3 (2008)	22.51	5.40	93.01	11.25	2.70	93.01	106.97
Fallow year 2 (2009)	10.13	2.43	90.10	5.07	1.22	90.10	96.38
Fallow year 1 (2010)	3.16	0.76	94.41	1.58	0.38	94.41	96.37
Cropping year (2011)	1.36	0.33	70.33	0.68	0.16	70.33	71.17
· Permanent Fields	21.55	6.27	51.43	10.77	3.13	51.43	65.34
· Paddy fields	4.08	0.98	46.91	2.04	0.49	46.91	49.44

Table 12 The total carbon storage in Tee Cha Village

Type of Land Use	Total Area		Total Carbon Storage (ton)			
	ha	%	Above Ground	Below Ground	Carbon Soil OM	Total
Natural Forest	555.7	51.41	47,090.97	11,301.83	45,500.06	103,892.86
· Conservation Forest and Head water	84.20	7.79	11,412.54	2,739.01	8,805.26	22,956.81
· Community Forest	47.20	4.37	2,161.18	518.68	4,603.65	7,283.52
· Utility Forest: Deciduous	424.30	39.25	33,517.25	8,044.14	32,091.14	73,652.53
Agriculture Lands	519.7	48.08	5,522.46	1,334.21	42,640.48	49497.16
· Shifting Cultivation	495.6	45.85	5,332.66	1,279.84	41,437.17	48,049.66
Fallow year 6 (2005)	70.61	6.53	1,632.77	391.86	4,937.95	6,962.59
Fallow year 5 (2006)	57.71	5.34	1,054.00	252.96	4,484.05	5,791.01
Fallow year 4 (2007)	59.78	5.53	917.92	220.30	5,367.63	6,505.85
Fallow year 3 (2008)	104.43	9.66	1,175.10	282.02	9,713.48	11,170.61
Fallow year 2 (2009)	86.32	7.99	437.21	104.93	7,777.19	8,319.33
Fallow year 1 (2010)	69.94	6.47	110.42	26.50	6602.99	6,739.91
Cropping year (2011)	46.81	4.33	31.89	7.65	3292.04	3,331.58
· Permanent Fields	16.1	1.49	173.48	50.45	828.07	1,052.00
· Paddy fields	8	0.74	16.33	3.92	375.25	395.50
Village Site	5.5	0.51				
Total	1,080.9	100.00	52,613.43	12,636.04	88,140.54	153,390.01

3.1.5 Land use and carbon dynamics: reference level, carbon stock changes and future scenarios

The total carbon storage in this village is 153,390 ton. In the national forest areas; the highest total carbon content was recorded in conservation forest while the difference in carbon density utility and community forest was negligible. For the agriculture lands; highest total carbon content was found in shifting cultivation followed by permanent fields and paddy fields (figure 5).

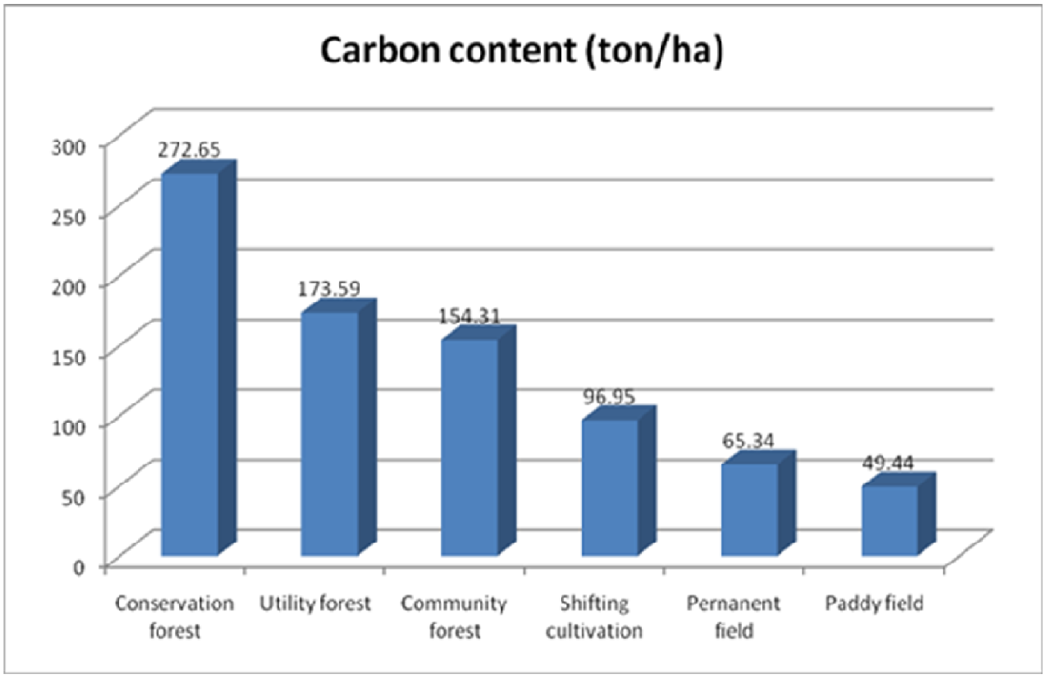


Figure 5 The total carbon content (ton per hectare) of different land use in Tee Cha Village

We predict the length of cultivation cycle in future from current situation of land use demand of farmers and rate of the increase in population. The shifting cultivation cycle in future scenarios and reference levels are presented in table 13.

Table 13 The shifting cultivation cycle of farmers in Tee Cha Village

Year	Rotational shifting cycle (years)
1990	20
1995	15
2000	10
2005	7
2012	7
2015	4
2020	3
2025	2
2030	2

If the farmers change the fallow area to the forest (Reforestation or with REDD+), the changed scenarios of land cover-land use and carbon stocks are presented in figure 6 and figure 7.

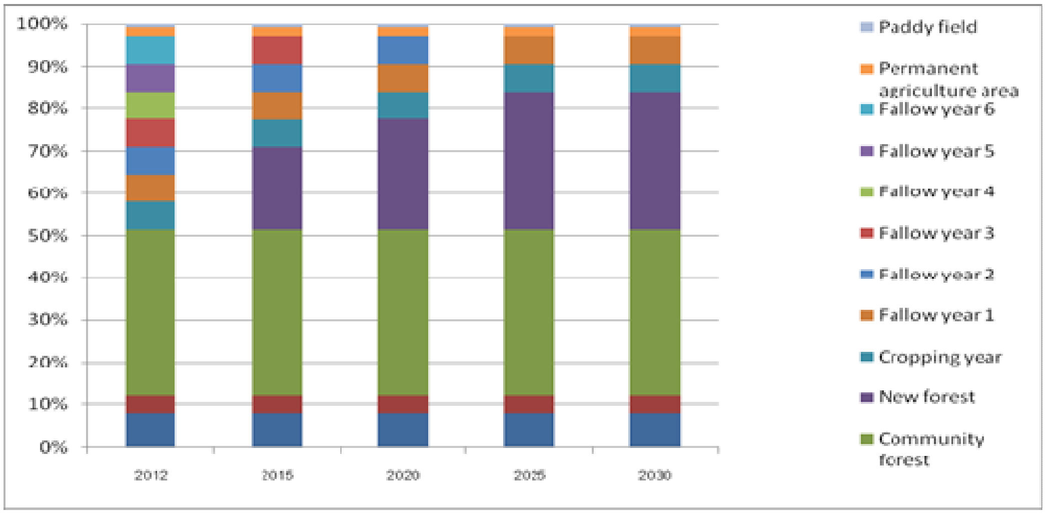


Figure 6 Land use areas (%) of farmers in Tee Cha Village

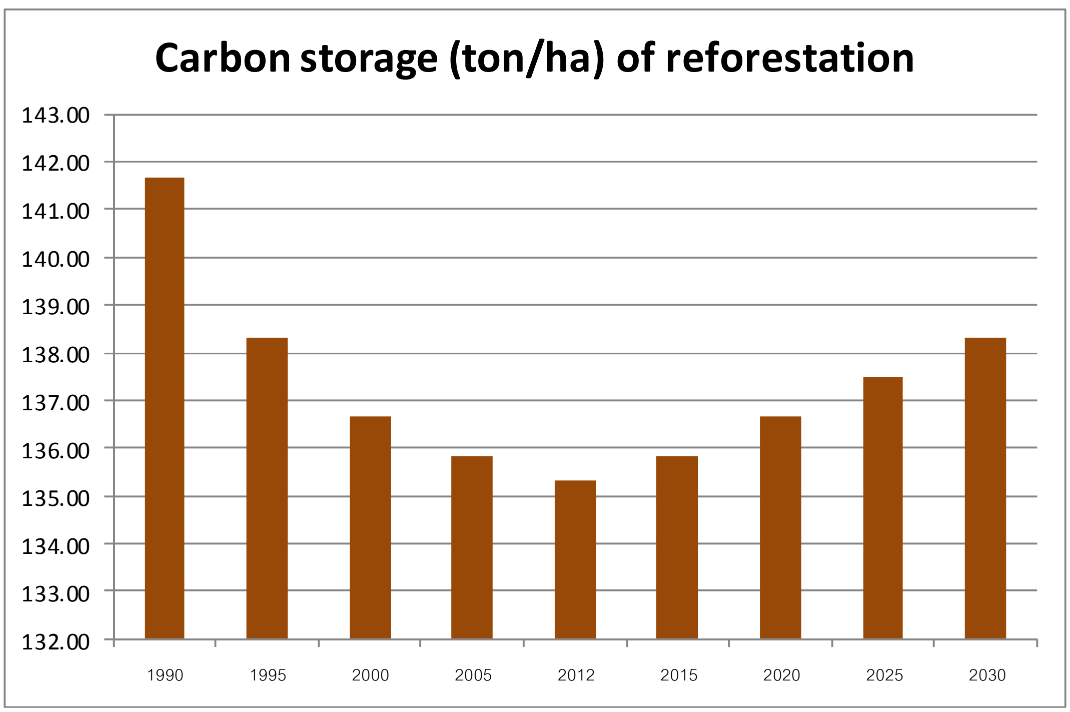


Figure 7 Carbon storage change of Tee Cha Village (in period 1990-2030) in case of reforestation (with REDD+)

If farmers change the fallow area to short cycle (from 7 years to 2 years) of the shifting cultivation system (deforestation or without REDD+) we can estimate the land use change (%) same in figure 8 and carbon storage change show in figure 9

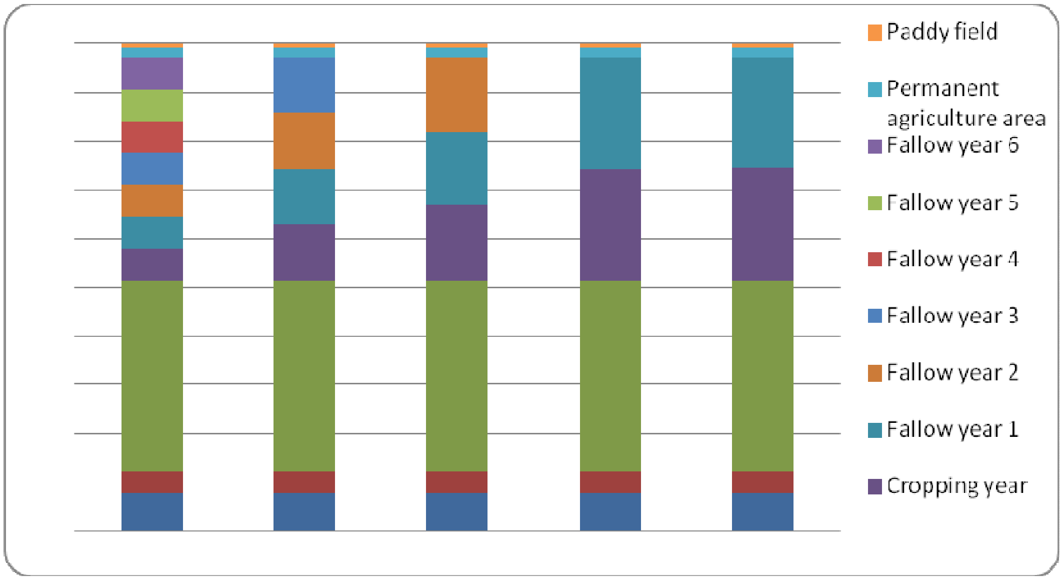


Figure 8 Land use areas (%) of farmers in Tee Cha Village (Deforestation)

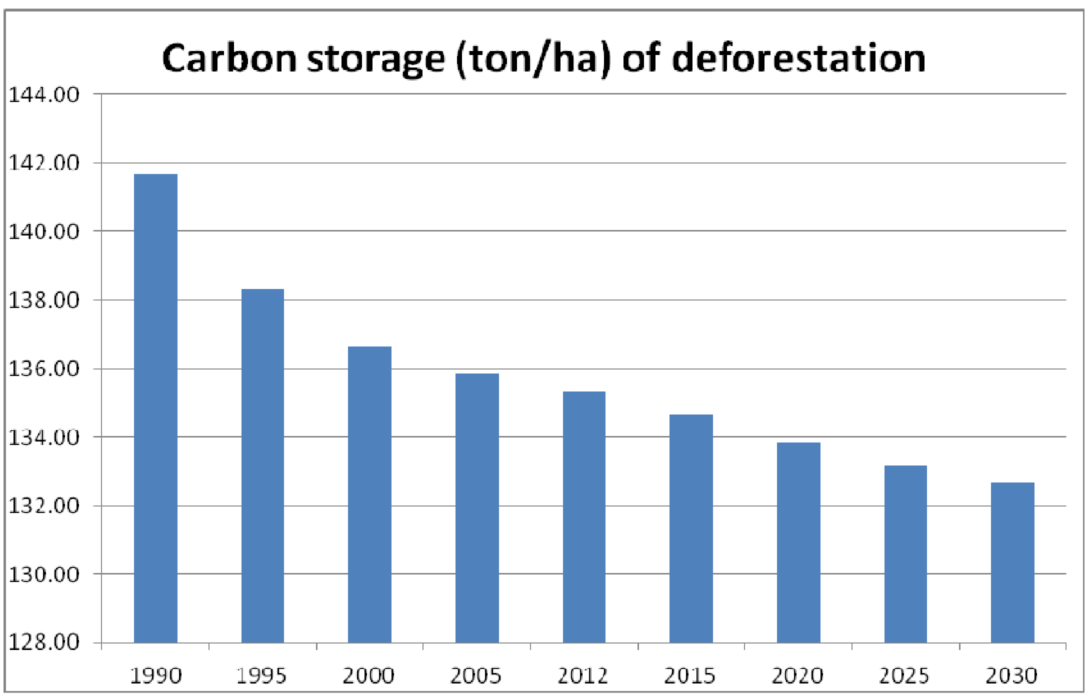


Figure 9 Carbon storage change of Tee Cha Village (in period 1990-2030) in case of deforestation (without REDD+)

There were two scenarios of carbon storage change of Tee Cha village in case of deforestation (without REDD+) (table 14) and reforestation (with REDD+) (table 15). In consequences, historical and future scenarios of carbon stock (ton/ha) in Tee Cha village (in1990-2030) the carbon stock in the area will increase from 132.72 ton per hectare to 138.39 ton per hectare. Carbon credit will be carbon-stock 5.57 ton per hectare (table 16 and figure 10).

Table 14 Future scenarios carbon stock (ton/ha) in case of deforestation

Land use	Year				
	2012	2015	2020	2025	2030
Rotation cycle (year)	7	4	3	2	2
Conservation forest	272.65	272.65	272.65	272.65	272.65
Utility forest	173.59	173.59	173.59	173.59	173.59
Community forest	154.31	154.31	154.31	154.31	154.31
Shifting cultivation	96.95	92.72	87.97	83.77	81.00
Permanent field	65.34	65.34	65.34	65.34	65.34
Paddy field	49.44	49.44	49.44	49.44	49.44
Total	812	808	803	799	796

Table 15 Future scenarios carbon stock (ton/ha) in case of reforestation

Land use	Year				
	2012	2015	2020	2025	2030
Rotation cycle (year)	7	4	3	2	2
Conservation forest	272.65	272.65	272.65	272.65	272.65
Utility forest	173.59	173.59	173.59	173.59	173.59
Community forest	154.31	154.31	154.31	154.31	154.31
Shifting cultivation + new forest	96.95	100.00	105.00	110.00	115.00
Permanent field	65.34	65.34	65.34	65.34	65.34
Paddy field	49.44	49.44	49.44	49.44	49.44
Total	812	815	820	825	830

Table 16 Historical and future scenarios of carbon stock (ton/ha) in Tee Cha Village

Year	Deforestation	Reforestation
1990	141.67	141.67
1995	138.33	138.33
2000	136.67	136.67
2005	135.83	135.83
2012	135.33	135.33
2015	134.67	135.83
2020	133.83	136.67
2025	133.17	137.50
2030	132.67	138.33

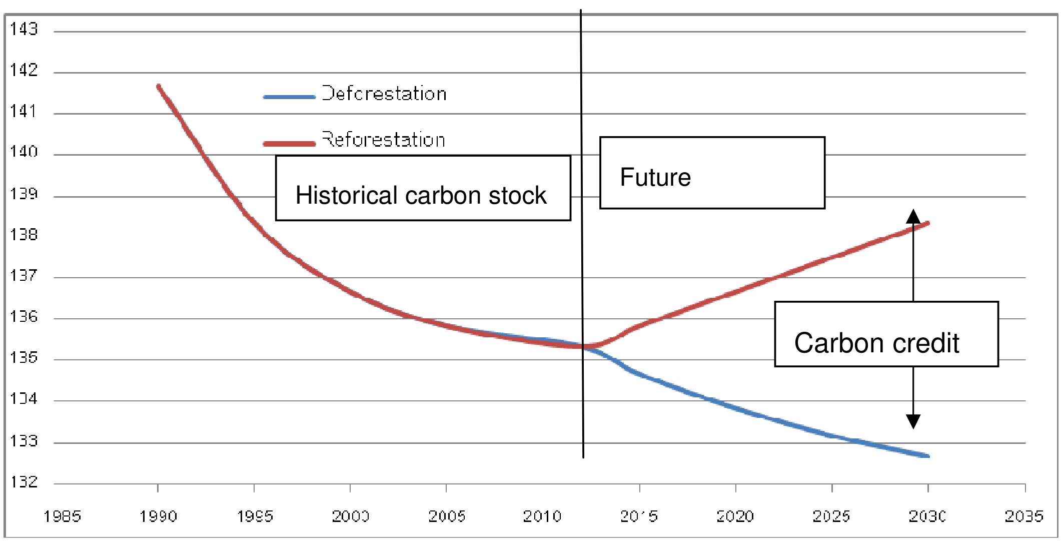


Figure 10 Carbon dynamic and reference levels

3.1.6 Economic analysis- opportunity cost/benefit analysis

The costs and benefits under different land uses including upland rice system, paddy rice system and permanent system for example coffee system show in table 17-19.

Table 17 Costs and benefits of upland rice system

Costs				
Items	Unit	Costs /Unit	Costs (THB)	Costs (US)
Seed	65 kg	20 THB/kg	1,300	43.33
Land preparation	125 man day	150 THB/ man day	18,750	625.00
Planting	31 man day	150 THB/ man day	4,650	155.00
Weeding	94 man day	150 THB/ man day	14,100	470.00
Total				1,293.33
Benefits				
Land used type	Yield (ton/ha)	Benefits/Unit	Benefits(THB)	Benefits (US)
7 years cycle	3	15,000 THB	45,000	1,500.00

Table 18 Costs and benefits of paddy rice system

Costs				
Items	Unit	Costs /Unit	Costs (THB)	Costs (US)
Seed	35 kg	20 THB/kg	700	23.33
Land preparation	10 man day	150 THB/ man day	1,500	50.00
Planting	31 man day	150 THB/ man day	4,650	155.00
Fertilizer	6 sacks	1000THB/sack	6,000	200.00
Weeding	18 man day	150 THB/ man day	2,700	90.00
Total				518.33
Benefits				
Land used type	Yield (ton/ha)	Benefits/Unit	Benefits(THB)	Benefits (US)
Every year	1.5	15000 THB	22,500	750.00

Table 19 Costs and benefits of permanent system: case of coffee system

Costs				
year 1-3				
Items	Unit	Costs /Unit	Costs (THB)	Costs (US)
Seedling	2,500	10 THB/seedling	25,000	833.33
Land preparation	12.5 man day	150 THB/ man day	1,875	62.50
Planting	31 man day	150 THB/ man day	4,650	155.00
Fertilizer	6 sacks	1,000 THB/sack	6,000	200.00
Weeding	18 man day	150 THB/ man day	2,700	90.00
Total				1,340.83
year 4-20				
Items	Unit	Costs /Unit	Costs (THB)	Costs (US)
Seedling	2,500	10 THB/seedling	25,000	833.33
Land preparation	12.5 man day	150 THB/ man day	1,875	62.50
Planting	31 man day	150 THB/ man day	4,650	155.00
Fertilizer	20 sacks	1,000THB/sack	20,000	666.67
Weeding	18 man day	150 THB/ man day	2,700	90.00
Total				1,807.50
Benefits				
Land used type	Yield (ton/ha)	Benefits/Unit	Benefits(THB)	Benefits (US)
1 - 3 years	0	0	0	0
4 - 20 years	5	15000	75000	2500.00

The estimation of NPV carbon stock and CO_2 stock under different land uses over 20 years is presented in table 20.

Table 20 The NPV carbon stock and CO_2 stock of different land use types

Type of land use	Total NPV (US$)	NPV (US$/ha/year)	Carbon stocks (ton/ha)	CO_2 stocks (ton/ha)
Upland rice	785.35	39.27	97	355.99
Paddy rice	4401.73	220.09	50	183.5
Coffee	7161.39	358.07	65	238.55
Forest	28.50	1.43	273	1001.91

Net present value from different land uses

Among four main land uses in study site, it was found that coffee plantation had the highest NPV (358.07 US/ha/year), followed by paddy rice (220.09 US/ha/year) and upland rice (39.27 US/ha/year) (figure 11). The forest had the lowest NPV at 16 US$ /ha/year.

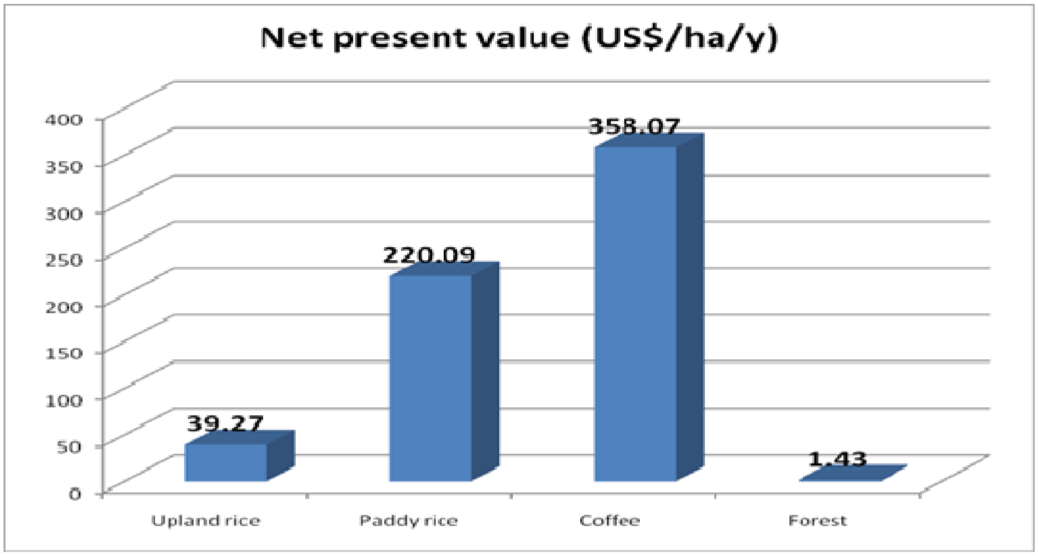


Figure 11 Net present values from different land use

Carbon stock under different land use

In terms of carbon stock, forests had the highest carbon stock of 273 ton/ha, followed by upland rice (97 ton/ha) and coffee (65 ton/ha). The paddy rice had the lowest carbon stock at 50 ton/ha. Calculation of carbon stock losses from converting forest to agriculture land use can show in Figure 12

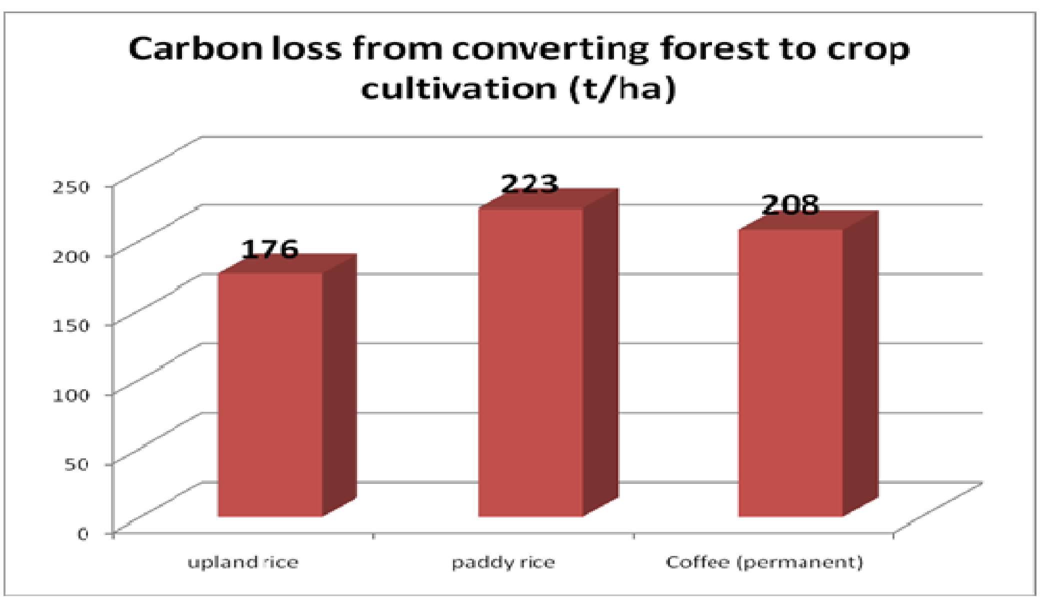


Figure 12 Carbon stock losses from converting forest to agriculture land use

Profit gain from converting forest to agricultural land

Conversion from forest to coffee plantation had the highest profit (NPV/ha) at 356.64 US/ha, followed by changing forest to paddy rice (NPV 218.66 US/ha) and conversion of forest to rice (NPV 37.84 US/ha) (Figure 13).

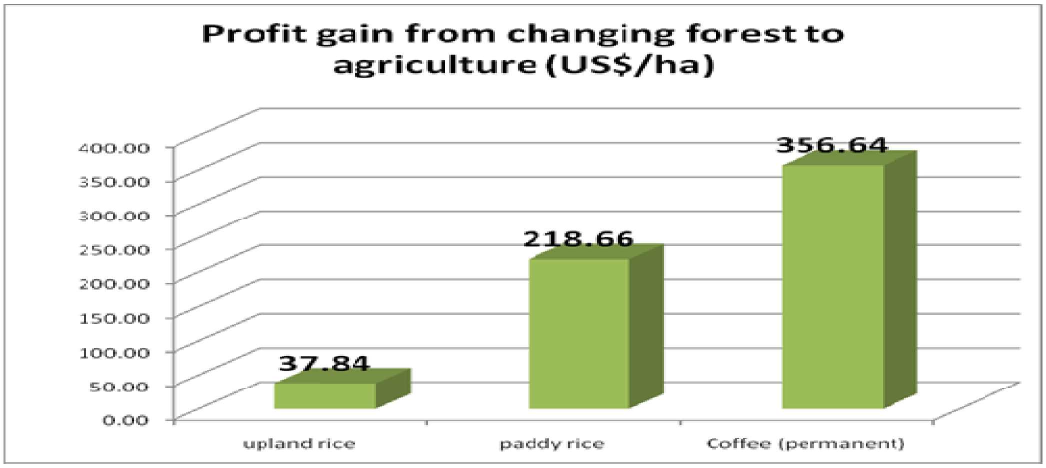


Figure 13 Profit gain from changing forest to agriculture land use

Opportunity cost of different land use change

The study assessed the opportunity cost of three types of land use changes: 1) conversion from forest to coffee plantation; 2) forest to paddy rice; and 3) forest to upland rice). The results show the conversion from forest to coffee plantation had the highest opportunity cost (0.47 US/ton CO2), followed by changing from forest to paddy rice (0.27 US/ton CO2). The conversion from forest to upland rice had the lowest opportunity cost at 0.06 US/ton CO2 (Figure 14).

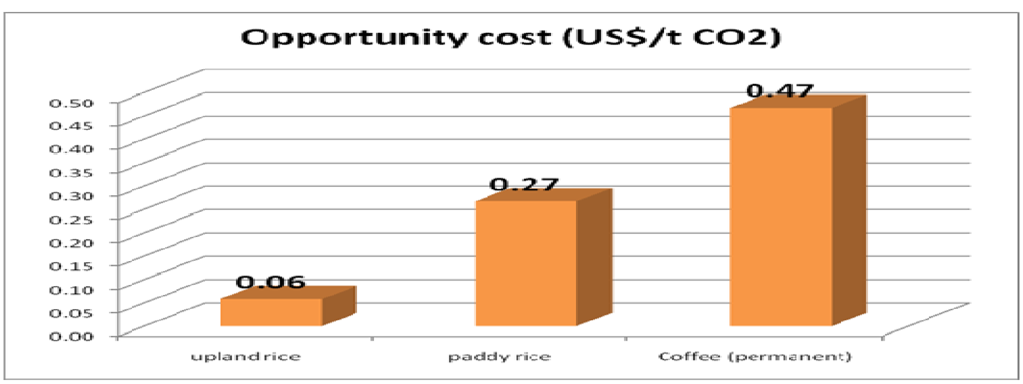


Figure 14 Opportunity cost of different agriculture land use

3.1.7 Community based MRV process

The specific objective of community-based MRV is to increase awareness of the impacts of climate change due to carbon emissions from land use change at village level and encourage villagers to manage, monitor and verify of carbon storage in the community. The study emphasized on the reduction of carbon emissions and forest degradation by enhancing social fencing, increasing forest cover areas and applying of good SLM agricultural practices.

3.2 LAOS

3.2.1 General background of project site in Laos

The project site-Laksip Village, Luang Prabang Province, is a mountainous Khmu village in northern part of Lao PDR. The village is located at 10 kilometres from Luang Prabang along the national road No. 13 linking the northern provinces of the Lao PDR to Vientiane. The village (102° 08' 38" - 102° 11' 33" E latitude and 19° 47' 42" - 19° 52' 00" N longitude) comprises 95 households, with a total of population of 450 persons. Three main ethnic groups currently live in Laksip Village: 89% for Khmu, 9.5% for Laolum, and 1.5% for Hmong. The majority of family heads graduated only from primary school. Few graduated from the secondary school. Shifting cultivation remains the livelihood for majority of villagers. This area has a tropical monsoon climate with April to October being hot-wet and November to March cool-dry seasons. Settlement of Laksip Village began in 1962 by Pho Thao Phuy from Oudomxay, and two more families following him. The population increased slowly between 1962 and 1975 with the arrival of new families fleeing the war in the northern provinces of Laos, temporally resettled in the village and then moved out from the village. In 1997, after Huaynokpit Village merged with Laksip Village based on the agreement of the district committee dated 27 April 1999.

Currently, Laksip Village covers an area of 1,746 ha largely allocated for agriculture and forests. Agricultural lands comprise cropped fields and 1-4 years' fallows under short rotational shifting cultivation in narrow valleys and catchments. Agriculture covers 240 ha or 14 % of the total village area. Forests consist of dense forest (conservation, sacred, cemetery forests), open forest (degraded forests with Dipterocarpus sp.), teak plantations and > 5 year old shifting cultivation fallows. Forests cover 1,496 ha or 85.6 % of the total village area. Forest land can be subdivided in 3 sub groups: conservation forest, protection forest, and production forest. Most of conservation forest is located at high mountains in the north and southwest part of the village. Teak plantations have expanded from less than 20 ha in 1995 to 477 ha in 2011. Most teak plantations are developed through intercropping of teak seedlings with annual crops in the shifting cultivation. The common practice is to intercrop teak seedlings with rice in the first year, maize in the second year and job's tear in the third year. The plot is left to teak plantation alone after the fourth year. Due to allocation of the old fallows for forest conservation and conversion of short fallows for teak plantation, land available for cropping has been significantly reduced. Consequently, fallow period has to be shortened from more than 8 years in 1970' to about 2 years at present.

In spite of transition to a commercial production of teak, local farmers continue to conserve crop diversity. However, NTFPs have been reduced as a result of conversion of fallow land to teak plantation. Nevertheless, the Laksip Village is still home to more than 900 plant species wild plant species.

The main crops include upland rice for subsistence as well as maize, while cash income comes from vegetable production, collecting forest products (e.g. job's tear, fuel wood, mushrooms, and bamboo shoots), livestock farming, and perennial tree production. Some villagers are now working in off-farm activities such as government officers, traders and handicraftsmen in Luang Prabang City nearby.

3.2.2 Land use and land cover mapping

In Laksip Village, the natural forest covers about 1,019 ha or 58% of total land area, including dense forest comprising of conservation and sacred forest, open forest and forest re-growth in old shifting cultivation fields. The remaining 719 ha or 41% of total land is agricultural land including teak plantation, rotational fallow lands and annual crop fields (Table 21 and Figure 15)

Table 21 Land use in Lak Sip village in 2011

Type of Land Use	Area	
	ha	%
Natural Forests	1019	58.33
• Dense forest (Conservation forest)	476	27.25
• Open forest (Protection forest)	12	0.69
• Old fallow (Abandoned shifting cultivation)	531	30.40
Agricultural Land	719	41.11
Plantation forest (Teak)	477	27.30
Rotated fallow land for shifting cultivation	195	11.15
• Annual field crops	46	2.60
• Fish pond	1	0.06
Residential area	9	0.56
Total Area	1747	100.00

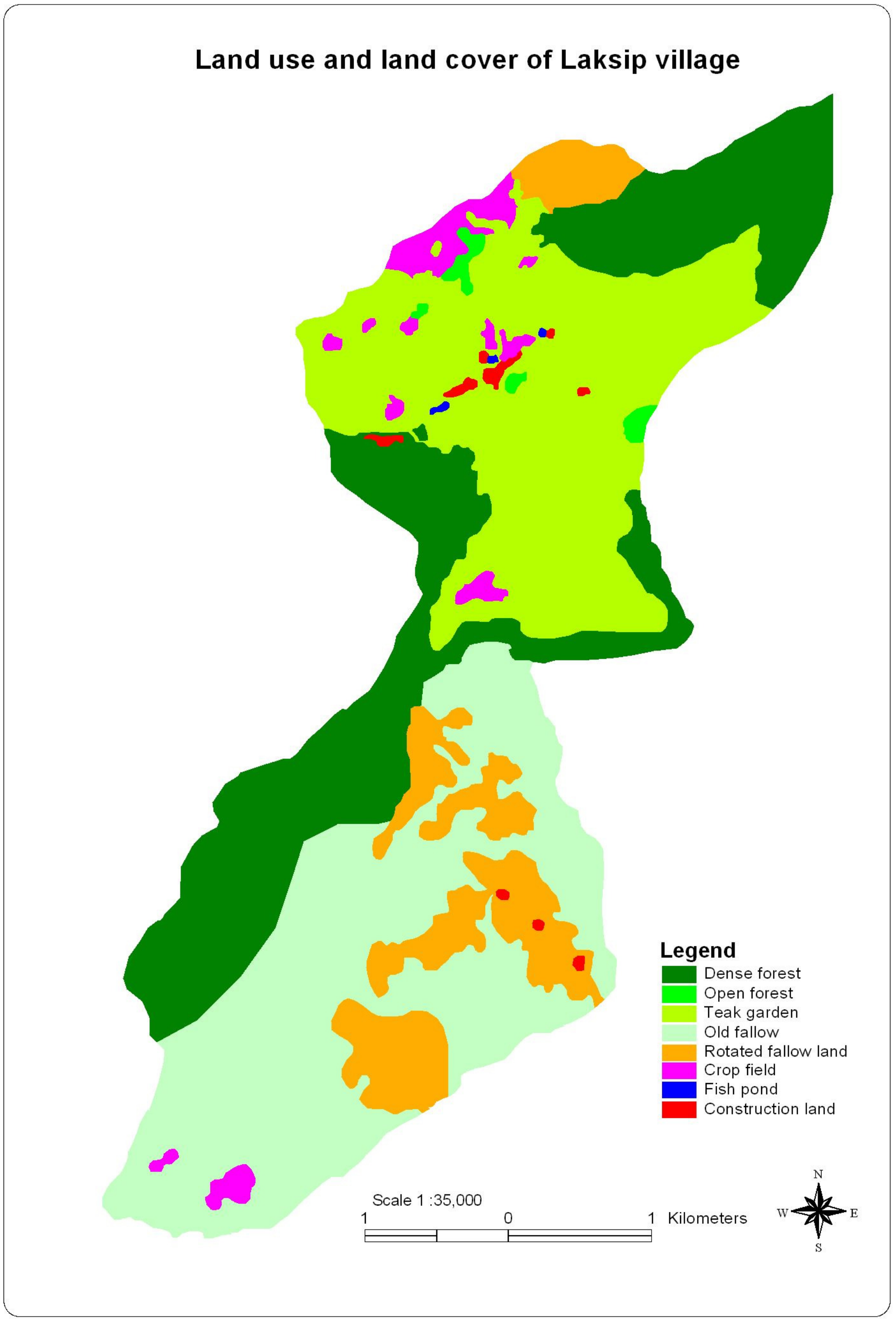


Figure 15 Land use map of Laksip Village in 2011

3.2.3 Plant biodiversity under the different land uses

Plant species in dense forest

Wood species

There are 29 major woody species. Three species are highly valuable timber: *Dalbergia Lanceoraria, Afzelia Xylocarpa* and *Pterocarpus macrocarpus*. The common woody species are *Bischoffia Javanica. Duabanga soneratioides, Chakrasia. Tabularis, Diospyros eugenii, Mangifera sp., Amorphophallus paenonufolius, livistona speciosa, afzelia Xylocarpa, Dalbergia lanceoraria, Albizia procera, Dipterocarpus intricatius, tretameles. Nudiflora, Ficus drupacea, Protium Serrotium. Symplocus racemosa, Erutrina fusca, Astonia rostrata, ficus spp, Ardisia evanymifolia, Dipterocarpus intricatus, Ailanthus trifisa, Paramichelia baillonni,Spondrias. Lakonensis, Elacocarpus robustus, Cassia garrettiana, pometia eximia, Eugenia fluviatilis, Banlox albidium* and *Largerstroemia villosa.*

Non timber forest products (NTFP) species

Edible plants

There are 17 species of plants whose fruits, stems and young leaves are used as food and spices by local farmers: *Spathodea stipulate, Amorphophallus campanulatus, Celatrus multiflorus, Paper boehmeriafolium, Castanopsis macrostachya, Baccaurea ramiflora, Flacourtia sepiaria, Livistona cochinchinensis, Mangifera pinnata, Bignonia indica, Averrhoa pentandra, Amalocalyx burmanicus, Arenga westerhoutii (Palmae), Acacia pennata, Melientha acuminata, Rhus semialata, Ficus semicordata.*

Herbs or medicinal plants

Five species are used in local health care: *Dracaena chochinchinensis, Zingiberaceae, Tinospora tuberculata, Amomum microcapum, Smilax hookeri.*

Fibers

Bambusa tulda, Oxytenanthera parviflora, Dendrocalamus spp, Calamus poilanei, Calamus henyanus, Daemononus jenkinsiana are the fibre species occurring in Laksip village.

Plant species in open forest

The common species in open forests are: *Shorea siamensis, Mangifera spp, Dimocarpus longan, Protium serratum, Macaranga denticulate. Alstonia rostrata, Cratoxylum formosum, Leguminosae - Caesalpinioideae, Pistachia aleosa, Dalbergia lanceolaria, and some natural grasses like Imperata cyllindrica, Vetiveria species* and *Celastrus paniculatus.*

Plant species under teak plantation

There are very few plant species under teak plantation. *Mimosa invisa, chromolena odorata and Lygopodium* are the weeds common in teak plantations

Plant species in fallow land

Fallow land is very rich in plant diversity, especially; it is very rich in weed species.

Wood and shrub species

There are more than 73 species of woody species in fallow land including *Acacia concinna, Omosia cambodiana, Lepisanthes rubiginosa, Protium serratum, Antidesma acidum, Broussonetia papyrifera,* *Cassia fistula, Ardisia spp, Ficus hispida, Zizyphus cambodiana, Bauhinia monandra, Harrisonia perforate, Millettia pubinervis, Boehmera nivea, Apurosa octandra, Albizia odoratissima, Flacourtia jangomus, Wikstroemia meyeniana, Celastrus paniculatus, Quigualis indica, Polyathia corticosa, Gardenia philastrei, Stixis flavescens, Phyllostachys sp, Milientha suavis, Albizia procera, Spodias pinnata, Zizyphus oenoplia, Ixora stricta, Fluggea microcarpa, Bambusa arundinacea, Xerospermum laoticum, Oroxylum indicum, Caesalpinia decapetala. Terminalia belerica, Duabenga grandiflora, Euonymus similis, Crateva maqua, Markhamia stipulate, Femandoa adenophylla Lagerstreomia venusta, Bambusa tulda, Zygostelma bentham, Bauhinia malabanica, trevisia lateopera, Holarrhena pubescens, Caesalpinia enneaphylla, Baccaurea ramiflora, Quescus kingiane, Largerstreomia macrocarpus, Parane phelium, Grewia abutifolia, Apostia wallachii, Stereospermum neuranthum, Zanthoxylum avicennae, Eriolaena candollei, Siegesbeckia orientalis, Helicteres elongate, Embelia sessiliflora, Celosia argentea, Argyreia pierreana, Catunaregam spinosa.*

Weeds, herbs and lianas

It was found that there are more than 72 species of weeds and 28 species of lianas in the fallow land, out of which 13 species are classified as edible plants for local farmers such as *Lygopodium flexuosum, Passiflora foetida, Amalocalyx microlobus, Limacia triandra, Amaranthus xaudasus, Amorphophallus paeonifolius, Spilanthes paniculata, Oxalis corniculata, Momordica charantia, Breynia glauca, Dioscorea glabra, Cyclea barbata, Calamus viminalis,* and 5 species are used as medicine plants such as *Vernonia cinerea, Ficus hispida, Paederia pilifera, Senna tora, Blumea balsamifera.*

Major herbs, lianas and weeds found in fallow land are: *Chomolaena odorata. Mimosa invisa, Imperata cylindrical, Lygopodium flexuosum, Saccharum spontaneum, Microstegium ciliatum, Passiflora foetida, Ageratum conyzoides, Crassocephalum crepidioides, Amalocalyx microlobus. Conyza sumatrensis Cyperus cyperoides, Vernonia cinerea, Piper sylvaticum, Mollugo pentaphylla, Diphyllarium mekongense, Tiliacora triandra, Cissus adnata, Commelina benghalensis, Solanum torvum, Bidens pilosa, Mucuna pruriens, Thunbergia grandiflora, Smilax ovalifolia, Amaranthus viridis, Euphorbia hirta, Amischotolype glabrata, Amorphophallus paeoniifolius, Costus speciosus, Pennisetum purpureum, Lepistemon binectariferum, Cyanotis cristata, Spilanthes paniculata, Scleria terrestris, Pueraria phaseoloides, Paederia pilifera, Momordica charantia, Ichnocarpus frutescens, Momordica subangulata, Calamus viminalis, Clausena excavate, Dioscorea glabra, Pueraria lobata, Phyllanthus amarus, Eleusine indica, Cyclea barbata, Angiopteris evecta, Thelypteris subelata, Selaginella helferi, Microlepia speluncae, Adiantum zollinger, Tectaria impressa, Pteris vittala, Stereospermum colais, Tectaria sp, Lygodium polystachyum, Thelypteris ciliate, Cyperus iria, Cyperus laxus, Echinochloa crusgalli, Panicum cambogiense, Setaria palmifolia, Panicum notatum, Oplismenus compositus, Panicum sarmentosum, Echinochloa colona, Paspalum urvillei, Dioscorea japonica, Digitaria thyrsoidea, Blumea mollis, Digitaria radicosa, Axonopus compressus, Mallotus barbatus, Achyranthes aspera, Panicum brevifolium, Jasminum nervosum, Knoxia mollis, Dioscorea bulbifera, Dioscorea alata, Aristolochia tagala, Mukia maderaspatana, Stephania crebra, Dalbergia foliacea, Trevesia palmate, Lysimachia fortunei, Colona floribunda, Blumea balsamifera, Distemon indica, Abelmoschus moschatus, Torenia cordifolia*

3.2.4 Biomass and carbon storage estimations in different land uses

For carbon stock measurement, land use-land cover in Laksip Village was classified as:

1. Natural forests included dense forest (dry evergreen forest), open forest (dry dipterocarpus) and old fallow (abandoned shifting cultivation)
2. Plantation forest included young teak (1-4 years), medium teak (5-10 years) and old teak (more than 10 years**)**
3. Fallow land (rotated shifting cultivation land) included 1 year's fallow, 2 year's fallow, 3 year's fallow, and 4-5 years fallow
4. Field crops include maize, jobs tears and upland rice

Table 22 Allometric equations used for biomass estimation

Allometry	Forest Type	Sources
Stem (W_S) = $0.0396*(D^2H)^{0.9326}$	dry dipterocarp	Ogawa et al. (1965)
Branch (W_B) = $0.003487*(D^2H)^{1.027}$	mixed deciduous	
Leaf (W_L) = $((28.0/Ws+W_B)+0.025)^{-1}$		
Stem (W_S) = $0.0509*(D^2 H)^{0.919}$	dry evergreen	Tsutsumi et al. (1983)
Branch (W_B) = $0.00893*(D^2 H)^{0.977}$	hill evergreen	
Leaf (W_L) = $0.0140*(D^2 H)^{0.669}$	tropical rain forest	
Root (W_R) = $0.0313*(D^2 H)^{0.805}$		
Log WS = 0.9797 log (D^2H) – 1.6902 ; r^2 = 0.9930	teak plantation	Petmark and Sahunalu (1980)
Log WB = 1.0605 log (D^2H) – 2.6326 ; r^2 = 0.9567		
Log WL = 0.7088 log (D^2H) – 1.7383 ; r^2 = 0.8523		
where, D = Diameter at breast height (cm)		
H = Height of tree (m)		
WS = Stem biomass (kg)		
WB = Branch biomass (kg)		
WL = Leaf biomass (kg)		

Allometry	Forest Type	Sources
	Rainfall (mm/yr)	
W = 0.139 D2.32	Dry (<1500)	(Brown, 1997)
W = 0.118 D2.53	Moist (1500-4000)	(Brown, 1997)
W = 0.049 D2H		(Brown et al., 1995)
W= 0.037 D1.89H	Wet (>4000)	(Brown, 1997)
W = Tree Biomass(kg/tree)		
D=dbh(cm)		
W= 0.0303 D2.1345;R2=0.9887	Banana	(Arifin, 2001)
W = 0.2811 D2.0635;R2=0.9455	Coffee	(Arifin, 2001)
W = 0.1594 D1.1517	Tea (Camelia sinensis)	(Hariyadi, 2005)
Wt = 0.22187 (D)2.2749	Bamboo(*Thyrsostachys siamensis*)	Suwannapinunt (1983)
Wt = 0.17446 (D2)1.0437	Bamboo(*Cephalostachyum pergracile*)	Kutintara et al. (1995)
Stem (W_S) = $89.3059(D^2 H)^{0.66513}$	tree higher than 1.3 m.	Manop (1982)
Branch (W_B) = $15.3063(D^2 H)^{0.58255}$	and the diameter at breath <4.5cm.	
Leaf (W_L) = $19.399(D^2 H)^{0.44363}$		
Root (W_R) = $0.0313*(D^2 H)^{0.805}$		

Dry biomass under natural and plantation forests

The highest biomass was found in dense forest, with 339 ton per hectare of aboveground and 41 tons per hectare of belowground biomass.

The open forest contained a total biomass of 121 tons per hectare, of which 98 tons per hectare was from above ground (stems, branches, leaves, ground cover and litter) and 23 tons per hectare from below ground (roots). Total biomass found in old fallow forest is 41 tons per hectare, of which 34 tons was from above ground and 7 ton per hectare was from below ground, presents in table 23.

Among teak plantation forest, the old teak (>10 years) contained the highest total dry biomass of 102 tons per hectare, of which 93 ton per hectare was from above ground and 9 tons per hectare was from below ground followed by the medium teak (6-10 year old) which had a total biomass of 53 tons per hectare, of which 47 tons was from above ground and 5 tons from below ground. The young teak (1-5 year old) contained the lowest biomass of 12 tons per hectare only, of which 10.40 tons (stems, branches, leaves) was from above ground and 1.95 tons was from below ground (roots).

Table23 Dry biomass, ton per hectare under different forest types

Forest types	Above ground (ton/ha)	Below ground (ton/ha)	Total biomass (ton/ha)
Natural forest	**157.00**	**40.89**	**194.55**
Dense forest	339.00	81.00	420.00
Open forest	98.00	23.50	121.50
Old fallow	34.00	8.16	42.16
Plantation forest	**151.68**	**36.40**	**188.08**
Young teak	10.40	2.50	12.90
Medium teak	47.52	11.40	58.92
Old teak	93.76	22.50	116.26

Carbon content under different forest types

The highest total carbon content was found in dense forest. The amount of carbon stock is followed by open forest and old fallow (abandoned shifting cultivation) as per details given in Table 24.

Table 24 Carbon stock ton per hectare under natural forest

Land use types	Biomass (ton/ha)		Carbon contents (ton/ha)			Total carbon content (ton/ha)
	Above ground	Below ground	Above ground	Below ground	Soil carbon	
Natural forests	**157**	**37.55**	**78.50**	**18.78**	**78.15**	**175.43**
Dense forest	339	81	169.5	40.5	98.25	308.25
Open forest	98	23.50	49	11.75	66.95	127.70
Old fallow	34	8.16	17	4.08	69.25	90.33

Carbon stock under plantation forest (teak)

Total carbon stock under teak plantation was 273.19 tons per hectare. Among forest plantation , the old teak (>10 years) produced the highest total carbon content of 108 tons per hectare of which 46.8 tons were from above ground (stems, branches, leaves, ground cover and litter)and 11.25 tons were from below ground (roots) and 50.75 tons were from soils. The medium teak (6-10 years old) produced carbon content, total carbon was 89.76 tons per hectare of which 23.76 tons was from above ground and 5.7 tons from below ground (roots) and 60.3 tons were from soil. The young teak (1-5 years old) produced total carbon content of 74.55 tons per hectare of which 5.20 tons was from above ground (stems, branches, leaves, ground cover and litter) and 68.1 tons was from below ground (roots) and 29.37 tons were from soil. (Table 25)

Table 25 Carbon stock ton per hectare under plantation forest (teak)

Land use types	Biomass (ton/ha)		Carbon contents (ton/ha)			Total carbon content (ton/ha)
	Above ground	Below ground	Above ground	Below ground	Soil carbon	
Plantation forest	**50.56**	**12.13**	**25.28**	**6.07**	**59.72**	**91.05**
Young teak	10.40	2.50	5.20	1.25	68.10	74.55
Medium teak	47.52	11.40	23.76	5.70	60.30	89.76
Old teak	93.76	22.50	46.88	11.25	50.75	108.8

Dry biomass under fallow land

The highest dry biomass obtained in 4-5 year's fallow, with an amount of biomass of 73.34 tons per hectare, followed by 3 year's and 2 year's fallow which produced the amount of dry biomass of 47.93 and 18.42 tons per hectare respectively. The lowest biomass was found in the 1 year's fallow (7.29 tons per hectare), presents in table 26.

Table26 Dry biomass, ton per hectare under different fallow types

Fallow types	Above ground biomass (ton/ha)	Below ground biomass (ton/ha)	Total biomass (ton/ha)
1 year's fallow	5.88	1.41	7.29
2 year's fallow	14.86	3.56	18.42

3 year's fallow	38.66	9.27	47.93
4-5 year's fallow	59.15	14.19	73.34

Carbon content under fallow land

Among four different fallow types, the 4-5 year's old fallow produced the highest total carbon content of 107.32 tons per hectare of which 36.67 tons per hectare were from above and below ground biomass and 70.65 ton per hectare were from soils, followed by 3 year's old fallow which produced total carbon of 90.41 tons per hectare, of which 23.96 tons of carbons were from above and below ground biomass and 66.45 tons were from soil. The 1 year's fallow produced the lowest total carbon content which produced total carbon content of 69.95 tons per hectare of which 3.64 tons were from above and below ground biomass and 66.30 tons of carbon were from soil. While the 2 year's fallow produced also low carbon content, total carbon is 72.41 tons per hectare of which 9.21 tons was from above and below ground biomass and 63.20 tons were from soil (table 27).

Table 27 Carbon stock, ton per hectare under different fallow types

Land use types	Biomass (ton/ha)	Carbon contents (ton/ha)		Total carbon content (ton/ha)
		Carbon from Biomass	Carbon from soil	
Fallow land	**49.99**	**24.50**	**88.87**	**133.37**
1 year's fallow	7.29	3.64	66.30	69.95
2 year's fallow	18.42	9.21	63.20	72.41
3 year's fallow	47.93	23.96	66.45	90.41
4 year's fallow	73.34	36.67	70.65	107.32

Dry biomass under different field crops

The highest total dry biomass was found in jobs tears field, with an amount of total biomass of 9.68 ton per hectare, followed by maize field which produced the amount of dry biomass of 7.92 tons per hectare. The lowest biomass was found in rice field (5.22 ton per hectare), presents in table 28.

Table 28 Dry biomass, ton per hectare under different field crop types

Crops	Above biomass	Below biomass	Total biomass

Maize	6.39	1.53	7.92
Job's tears	7.81	1.87	9.68
Rice	4.21	1.01	5.22

Carbon content under different field crops

Among three different field crop types, the jobs tears field produced the highest total carbon content of 70.64 tons per hectare of which 4.84 ton per hectare was from above and below ground biomass and 65.80 tons per hectare from soil. While rice and maize produced as the nearly same amount of total carbon content. The amounts were 64.43 tons and 65.76 tons for rice and maize respectively in table 29.

Table 29 Carbon stock, ton per hectare under different field crop types

Land use types	Biomass (ton/ha)	Carbon contents(ton/ha)		Total carbon content (ton/ha)
		Carbon from biomass	Carbon from soil	
Field crops	**7.61**	**3.81**	**63.14**	**66.94**
Maize	7.92	3.96	61.80	65.76
Jobs steers	9.68	4.84	65.80	70.64
Rice	5.22	2.61	61.82	64.43

Table 30 Summary of carbon storage (Ton per hectare) under different land use types

Land use types	Biomass (ton/ha)		Carbon storage (ton/ha)			Total carbon storage (ton/ha)
	Above ground	Below ground	Above ground	Below ground	Soil carbon	
Natural forests	**157**	**37.55**	**78.50**	**18.78**	**78.15**	**175.43**
Dense forest	339	81	169.5	40.5	98.25	308.25
Open forest	98	23.50	49	11.75	66.95	127.70
Old fallow forest	34	8.16	17	4.08	69.25	90.33

Plantation forest	**50.56**	**12.13**	**25.16**	**6.07**	**59.72**	**91.06**
Young teak	10.40	2.50	5.20	1.25	68.10	74.55
Medium teak	47.52	11.40	23.76	5.70	60.30	89.76
Old teak	93.76	22.50	46.88	11.25	50.75	108.8
Fallow land	**118.55**	**28.43**	**59.27**	**14.22**	**266.60**	**340.10**
1 year's fallow	5.88	1.41	2.94	0.72	66.30	69.95
2 year's fallow	14.86	3.56	7.43	1.78	63.20	72.41
3 year's fallow	38.66	9.27	19.33	4.63	66.45	90.41
4 year's fallow	59.15	14.19	29.57	7.09	70.65	107.32
Field crops	**18.41**	**4.41**	**9.20**	**2.20**	**189.42**	**200.83**
Maize	6.39	1.53	3.19	0.76	61.80	65.76
Job's tears	7.81	1.87	3.90	0.95	65.80	70.64
Rice	4.21	1.01	2.10	0.50	61.82	64.43

Total Carbon storage at village level

Total carbon storage in Laksip Village was 255,650 tons out of which natural forest where the area was 1,019 ha or occupies 58.68% of total village land use areas produced highest carbon storage of 196,224 tons, followed by plantation forest (teak) where the areas was 477 ha or occupies 27.46 % of total village land use areas produced 41,004 tons. The fallow land where the areas was 195 ha or occupies 11.22% of total village land use areas produced 15,377 tons and field crops where the areas was 46 ha or occupies 2.64% of total village land use areas produced 3,036 tons in table 31.

Table 31 Total carbon storage in Laksip village: for better presentation: columns should be 1. Area of a given land use (ha), 2- Carbon density (t/ha) – aboveground, belowground biomass and soil organic carbon 3. Total carbon density = aboveground +belowground biomass+ soil organic carbon 4. Total carbon in a given land use = value in column 1 x value in carbon3

Land use types	Area		Carbon storage (ton)			Total carbon at. village level (ton)
	ha	%	Above ground	Below ground	Soil carbon	
Natural forests	**1,019**	**58.68**	**90,297**	**21,585**	**84,342**	**196,224.00**

Dense forest	476.00		80,682	19,278	46,767	14,6727
Open forest	12.00		588	141	803	1,532
Old fallow forest	531.00		9027	2,166	36,771	47,965
Plantation forest	**477.00**	**27.46**	**9,112**	**2,187**	**29,712**	**41,011**
Young teak	238.00		1,237	297	16,207	17,743
Medium teak	144.00		3,421	820	8,683	12,925
Old teak	95.00		4,453	1068	4,821	10,343
Fallow land	**195.00**	**11.22**	**2,095.33**	**502.97**	**12,779.55**	**15,377.85**
1 year's fallow	58.00		170.52	41.76	3,845.4	4,057.68
2 year's fallow	78.00		579.54	138.84	4,929.6	5,647.98
3 year's fallow	39.00		753.87	180.57	2,591.55	3,525.99
4 year's fallow	20.00		591.4	141.8	1413	2146.2
Field crops	**46.00**	**2.64**	**123.32**	**29.58**	**2,883.36**	**30,36.26**
Maize	8.00		25.52	6.08	494.40	526.00
Job's tears	10.00		39.00	9.50	658.00	706.00
Rice	28.00		58.80	14.00	1,730.96	1,803.00
Total	**1737.00**	**100**				**255,650.90**

3.2.5 Land use and carbon dynamics: reference level, carbon stock changes and future scenarios

The highest total carbon content were found in dense forest , with an amount of carbon stock of 308 tons per hectare, followed by open forest and abandoned shifting cultivation (old fallow). The open forest produced total carbon content of 127 tons per hectare. Total carbon content obtained from old fallow forest was 90 tons per hectare.

Among teak plantation, the old teak (>10 years) produced the highest total carbon content of 108 tons per hectare. The medium teak (6-10 year old) produced nearly 89 tons per hectare for carbon content. The young teak (1-5 year old) produced total carbon content of 74 tons per hectare.

Among four different fallow types, the 4-5 year's old fallow produced the highest total carbon content of 107 tons per hectare, followed by 3 year's old fallow which produced total carbon of 90 tons per hectare. The 1 year's fallow produced the lowest total carbon content which produced total carbon content of 30 tons per hectare. While the 2 year's fallow produced also low carbon content, total carbon was 69 ton per hectare.

Among three different field crop types, the jobs tears field produced the highest total carbon content of 70 tons per hectare. While rice and maize produced as the nearly same amount of total carbon content. The amounts were 64 tons and 65 tons for rice and maize respectively (table32)

Table 32 C-stock (ton/ha) of different land use types

Land uses	C-stock (T/ha)
Dense forest	308.25
Open forest	127.70
Old fallow	90.33
Old teak	108.80
Medium teak	89.75
Young teak	74.55
Fallow 4 years	107.32
Fallow 3 years	90.41
Fallow 2 years	72.41
Fallow 1 year	69.95
Maize field	65.76
Jobs tear field	70.64
Rice field	64.43

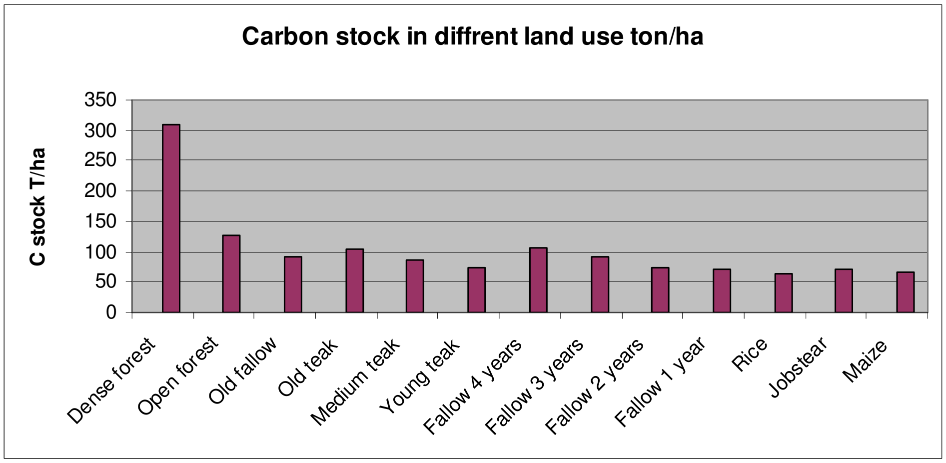


Figure 16 Carbon stock in different land use in Laksip Village

Past land use changes and carbon dynamics in Laksip village

Before the year 2000, large areas of forest land was used for shifting cultivation of rice based farming. There were around 1,250 ha of fallow land or 70% of total land areas of the village. So, young fallow lands with 1 and 2 year's old were the predominant land use of this area, young fallow land covered around 50% and rice field around 15% of total village land.

In 2000, about 530 ha of fallow land or 30 % of total land area were classified as head water area which was prohibited to use for shifting cultivation. This area was incrementally recovered, and fully recovered by old forest fallow in later 2011 (figure 17). The remaining area of 720 ha of fallow land or 40% of total land, of which 475 ha or 25% were converted to teak plantation and 240 ha of fallow land or 13% of total land were used for slash and burn agriculture including young fallow and field crops. In correlation with land use changes, also increasing of carbon stock from 136 tons per hectare in 2000 to 146 tons per hectares in 2011 (figure 18)

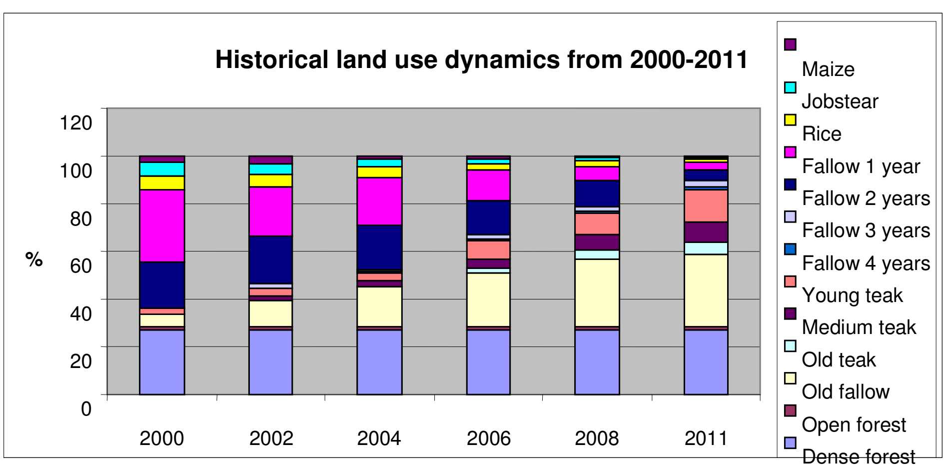


Figure 17 land use changes from 2000 to 2011

Table 33 Land use changes in Lak Sip Village from 2000 to 2011

Land use types	2000	2002	2004	2006	2008	2011
Dense forest	27.40	27.40	27.40	27.40	27.40	27.40
Open forest	0.69	0.69	0.69	0.69	0.69	0.69
Old fallow	5.76	11.51	17.27	23.03	28.79	30.57
Old teak	0	0	0	2.01	4.03	5.47
Medium teak	0	1.44	2.30	3.91	5.87	8.29
Young teak	2.30	3.45	3.17	7.48	9.10	13.70
Fallow 4 years	0	0	0.58	0.86	1.15	1.15
Fallow 3 years	0	1.73	1.15	1.44	1.73	2.25
Fallow 2 years	19.46	20.15	18.54	14.39	10.71	4.49
Fallow 1 year	29.94	21.01	20.15	13.24	6.28	3.34
Rice	6.28	4.95	3.97	2.59	2.19	1.61
Job's tear	5.64	4.49	3.17	1.84	1.61	0.58
Maize	2.53	3.17	1.61	1.09	0.46	0.46

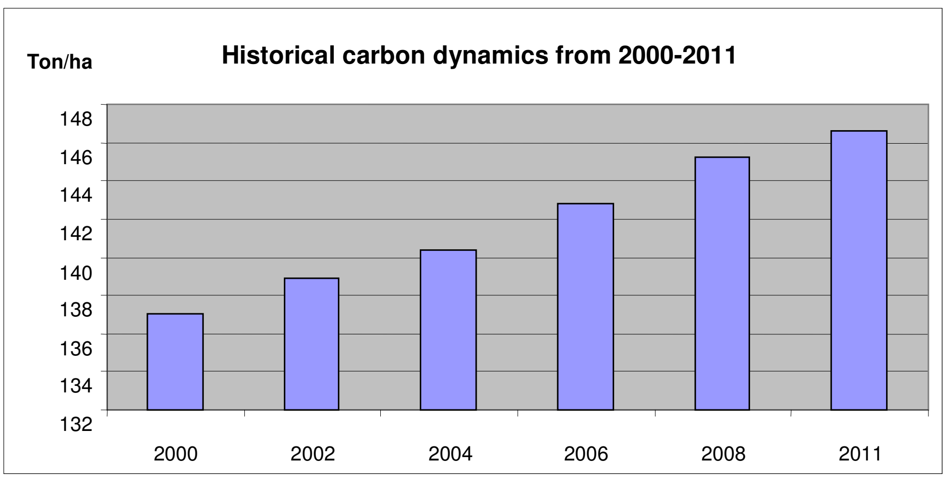


Figure 18 Historical carbon stock dynamic from 2000 to 2011

Table 34 Trend of carbon stock in Lak Sip Village from 2000 to 2011

Years	2000	2002	2004	2006	2008	2011
C stock T	137.00	138.88	140.35	142.82	145.20	146.64

Future scenarios of land use change in case of deforestation and forest degradation without REDD from 2011 – 2012 in Laksip Village

Two scenarios have been worked out : (i) Scenario 1 without REDD– with increase in population pressure and lack of REDD, shortening of shifting cultivation continues and hence old fallows get converted to young fallows and (ii) Scenario 2 with REDD for forest conservation, the young fallows are converted to forest fallows.

If old fallow, which occupied nearly half of forest land in 2011, is converted without REDD to young fallow (1 years fallow), in year's 2020, as shows in figure 19. In consequences, carbon stock in the area would decrease from 146 C-ton per hectare to 135 ton per hectare figure 20 – in fallow fields or the entire village.

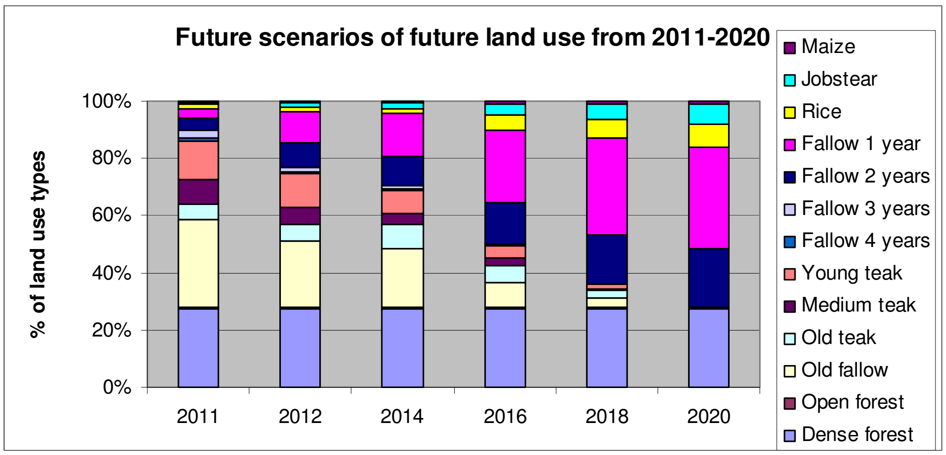
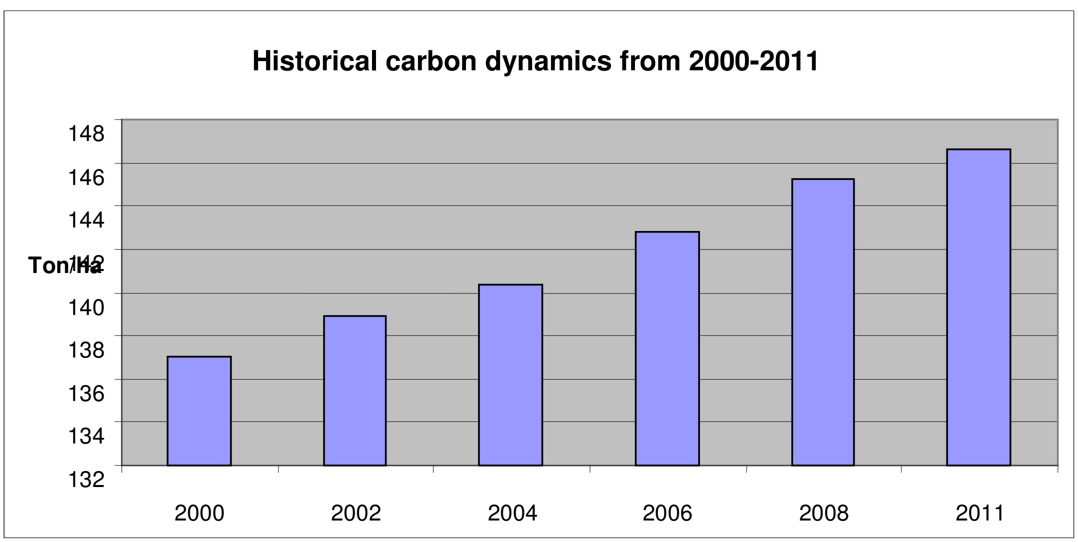


Figure 19 Future scenarios of future deforestation and forest degradation in Laksip Village.



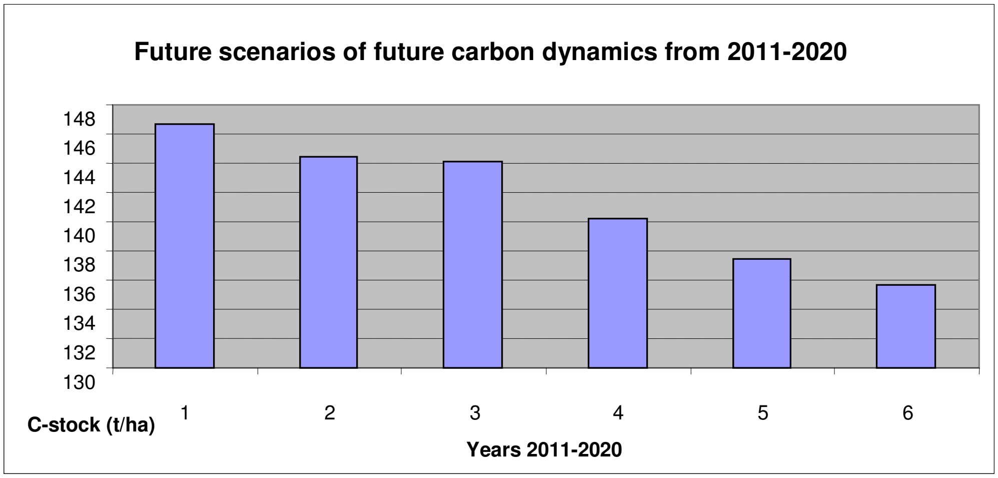


Figure 20 Future scenarios of carbon dynamics under future deforestation and forest degradation in Laksip from 2011-2020

Future scenarios of future land use and carbon dynamics in case of reforestation with REDD

If young fallows (fallow 1-2 years), and annual crop field in 2011, are converted to old forest fallow in 2020 (figure 21). In consequences, the conversion will increase carbon stock from 146 tons /ha in 2011 to 155 tons/ha in 2020 – in the fallow fields or in the entire village (figure 22).

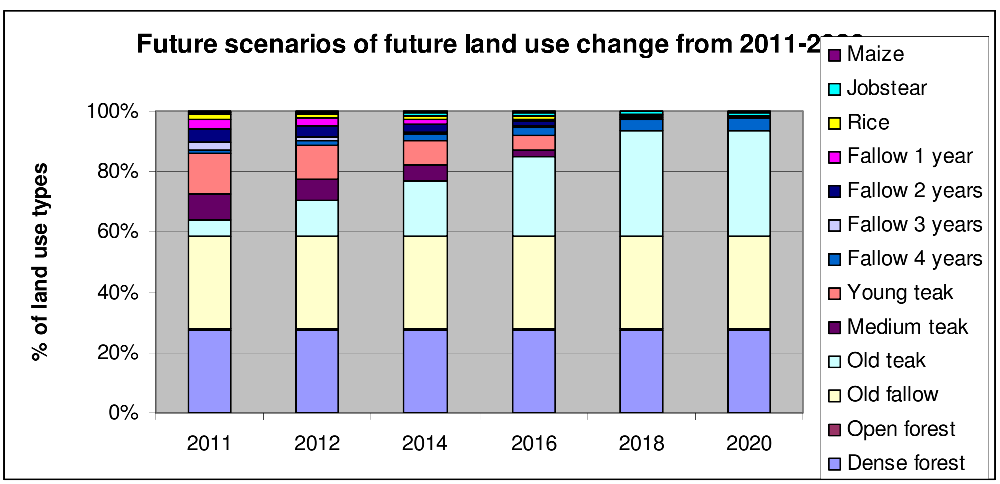


Figure 21 Future scenarios of land use changes in case of reforestation

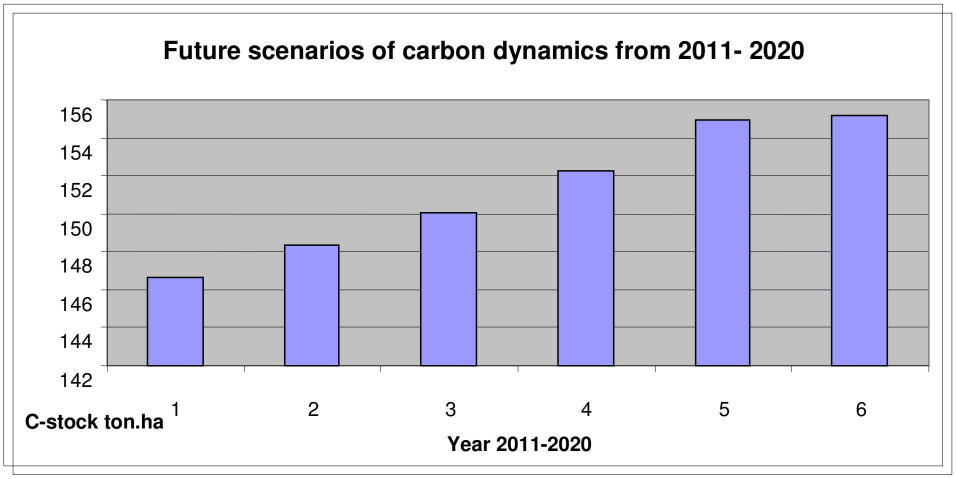


Figure 22 Future scenarios of carbon dynamics in case of reforestation

Carbon dynamic and reference levels

Two future scenarios of carbon dynamics and reference level: The first scenarios without REDD+. So changing land use from old fallow to young fallow. Old fallows, which occupied nearly half of forest land in 2011, are converted to young fallow (1 years fallow), in 2020, as shows in figure 19. In consequences, carbon stock in the area would decrease from 146 tons per hectare in 2011 to 135 ton per hectare in 2020. The second scenarios with REDD+, land use would be changed from young fallow to old fallow (Reforestation). The young fallows (fallow 1-2 years) and annual crop field in 2011, are converted to old forest fallow in 2020. The conversion would increase carbon stock from 146 tons /ha in 2011 to 155 tons/ha in 2020.

(Figure23)

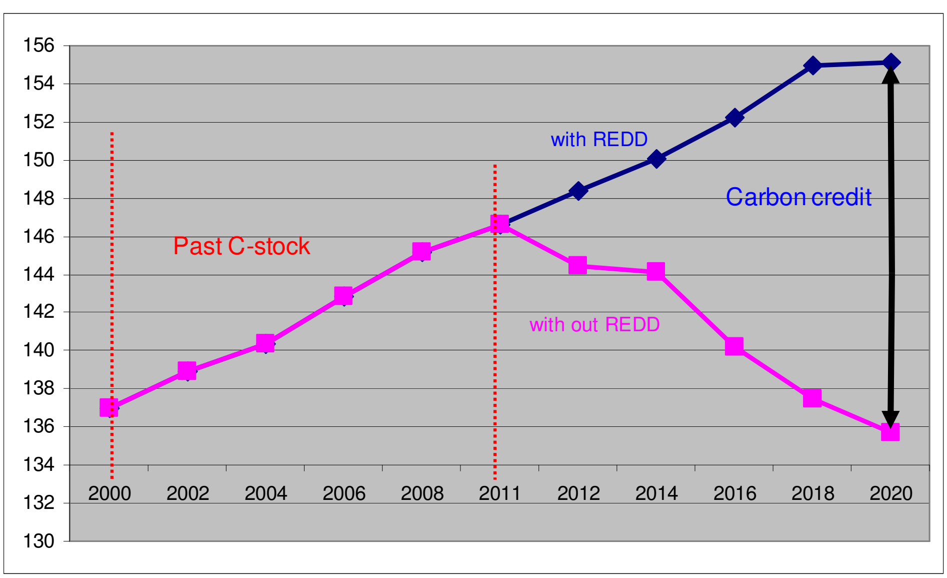


Figure 23 Carbon dynamic and reference levels (C stock Ton/ha).

We can summarize two scenarios of carbon storage change of Laksip Village (in period from 2000 - 2020) in case of deforestation (without REDD+) (figure 20). In consequences, carbon stock in the area would decrease from 146 C-ton per hectare to 135 ton per hectare. Reforestation scenario with REDD+ (figure 22) would increase carbon stock in the area from 135 ton per hectare to 155 ton per hectare. Carbon credit would be 20 ton per hectare (figure 23).

3.2.6 Economic analysis- opportunity cost/benefit analysis

The opportunity cost of converting natural forest (dense forest) to 4 alternative land uses including teak plantation, rice cultivation, maize cultivation and jobs tears cultivation were worked out.

Cost of implementation and maintenance of different land uses

Implementation costs included material costs (i.e. seeds and seedlings) and labour costs for land clearing and weeding.

Table 35 Cost of teak plantation in 2012

No	Items	Unit (person-labour days)??	Cost/Unit	Cost(kips)	Cost(US$)
1	Teak seedling	1,100	500	550,000	68.75
2	Land clearing	30	30,000	900,000	112.5
3	planting	20	30,000	600,000	75
4	weeding	50	30,000	1,500,000	187.5
	Total cost			3,550,000	443.75

Table 36 Cost of rice production in 2012

No	Items	Unit	Cost/Unit	Cost(Kips)	Cost(US$)
1	Rice seed	50	5000	250,000	31.25
2	Land Clearing	58	30,000	1,740,000	217,5
3	Planting	10	30,000	300,000	37.5
4	Weeding	74	30,000	2,220,000	277.5

	Total cost			4,510,000	563.75

Table 37 Cost of Jobs tear production in 2012

No	Items	Unit	Cost/Unit	Cost(Kips)	Cost(US$)
1	Jobs tear seed	30	6,000	180,000	22.5
2	Land Clearing	60	30,000	1,800.000	225
3	Planting	8	30,000	240,000	30
4	Weeding	50	30,000	1,500,000	187.5
	Total cost			3,720,000	465

Table 38 Cost of maize production in 2012

No	Items	Unit	Cost/Unit	Cost(Kips)	Cost(US$)
1	Maize seed	20	5,000	100,000	12.5
2	Land Clearing	60	30,000	1,800,000	225
3	Planting	8	30,000	240,000	30
4	Weeding	45	30,000	1,350,000	168.75
	Total cost			3,490,000	436.25

Profit from different land use types

Benefits from different land uses were products or yield obtained from land unit (ha) and converted to monetary values (US$/ha)

Table 39 Teak product and profit in 2012

Ages	Yield (m^3)	Cost/m^3	Cost/ha in (US$)
1 to 5	75	-	-
5 to 10	88	-	-
10 to 15	103	-	-
15 to 20	128	-	-

More than 20	150	100	15,000

Table 40 Rice product and profit in 2012

Category of land	Yield (ton/ha)	Cost/ton in US$	Cost/ha (US$)
newly open forest	3	250	750
fallow 3 years	2	250	500
Fallow 2 years	1	250	250
fallow 1 year	0.8	250	200

Table 41 Jobs tear product and profit in 2012

Category of land	Yield (ton/ha)	Cost/ton in US$	Cost/ha (US$)
newly open forest	4	375	1500
fallow 3 years	3	375	1125
fallow 2 years	2.5	375	937.5
fallow 1 year	2	375	750

Table 42 Maize product and profit in 2012

Category of land	Yield (ton/ha)	Cost/ton in US$	Cost/ha (US$)
newly open forest	4	225	900
fallow 3 years	3	225	675
fallow 2 years	2	225	450
fallow 1 year	1	225	225

Net present value from different land uses: Among 5 different land uses, it was found that teak plantation gave the highest NPV. The NPV was 599 US$/ha, followed by Jobs tear which produced NPV of 214 US$/ha, and Maize, NPV was 84 US$/ha. The lowest NPV was under rice where the NPV was 16 US$/ha only. However, the NPV of dense forest was 1.42 US$/ha, of which benefits were mostly from non timber forest products.

Table 43 Net present value from different land use from 2000-2020

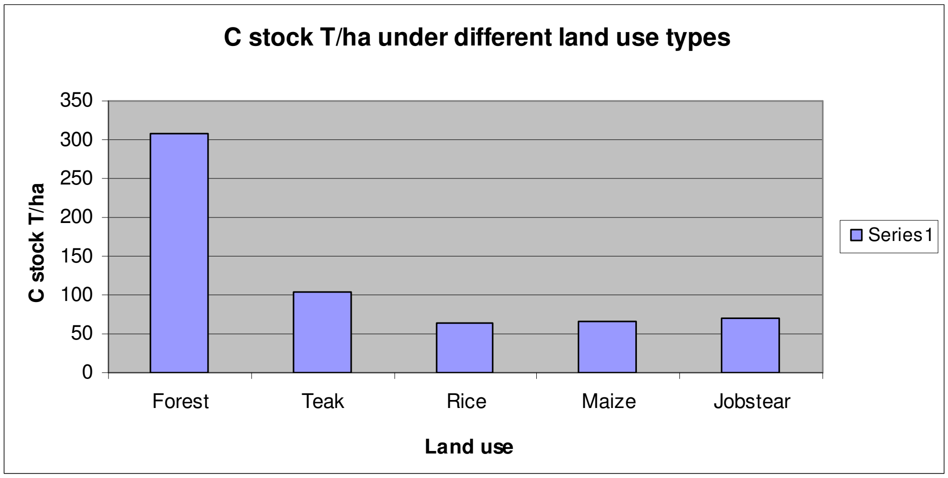
Land use type	Real NPV (US$)	NPV (US$/ha/y)	Carbon stock (t/ha)	CO_2 stock (t/ha)
Forest	29.925.00	1.42	308.30	1131.00
Teak	12577.20	599.00	103.40	279.30
Rice	347.70	16.50	64.43	236.50
Maize	1763.20	84.00	65.76	241.30
Jobs tear	4495.40	214.00	70.64	259.20

Carbon stock under different land use

In terms of carbon stock, dense forest produced the highest C stock of 308 tons/ha, followed by teak plantations where the C-stock was 108 tons/ha , jobs tear produced 70 tons/ha of C-stock and Maize produced 65 tons /ha of C-stock. The lowest of carbon stock was found under rice field (64 tons per hectare).

Table 44 Carbon stock in different land use

Land use	C stock (ton/ha)
Forest	308
Teak	108
Rice	64
Maize	65
Jobs tear	70



Carbon loss from converting forest to agriculture

Conversion of forest to rice and maize cultivation follows the loss of around 240 ton/ha in the whole village or in the forest area converted to agriculture?? In converting forest to jobs tear cultivation, the loss of carbon was 237 tons/ha. The lowest carbon loss was found under teak plantation where the loss was 204 tons/ha.

Table 45 Carbon loss from converting forest land to agricultural land

Land uses	Carbon loss (ton/ha)
Teak	204
Rice	243
Maize	242
Jobs tear	237

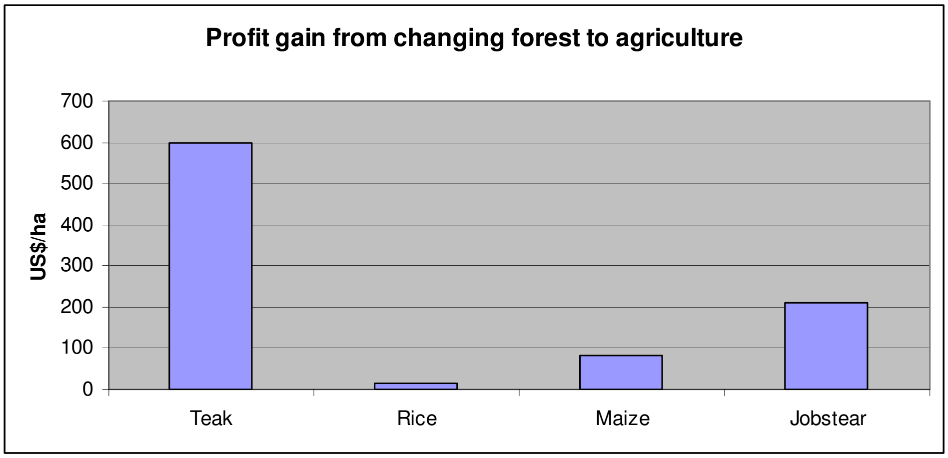
Profit gain from converting forest to agricultural land

The opportunity cost of not changing forest to 4 different land use types, it was found that from changing forest to teak plantation gave the highest profit (NPV/ha). The profit (NPV/ha) was 597.58US$/ha, followed by changing forest to jobs tear which produced profit (NPV/ha) of 212 US$/ha, and Maize, profit (NPV/ha) was 82 US$/ha. The lowest profit (NPV/ha) was under rice where the profit (NPV/ha) was 14.58 US$ only.

Table 46 Profit (NPV/ha) gain from converting forest to agriculture land use types

Land use	Profit (NPV/ha) (US$/ha)
Teak	597.58

Rice	14.58
Maize	82.58
Jobs tear	212.58



Opportunity cost of different land use change

The opportunity cost of four types of land use changes (forest to teak plantation, rice, maize and jobs tear), it was found that the change from forest to teak plantation gave the highest opportunity cost, The opportunity cost was 0.795US$/ton CO2, followed by changing from forest to jobs tear which produced opportunity cost of 0.244 US$/ton CO2, and changing from forest to maize, opportunity cost was 0.093 US$/ton CO2. The lowest opportunity cost was under changing from forest to rice where it was 0.093 US$/tonCO2 only.

Table 47 Opportunity cost of different land use changes

Land use	Opportunity cost (US$/ton CO2)
Teak	0.795
Rice	0.016
Maize	0.093
Jobs tear	0.244

3.2.7 Community based MRV process and demonstration of good land use practices

The main objective of community-based MRV was to increase awareness about emerging economic opportunities from climate change mitigation through carbon sequestration and stipulated mechanism of managing, monitoring and verifying (MRV) carbon storage.

The project teams in Laos presented the existing land use available in the village to the villagers.

The villagers were informed that:

- Natural forest produced highest carbon stock of 526 tons/ha of which Carbon storage is very high in dense forest. The content of carbon is up to 308 tons per ha
- Plantation forest teak produced 264 ton per ha of which old teak produced highest carbon of 108 tons per ha
- Rotated fallow land produced 340 tons per hectare of which 4 years fallow produced highest carbon of 107 tons per ha
- Field crops produced less carbon storage of 200 tons per hectare only.

Demonstration of good land use practices

- Silva-cultural practices to enhance soil C stock and diversify of plant species under teak, including planting space, thinning, no burning leave residues and keep litter under teak plantation were demonstrated by making a comparison of two demonstration plots. One plot of teak with burning of teak leaves and weed residues and another one without burning and clearing of crop residues. The plot without burning and clearing of crop/weed residues showed better tree growth as well as soil carbon stocks and soil fertility levels.
- Agro-techniques for field crop cultivation to increase carbon in soil and sustain crop yield by using mulching of crop residues, cover crops (leguminous) interplant with annual crops and restoration of soil fertility by natural way through keeping fallow for long period (more than 3 years) and by leguminous fallows such as pigeon pea. A demonstration of short fallow of 2 years and long fallow of 4 years fallow were compared during the site visit, Laksip villagers observed that under long fallow of 4 years, there are more plant diversity especially wood and shrub species, soil is soft and has dark colour that is indicator of high organic matter content while the plot of short fallow of 2 years there are less shrubs and wood species but more weed species, the soil is hard and has red colour that means low content of soil organic matter. And two plots of field crops (rice) also demonstrated to villagers the first one is upland rice field with 4 years fallow and the second one is upland rice field with 2 years fallow. It showed that the first one the rice stalk is more thick and high while the second one the rice stalk is very thin and short and the yield from the first one is much higher than the second one.

3.3 INDIA

3.3.1 General background of associated project site in India

Himalaya, a vast mountain system extending across eight Asian countries (viz., Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal and Pakistan), is a biodiversity hotspot (Myers et al., 2000). Deforestation and forest degradation are widespread, with immense variation in their rates and driving factors (Rao and Pant, 2001; Wangda and Ohsawa, 2006; Panta et al., 2008). Scarcity of fodder, manure (the mixture of forest leaf litter and livestock excreta), fuelwood and a range of other non-timber forest products crucial for local livelihoods coupled with increasing aspiration for off-farm economy resulted in outmigration and abandonment of agricultural land use after 1980 (Maikhuri et al., 1995). Degraded forests and abandoned agricultural lands cover 37% area of the total geographical area of Indian Himalaya (59 million ha) (Maikhuri et al., 1997).

Farmers of Himalaya have been using and managing several multipurpose tree species (Thapa et al., 1995; Singh et al., 2008) as also by farmers in mountain regions of south-east Asia (Mulyoutami et al., 2009) and Latin America (Diemont and Martin, 2009). However, cover and vigor of these species are quite poor due to: (i) selective protection of natural regeneration rather than systematic tree planting, (ii) excessive lopping (Semwal et al., 2002), (iii) small farm holdings, (iv) restrictions on commercial utilization of tree products (Singh et al., 2008; Sood and Mitchell, 2009), (v) stress on planting timber/industrially valued species by government agencies and (vi) exclusion of people in designing plantation programmes (Maikhuri et al., 1997; Lamb and Gilmour, 2003). Tree planting in degraded lands, apart from enhancing ecosystem functions of the treated areas, contributes to conservation of the remaining forests (Lamb et al., 2005), climate change mitigation (Antle et al., 2007) and to socio-economic upliftment of local communities (Hayes and Persha, 2010; Adnan and Holscher, 2011) in developing countries. Though huge investments have been made to rehabilitate degraded lands by planting trees since the 1970s in the Himalayan region, the impact has, by and large, been poor because of inappropriate technologies and callous or negative attitudes of the local people (Saxena et al., 2001; Lamb and Gilmour, 2003).

As a result of research priorities on industrially valued tree species, quantitative information on growth and ecological impacts of multipurpose trees in Himalaya is quite limited (Gilmour et al., 1990; Maikhuri, 1993; Dhyani and Tripathi, 1999) as is also the case with other developing regions (Deans et al., 2003; van Breugel et al., 2011). Deficiency of long-term data on performance of multipurpose tree plantations in degraded lands delimits the scope of realization of economic benefits from the United Nations- REDD+ (Reducing Emissions from Deforestation and Forest Degradation) initiative of climate change mitigation by making payments for reducing emissions in developing countries. Repeated sampling of a plantation over long term is likely to yield more accurate biomass/carbon accumulation trends compared to the chronosequence based ones (Johnson and Miyanishi, 2008; Walker et al., 2010) but has been rarely attempted.

We developed participatory approaches to tree planting as a component of land rehabilitation plans in selected villages in Indian Himalaya spread over an elevation range of 1200–2500 m amsl. (Maikhuri et al., 1995, 1997; Rao et al., 1999). At mid-elevations (1200–1350 m amsl.), mixed plantation of ten multipurpose tree species with cropping developed in abandoned agricultural land sequestered carbon in tree component 2.8 times and in top 15 cm soil 1.5 times higher compared to exclusive tree plantation in degraded forest land, with *Alnus nepalensis, Albizzia lebbeck* and Albergia *sissoo* showing higher mortality at the latter site but insignificant site effect on aboveground biomass (Maikhuri et al., 2000). Comparison of crop performance under varied lopping regimes in 6-yearold tree-crop mixed system suggested that retention of 25% branches did not reduce crop yields (Semwal et al., 2002). The objective of the present study was to collect additional data on tree survival, growth and carbon stocks to describe the long term effects of growing multipurpose trees in degraded lands in Himalaya. To our knowledge, this is the first attempt of evaluating the performance of plantations in degraded lands based on repeated-measurements of the same sites over a 20-year-period in the Himalaya.

3.3.2 Study area and land use-land cover mapping

The study was carried out at Bhiri-Banswara village (latitude 30_270N and 79_50E) at 1200 m amsl. In Rudraprayag district in Garhwal region of Indian Himalaya. The climate is typical monsoon, with annual rainfall varying in the range of 1400–1700 mm and monthly minimum and maximum temperatures of 7–24 *C and 19–34*C, respectively. The soil is derived from feldspathic quartz schists, quartz muscovite schists and quartz chlorite schists and can be classified as Dystric Cambisol according to FAO system. Potential vegetation has been described as subtropical broadleaved/ pine forests (Champion and Seth, 1968). At the time of initiation of the study in 1990, the village community comprised 1400 people in 256 families, with mean land holding size of 0.45 ha.

Moderately degraded natural forests (15–25 m high trees on 25–30* slopes; tree density: 350 trees ha^{-1}; basal area: 41 m2 ha^{-1}), highly degraded natural forests (1–2 m tall herbaceous vegetation on 20–30* slopes with isolated stunted <5 m tall trees with basal area of <2 m2 ha^{-1}), pure crop system (5–8*outward sloping, 4–7 m-wide and 1–2 m-high terraces devoid of trees), tree-crop mixed agroforestry system (scattered 5–8 m tall multipurpose tree species maintained in land previously under pure crop system; tree density: 170 trees ha^{-1}; basal area: 13 m2 ha^{-1}) and abandoned agricultural land (herbaceous vegetation on damaged terraces) covered 46%, 3%, 35%, 10% and 6%, respectively, of the total village area (Bhadauria et al., 2012).

Plantation establishments

The information presented here is based on the previous studies of the same area (Maikhuri et al., 1997, 2000; Semwal et al., 2002). Interviews with the heads of 219 families staying permanently in Bhiri-Banswara in 1990–91 revealed farmers' preferences for planting eight tree species viz. *Boehmaria rugulosa Wedd., Grewia optiva J.R. Drummond ex Burret, Celtis australis L. and Ficus glomerata Roxb.* Valued most for fodder, *D. sissoo Roxb. and A. lebbeck (L.) Benth. for timber, Pyrus pashia Buch.-Ham. ex D. Don. for fuelwood and Prunus cerasoides D. Don* for its edible fruits and flowers attracting honeybees. Farmers were initially not willing to plant A. nepalensis D. Don and Sapium sebiferum (Michaux) Roxb. for their poor quality fodder and fuelwood. They agreed to plant A. nepalensis after we informed them of its scientifically proven potential to improve soil fertility and support high crop productivity (Singh et al., 1989) and S. sebiferum after we informed them of market value of its tallow and oil (Gaur, 1999). Except for B. rugulosa, an evergreen tree, all other species were deciduous between December and March/April, with minor species specific differences in leaf fall/production dynamics.

Site and treatment characteristics

After a series of participatory discussions, it was decided to (i) demarcate one plot (3 ha) each of abandoned agricultural land (AAL) and highly degraded forest land (HDFL) with similar topographic conditions but separated by a distance of 50–100 m, (ii) protect the plots from fire and grazing, (iii) transplant healthy saplings/ plantlets of the ten multipurpose tree species listed above obtained from the village farm/forest land in 45 x45 x 45 cm size pits providing 2 kg of traditional farmyard manure, the mixture of forest leaf litter and livestock excreta (moisture: 265%; C: 29.2%; N: 1.28%), at 3 m spacing in July 1991, (iv) mix species such that neighboring individuals did not belong to the same species, (v) construct a tank with locally available resources to store water to alleviate stress to crops during dry spells only at the AAL site and (vi) monitor all costs/inputs and benefits/outputs related to the trials in each site (Maikhuri et al., 1997). Soil at the AAL site had lower bulk density, higher organic carbon, total nitrogen and exchangeable potassium, calcium and magnesium compared to the HDFL site, while the two sites resembled in terms of soil texture and water holding capacity (Table 35). A summary of management practices at the two sites is provided in Table 2. At the AAL site, the terraces were repaired and annual food crops were grown providing farm yard manure (40 Mg ha^{-1} $year^{-1}$ during the first-five years and 20 Mg ha^{-1} $year^{-1}$ during 6–10-year period) and turmeric from eleventh year onwards with average manure input of 2 Mg ha^{-1} $year^{-1}$. Trees were lopped from the sixth year onwards during winter season only at the AAL site.

Table 48 Selected attributes of the abandoned agricultural land (AAL) site and highly degraded forest land (HDFL) site in Bhiri-Banswara village landscape, Central Himalaya, India at the time of tree planting in the year 1991

Feature	AAL site	HDFL site
Ownership[a]	Private land till it was cultivated but village community land after it was abandoned in the 1970s	Land owned by the Government but village community empowered to use resources to meet their subsistence needs; non-forest land uses are not permitted
Relative area (%)[a]	6	3
Salient historical features	Abandonment followed migration of a group of families during 1970s and natural vegetation in their croplands was exposed to unregulated grazing, lopping and litter collection	After logging during 1940–50, the area was exposed to unrestricted forest resource uses and frequent ground fire
Vegetation[a]	Sparse herbaceous vegetation on damaged terraces	A few heavily pruned trees (<5 m tall; crown cover: <10%; basal area: 1 m^2 ha^{-1}) scattered in sparse herbaceous vegetation
Surface cover[*]	Herbaceous vegetation dominated by grasses, discontinuous <0.5 cm thick litter layer and livestock droppings throughout the year	Herbaceous vegetation dominated by grasses, discontinuous <0.5 cm thick litter layer and livestock droppings throughout the year
Resource utilization and human disturbances[a]	Unregulated grazing all through the year	Litter collection, unregulated grazing and pruning of trees; ground fire
Elevation	1200–1250 m above mean sea level	1200–1250 m above mean sea level
Slope and aspect	25–30° north-west facing terraced slope	25–30° north-west facing un-terraced slope
Soil (0–15 cm) characteristics (mean ± SD; $n = 3$)		
Clay (%)[b]	17 ± 4	14 ± 2
Silt (%)[b]	25 ± 2	22 ± 2
Sand (%)[b]	58 ± 4	62 ± 4
Bulk density (g cm^{-3})[c]	1.01 ± 0.22	1.27 ± 0.23
Water holding capacity (%)[b]	40 ± 6	36 ± 4
pH (1:5 soil water suspension)[c]	6.6 ± 0.6	6.2 ± 0.4
Organic carbon (%)[c]	0.94 ± 0.08	0.71 ± 0.06
Total nitrogen (%)[c]	0.15 ± 0.03	0.10 ± 0.02
Exchangeable potassium (mg kg^{-1})[c]	37 ± 5	20 ± 4
Exchangeable calcium (mg kg^{-1})[c]	501 ± 12	306 ± 9
Exchangeable magnesium (mg kg^{-1})[c]	50 ± 2	23 ± 3

[a] Based on Bhadauria et al. (2012).
[b] Soil particle size analysis by hydrometer method and field water holding capacity by estimating moisture percentage in saturated soil following Anderson and Ingram (1993).
[c] Based on Semwal et al. (2002).

3.3.3 Tree survival, tree growth and carbon stock measurements

Survival rate was assessed based on complete census of all planted individuals at the end of 1, 3, 5, 7, 15 and 20 years of plantation. Density of trees established through natural regeneration was determined based on observations in 30 quadrats, each of 10 m x 10 m, in each site only after 20 years of plantation. Twenty random individuals of each species at each site were selected to measure height and girth (10 cm above ground level at the age of 1 and 3 years and at breast height at 5–20 years). Carbon stocks in vegetation, litter and soil and material inputs/outputs were estimated before and 5, 15 and 20 years after-treatment in each site.

At 5, 15 and 20 years, five plots of 10 m x 10 m were laid out in each site and one randomly selected tree of each species in each plot was harvested, aboveground biomass separated into bole, branches and leaves and fresh weights obtained in the field. Shrub biomass was estimated in a 5 m x5 m quadrat nested in the centre and herbaceous biomass in five 1 m^2 quadrats, one each around the central and corner points, of the 10 m x 10 m plots. Surface litter was collected from ten 1 m^2 quadrats, two each around central and corner points of the 10 m x 10 m plots.

Aboveground shrub/herbaceous biomass was segregated by species and surface litter into leaf and woody material. In the centre of each litter quadrat, soil from 50 cm x 50 cm area was dug out up to 100 cm depth. Visible root fragments in 0–15, 15–30 cm and 30–100 cm soil layers were hand-picked. Subsamples of different vegetation components were dried at 80 ± 5 *C for 72 h and biomass of different components was computed using dry-fresh weight ratios. Weight and volume of gravels (>2 mm) in each of the three soil layers were determined and sub-samples of soil were dried at 105 ± 5 *C for 72 h to determine bulk density following Anderson and Ingram (1993). Soil organic carbon concentration was determined by the Walkley–Black dichromate oxidation method in <2 mm soil component finely ground to pass through 0.25 mm sieve (Jackson, 1962). Organic carbon stocks in different soil layers were determined based on the concentrations, bulk density and gravel content (Davids on and Ackerman, 1993). 50% of dry plant biomass was considered as its carbon content. Slope correction was applied for determining carbon stocks on per unit area basis.

Statistical analysis

Analysis of variance (ANOVA) and least significant difference (LSD) were applied to evaluate the effect of age and species on tree growth at different sites and change in carbon stock with time after testing the data for normality and independence by Kolmogorov–Smirnov test and runs test, respectively. Student t-test was used to compare growth of a species and carbon pools at the two sites at different stages of site development (Sokal and Rohlf, 1981). Because of operational constraints, we could not monitor growth and carbon stocks at uniform time intervals and replicate sites.

Table 49 Comparison of management practices adopted for rehabilitation of the abandoned agricultural land (AAL) and highly degraded forest land (HDFL) sites in Bhiri-Banswara village landscape, Central Himalaya, India.

Management practices	AAL site	HDFL site
Transplanting	20–40 cm tall saplings collected from farm/forest land transplanted at 3 m-interval in 45 × 45 × 45 cm size pits such that neighboring individuals did not belong to the same species; 110 saplings of each species or 1100 saplings of all species ha^{-1}; gravels from the dug out soil removed, soil mixed with 2 kg of farm yard manure and placed back in the pit	As at the AAL site
Protection	Protection from grazing and fire	As at the AAL site
Irrigation	Small scale irrigation system established to provide life saving irrigation to crops	No irrigation and cropping
Ploughing	25–30 cm deep ploughing, two times in October before sowing winter crop and three times in May before sowing rainy season crop, using bull-driven traditional plough	No ploughing
Weeding	Three times every year until 7 years after tree planting and subsequently once in a year	Cutting of grasses once a year until 8 years after planting
Lopping	From sixth year of plantation, with lopping of 50–80% branches of fodder species and 20–30% of other species during winter season	No lopping
Soil management	Farmyard manure applied at the rate of 20 Mg ha^{-1} incorporated before sowing of rainy season crop and equal amount before sowing of winter season crop (i.e., 40 Mg ha^{-1} year–1) during the first five years; 10 Mg ha^{-1} to each crop (i.e., 20 Mg ha^{-1} $year^{-1}$) from 6th to 10th year and 2 Mg ha^{-1} $year^{-1}$ thereafter; some gravels removed at the time of sowing of crops every time	No manuring or gravel removal after transplanting

Results

(1) Survival

At the abandoned agricultural land (AAL) site, *F. glomerata and P. cerasoides* did not suffer any mortality, *A. lebbeck, C. australis, B. rugulosa and G. optiva* suffered mortality only during the initial 3-year-period and *A. nepalensis, D. sissoo, S. sebiferum and P. pashia* during the initial 3-year-period and also after 7 years. At the highly degraded forest land (HDFL) site, all species experienced mortality only during the initial 3-year-period. Mortality was higher at the HDFL site compared to the AAL site, more so in *B. rugulosa, G. optiva and F. glomerata*. Average survival at the AAL site was 87% compared to 51% at the HDFL site, with 970 trees ha^{-1} at the former and 564 trees ha^{-1} at the latter site surviving after 20 years (Table 50).

Table 50 Number of surviving trees (trees ha^{-1}) of different species after 1, 3, 5, 7, 15 and 20 years of plantation at the abandoned agricultural land (AAL) site and highly degraded forest land (HDFL) site in Bhiri-Banswara village landscape, Central Himalaya, India (planting density: 110 saplings of each species ha^{-1} or 1110 saplings of all species ha^{-1}).

Species	Number of surviving trees ha^{-1}					
	AAL site				HDFL site	
	1 year	3–7 years[a]	15 years	20 years	1 year	3–20 years[b]
A. lebbeck	86	83	83	83	66	60
A. nepalensis	95	94	94	91	56	51
B. rugulosa	107	105	105	105	46	39
C. australis	101	97	97	97	65	63
D. sissoo	110	97	97	94	71	64
F. glomerata	110	110	110	110	52	48
G. optiva	110	107	107	107	46	43
P. cerasoides	110	110	110	110	74	72
P. pashia	102	100	93	83	69	69
S. sebiferum	95	94	94	90	56	55

[a] No mortality during 3–7-year period after planting at the AAL site.
[b] No mortality during 3–20-year period after planting at the HDFL site.

(2) Tree growth: height, girth and aboveground biomass

Height growth 7 years after plantation was negligible in *A. lebbeck, G. optiva, P. pashia* and *S. sebiferum* at the AAL site and in all species except *A. lebbeck, S. sebiferum and P. cerasoides* at the HDFL site. At the AAL site, *A. nepalensis* was taller than *C. australis and F. glomerata, and D. sissoo* taller than *P. cerasoides* until 7 years but the differences between the former three and between the latter two species became insignificant ($P > 0.05$) after 15 years. At the HDFL site, *A. nepalensis, D. sissoo and A. lebbeck* were taller than *P. cerasoides, and F. glomerata* taller than *S. sebiferum* until 7 years but the differences between the former four species and between the latter two species became insignificant ($P > 0.05$) after 15 years. Site effect was insignificant ($P > 0.05$) in *A. lebbeck* at all ages and in *P. pashia* 5 years after plantation. All other species grew taller at the AAL site compared to the HDFL site at all ages ($P < 0.05$). At the age of 20 years, *F. glomerata, B. regulosa and C. australis* trees were 2.1–2.9-times and *D. sissoo, A. nepalensis, P. cerasoides, S. sebiferum and G. optiva* 1.4–1.8-times taller at the AAL site than the HDFL site (Fig. 24a and b).

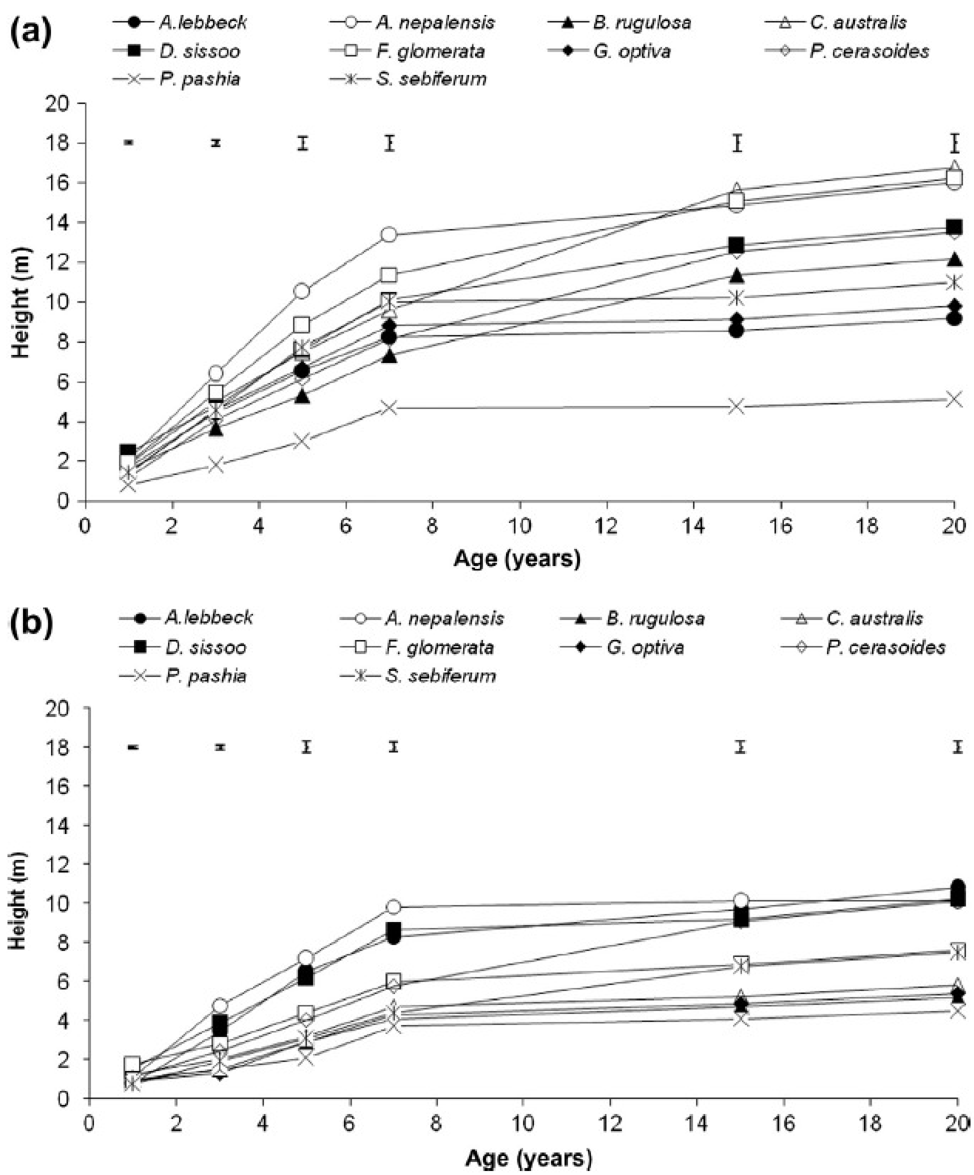


Figure 24 (a and b) Height of different tree species after 1, 3, 5, 7, 15 and 20 years of plantation at the (a) abandoned agricultural land (AAL) site and (b) highly degraded forest land (HDFL) site in Bhiri-Banswara, Central Himalaya India. Vertical lines represent the least significant differences (P = 0.05) between species at different ages. AAL: Fage (5, 1140) = 3145.4, Fspecies (9, 1140) = 462.7, Fagex species (45, 1140) = 40.4; DFL: Fage (5, 1140) = 2552.9, Fspecies (9, 1140) = 580.7, Fage x species (45, 1140) = 39.1.

Increase in girth was insignificant (P > 0.05) in *P. pashia* and *S. sebiferum* at the AAL site and *D. sissoo* at the HDFL site after 7 years and in other species at both sites after 15 years of plantation. At the AAL site, *A. nepalensis* had larger girth than *B. rugulosa* and *D. sissoo* larger than *C. australis and P. cerasoides* till 7 years but the differences between the former two and among the latter three species diminished by the age of 15 years. At the HDFL site, *A. nepalensis* had larger girth than *P. cerasoides* and *A. lebbeck* larger than *C. australis* till 7 years but the differences between the former two and the latter two species became insignificant (P > 0.05) by the age of 15 years. Site did not have any significant (P > 0.05) effect on girth of *A. lebbeck* on all sampling times and in *P. cerasoides* and *P. pashia* 7 years after plantation. At the age of 20 years*, F. glomerata* and *D. sissoo* had 2.0–2.3-times and *A. nepalensis, B. rugulosa, C. australis, G. optiva* and *S. sebiferum* 1.2–1.6-times larger girths at the AAL site compared to the HDFL site (Fig. 25a and b).

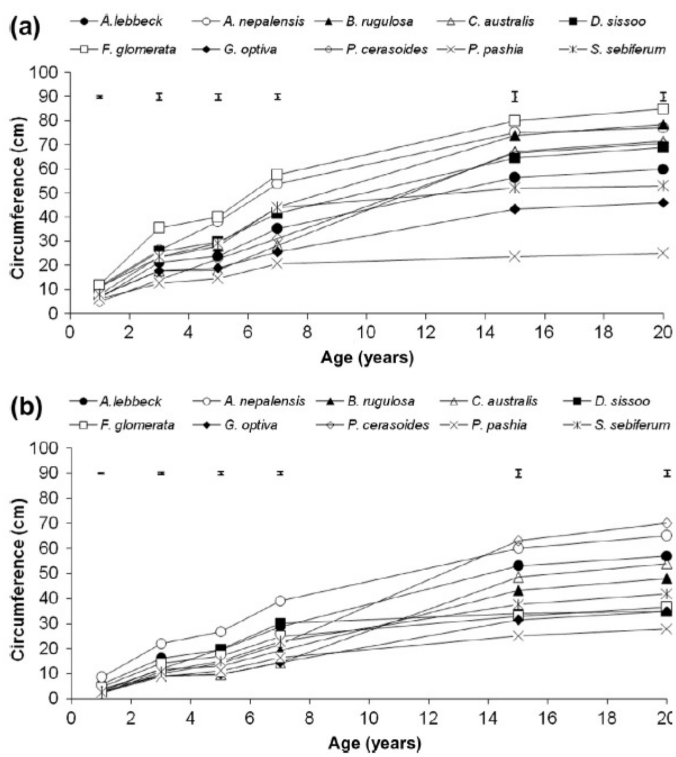


Figure 25 (a and b) Girth of different tree species after 1, 3, 5, 7, 15 and 20 years of plantation at the (a) abandoned agricultural land (AAL) site and (b) highly degraded forest land (HDFL) site in Bhiri-Banswara, Central Himalaya, India. Vertical lines represent the least significant differences (P = 0.05) between species at different ages. AAL: Fage (5, 1140) = 4525.5, Fspecies (9, 1140) = 554.1, Fage x species (45, 1140) = 54.9; DFL: Fage (5, 1140) = 6151.2, Fspecies (9, 1140) = 561.0, Fage x species (45, 1140) = 112.4.

A. nepalensis at both sites and *S. sebiferum* and *P. pashia* only at the AAL site did not show any significant ($P > 0.05$) increase in biomass after 15 years. All other species showed a linear increase in biomass till 20 years at the HDFL site unlike a sharp decline in biomass accumulation rates after 15 years at the AAL site. *B. rugulosa had 5.7-, G. optiva 3.2-, C. australis 2.3-, F. glomerata* 1.6- and P. cerasoides 1.5-fold higher aboveground biomass at the AAL site compared to the HDFL site after 20-years. A. nepalensis and D. sissoo had significantly ($P < 0.05$) larger and A. lebbeck lower biomass at the AAL site by the age of 20 years but differences between them were not significant ($P > 0.05$) until 5 years. P. pashia had significantly ($P < 0.05$) higher biomass at the AAL site than at the HDFL site until 5 years but the site effect was not significant ($P > 0.05$) by the age of 20 years. *S. sebiferum* accumulated larger biomass until 5 years but lower biomass thereafter at the AAL site compared to the HDFL site (Fig. 26a and b).

At the AAL site where trees were lopped, *F. glomerata, B. rugulosa, A. nepalensis,* and *G. optiva* yielded the highest amount of foliage biomass from lopped branches (83–96 kg $^{tree\_1}$) followed by *C. australis* (54 kg tree^{-1}*), S. sebiferum, P. cerasoides, D. sissoo* and *A. lebbeck* (36–43 kg tree^{-1}) and P. pashia (16 kg tree^{-1}). Fuelwood yield varied from 102 kg tree^{-1} from *A. nepalensis* and *F. glomerata* to 25 kg tree^{-1} from *P. pashia.*

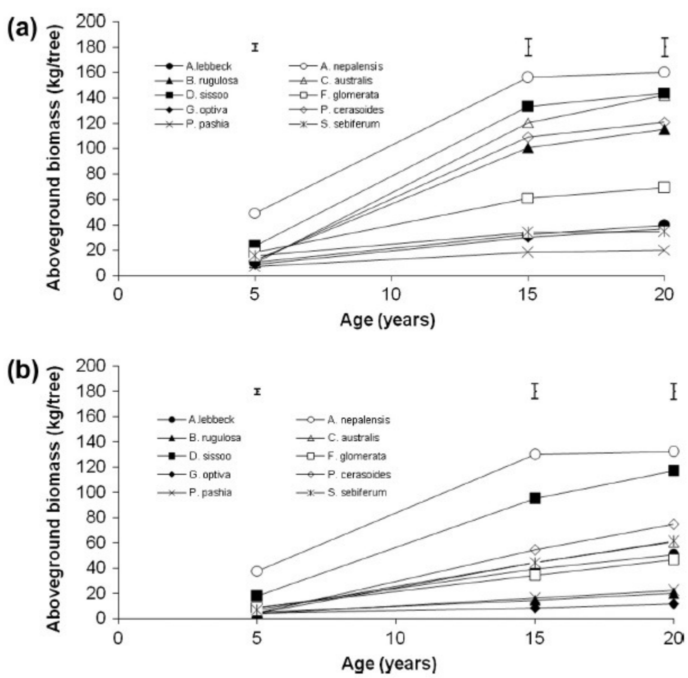


Figure 26 (a and b) Mean aboveground biomass of different species after 5, 15 and 20 years of plantation at the (a) abandoned agricultural land (AAL) site and (b) highly degraded forest land (HDFL) site in Bhiri-Banswara, Central Himalaya, India. Vertical lines represent the least significant differences ($P = 0.05$) between species at different ages. AAL: F_{age} (2, 120) = 4525.5, $F_{species}$ (9, 120) = 554.1, F_{age} x$_{species}$ (18, 120) = 54.9; DFL: F_{age} (5, 120) = 6151.2, $F_{species}$ (9, 120) = 561.0, F_{age} x species (18, 120) = 112.4.

(3) Natural regeneration

Cinnamomum tamala at the AAL site, Phyllanthus emblica and Syzygium cumini at the HDFL site and *Engelhardtia spicata, Lannea coromandelica, Toona hexandra, Bombax ceiba, Mallotus philippensis* and *Pinus roxburghii* at both sites established through selective protection of natural regeneration by farmers (Table 38). Of the planted species, *D. sissoo, S. sebiferum and P. cersaoides* regenerated only at the AAL site after 7 years but were weeded out.

(4) Carbon stock

Before plantation, the AAL site had slightly higher value of C stocks compared to the HDFL site which was due to an increase in soil organic C, despite the very high amounts of farmyard manure added to the AAL site in the past. Both sites received 6.5 Mg C ha^{-1} through farm yard manure added to the soil at the time of transplanting saplings. The AAL site received a huge additional amount of 117 Mg C ha^{-1} over the 20-year-period through manure applied primarily to benefit understorey crops. Around 7 Mg C ha^{-1} in palatable grass biomass was taken out from the HDFL site compared to 103 Mg C ha_1 in fodder, fuelwood and food taken out from the AAL site.

Setting aside the C pools taken out of the sites, the standing C pools at the two sites are shown in Fig. 27. C pool in the standing aboveground biomass after 20 years was 2.3-times lower at the AAL site and 3.1-times higher at the HDFL site compared to that taken out of the site. Changes in aboveground biomass C pools retained in the site during 16–20 year period were insignificant ($P > 0.05$) at the AAL site, while there was a significant ($P < 0.05$) but slow increase in the tree and shrub C pools at the HDFL site. Over the 20-year period, the AAL site accumulated C in standing aboveground pool at the rate of 2.09 Mg C ha^{-1} $year^{-1}$ compared to 0.95 Mg C ha^{-1} $year^{-1}$ at the HDFL site. At the AAL site, *A. nepalensis, B. rugulosa, C. australis, D. sissoo and P. cerasoides* were the most efficient species each making 14–17% of total C stock in aboveground tree biomass followed by *F. glomerata* (9%) and *A. lebbeck, S. sebiferum, G. optiva and P. pashia*, (2–5%). At the HDFL site, *A. nepalensis, D. sissoo and P. cerasoides* were the most efficient with their contributions to the total tree C stock varying in the range of 15–22% followed by *A. lebbeck, C. australis and S. sebiferum* (9–11%), and *B. rugulosa, F. glomerata, G. optiva and P. pashia* (1–6%).

Root C stocks were negligible compared to the soil organic C stocks at both sites. Total belowground (soil + root) C stock consistently increased till 20 years at the HDFL site unlike the AAL site where it increased during the initial 5 years followed by a margin decline during the 6–15-year period and insignificant change ($P > 0.05$) during the 16–20-year period. Over the 20-year period, the HDFL site accumulated belowground C at the rate of 1.37 Mg C ha^{-1} $year^{-1}$ compared to 0.44 Mg ha^{-1} $year^{-1}$ at the AAL site.

Total C stock (vegetation + soil) at the AAL site was 61% greater after 5 years of treatment compared to the HDFL site. The differences between the two sites gradually diminished and became insignificant ($P > 0.05$) by the age of 20 years, with both sites accumulating C at a rate of 2.3–2.5 Mg C ha^{-1} $year^{-1}$(Fig. 27). If agroforestry system was developed on all degraded lands in the village, a family would earn US 37 $family^{-1}$ $year^{-1}$ as compensation for carbon sequestration (considering compensation of US $ 10 Mg $CO2^{-1}$ and carbon sequestration rate of 2.5 Mg C or 9.2 Mg CO2 ha^{-1}) compared to US $ 400–900 $family^{-1}$ $year^{-1}$ from understorey food crops.

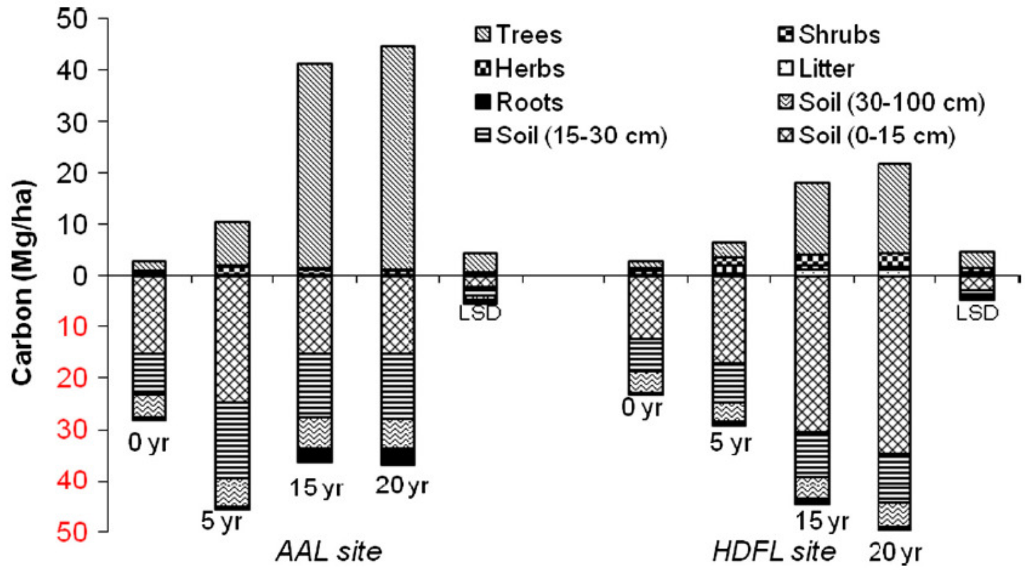


Figure 27 Carbon pools before (0 yr) and 5–20 years after tree planting with cropping at the abandoned agricultural land (AAL) site and without any cropping at the highly degraded forest land (HDFL) site in Bhiri-Banswara, Central Himalaya, India. The horizontal line crossing at '0' on y axis refers to the soil surface, with values above it depicting the aboveground biomass C pool (aboveground biomass C in trees, shrubs, herbs including crops at the AAL site and litter on ground) and below it the belowground C pools (soil organic C in 0–15 cm, 15–30 cm and 30–100 cm soil layers and roots). Least significant differences (P = 0.05) for carbon pools at different ages at the two sites are shown. Fage (3, 16) = 40.0, 33.9, 7.4, 32.5, 9.6, 12.3, not significant and 285.4 at the AAL site and 134.7, 23.1, 8.3, 17.4, 12.9, 15.9, 17.7 and 56.8 for soil (0–15 cm) organic C pool, soil (15–30 cm) organic C pool, soil (30–100 cm) organic C pool, root biomass C pool, litter biomass C pool, aboveground biomass C of herbs/crops, aboveground biomass C of shrubs
and aboveground biomass C of trees, respectively.

3.3.4 Discussion

Survival of transplants and natural regeneration

Better soil quality as a result of irrigation and addition of manure primarily applied to favor crop growth was the key factor favoring higher survival rates at the AAL site compared to the HDFL site until 5 years of tree growth when trees were not lopped and care was taken to avoid pruning of tree roots by ploughing. Subsequently, farmers started ploughing right up to the bole causing pruning of roots together with lopping of branches to minimize the risks of reduced crop yields due to negative tree-crop interactions (Maikhuri et al., 2000; Semwal et al., 2002). High quality fodder species B. rugulosa, G. optiva, F. glomerata and C. australis had lower capacity to survive in the more stressful soil conditions at the HDFL site but high capacity to survive the persistent disturbances of lopping of branches and pruning of roots caused by ploughing (Schroth, 1999) compared to A. nepalesnsis, D. sissoo, S. sebiferum and P. pashia showing some mortality after 7 years of growth only at the AAL site. Mature tree density of 564 trees ha^{-1} after 20 years of planting at the HDFL site is comparable to that of healthy Himalayan forests (Sharma et al., 2010). Nonetheless, average survival of 51% at the HDFL site was quite low and could be improved by more effective site preparation (Knapp et al., 2006; Fonseca et al., 2011), biological amendments (Tiwari et al., 2003), selection of healthy plantlets (Davidson et al., 1998; He et al., 2009) and by setting initial planting density higher than 1100 trees ha^{-1} in the present case. Enhancement of biodiversity through natural regeneration following protection and plantation in the present study was quite poor compared to other reports in the Himalaya (Gilmour et al., 1990) and elsewhere (Lee et al., 2005; Farwig et al., 2009) due partly to disturbances caused by intensive weeding at the AAL site and cutting of grasses at the HDFL site.

Table 51 Density (trees ha^{-1}) of naturally regenerated trees protected by the farmers at the abandoned agricultural land (AAL) site and the highly degraded forest land (HDFL) site after 20 years of tree planting in Bhiri-Banwara village landscape, Central Himalaya, India.

Species	AAL site	HDFL site
Bombax ceiba L.	12	20
Cinnamomum tamala (Buch-Ham.) Nees & Ebermaeir	1	–
Engelhardtia spicata Leschenault ex Blume	15	25
Lannea coromandelica (Houttuyn) Merrill	2	15
Mallotus philippensis (Lam.) Muell.-Arg.	25	42
Phyllanthus emblica L	–	1
Pinus roxburghii Sargent	2	5
Syzygium cumini (L.) Skeel	–	7
Toona hexandra (Wallich ex Roxb.) M. Roemer	10	18

Tree growth

Tree density (970 trees ha^{-1}) and basal area (34 m^2 ha^{-1}) after 20 years at the AAL site are fairly higher than 180–428 trees ha^{-1} and 6–26 m^2 ha^{-1} basal area in the age-old traditional farms in the Himalayan region (Singh et al., 2008). Interviews with Bhiri-Banswara farmers revealed that they considered 20-year-old trees at the HDFL site too weak to sustain lopping in the absence of any irrigation and manuring. Direct species interactions may have significant influence on performance of individual species in mixed plantations (Piotto et al., 2010) but may not be significant in the present case where lopping of branches and pruning of roots caused by ploughing delimited intermixing of neighboring trees at the AAL site and slow tree growth and low survival in the absence of irrigation and manuring at the HDFL site (Schroth, 1999; Jackson et al., 2000). At the AAL site, trees grew in better soil conditions arising from irrigation and manuring but faced disturbances of lopping of branches and pruning of roots caused by ploughing unlike the HDFL site with poorer soil conditions and absence of any disturbances caused by lopping and ploughing. The fodder trees *B. rugulosa, G. opitva, F. glomerata and C. australis and P. cerasoides* valued for its edible fruits and attracting honeybees having 1.6–5.7-fold higher aboveground biomass compared to that at the HDFL site after 20 years were more responsive to amelioration of soil fertility at the AAL site compared to *A. nepalensis and D. sissoo*, showing 1.2-fold difference between the two sites or P. pashia showing insignificant site effect. Better performance of *S. sebiferum and A. lebbeck* at the HDFL site compared to the AAL site after 5 years suggests their limited adaptation to persistent lopping, pruning of roots in surface soil and shade stress caused by neighboring taller species. Local people would prefer plantations dominated by *G. optiva, B. rugulosa, C. australis and F. glomerata* because fodder is crucial for their livelihood and policies do not provide for income from wood (Maikhuri et al., 2000; Singh et al., 2008). Poor performance of these species valued most by the farmers in more stressful soil conditions at the HDFL site suggests the necessity of soil and water management for their success. However, these fodder species with poor growth under soil moisture and nutrient stress conditions would be less efficient in carbon accumulation compared *to A. nepalensis and D. sissoo* maintaining fairly high biomass under such conditions. Further, the fodder species lacking nitrogen fixing potential and producing smaller quantities of slowly decomposing litter would not be as efficient in recuperating soil fertility in degraded lands as nitrogen fixing *A. nepalensis, D. sissoo* *and A. lebbeck* producing larger quantities of fast decomposing litter (Semwal et al., 2003). A species like A. nepalensis highly susceptible to pests and pathogens is not appreciated by local people because policies do not provide for freedom to farmers to remove diseased trees as well any income from the wood of such trees.

Carbon stocks

Against the net addition of 21 Mg C ha^{-1} through manure over 20-year period at the AAL site (124 Mg ha^{-1} input through manure – 103 Mg C ha^{-1} output in the form of food, fodder and fuelwood biomass taken out of the site = 21 Mg C ha^{-1}), increase in soil organic C stock was only 9 Mg C ha^{-1}, indicating a loss of 12 Mg C ha^{-1} from decomposition of manure favored by high levels of aeration, lack of moisture stress and abundance of soil biota under ploughed and irrigated soil (Albrecht and Kandji, 2003; Bhadauria et al., 2012). However, with accumulation of 44 Mg C ha^{-1} in biomass build up, there was a net sequestration of 32 Mg C ha^{-1} at the AAL site. At the HDFL site, with input of C through manure being just equal to the output through grass taken out of the site, lower biological activities releasing carbon dioxide from soil due to poor aeration and moisture and nutrient stress and higher inputs of litter to the soil in the absence of lopping, trees seemed to have significantly contributed to accumulation of 27 Mg C ha^{-1} in soil over the 20-year-period. Increase in soil organic C after tree planting corroborates similar trends reported by others (Paul et al., 2002; Wen-Jie et al., 2011; Rytter, 2012). C accumulation rate of 1.3 Mg C ha^{-1} $year^{-1}$ in complete soil profile (100 cm soil depth) over 20 year-period at the HDFL site is quite higher than the global average of 0.14 Mg ha^{-1} $year^{-1}$ in top 30 cm soil in 19-year-old plantations (Paul et al., 2002) but comparable to 1.4 Mg C ha^{-1} $year^{-1}$ in top 20 cm soil in 25-year-old larch plantations in China (Wen-Jie et al., 2011). However, reports of a decline or insignificant change in soil organic C pool after tree planting (Laclau, 2003; Jimenez et al., 2007; Potvin et al., 2011) warrant any generalization. Higher rates of soil C accumulation at the HDFL site with a long history of grazing before treatment compared to the AAL site do not support the conclusion that afforestation in croplands is more efficient in sequestering C in soil than in pastures (Guo and Gifford, 2002; Laganière et al., 2010).

Carbon stocks at the AAL or HDFL sites after 20 years of plantation (33–49 Mg ha^{-1} in soil and 23–48 Mg ha^{-1} in vegetation) were substantially lower compared to the natural forests in the region (87–231 Mg ha^{-1} in soil and 67–137 Mg ha^{-1} in vegetation) (Sheikh et al., 2009; Sharma et al., 2010; Singh et al., 2011) suggesting that 20-year-period is too short to fully recover C stocks, as is also the case with biodiversity (Bhadauria et al., 2012). Higher rates of C sequestration can be maintained by removing >15-yearold A. nepalensis trees, transforming the wood into long lasting products and appropriate replacements of the removed trees (Houghton, 2007; Mascaro et al., 2012) along with reduced risks of proliferation of pests/pathogens associated with this species. Such removals are not likely to affect forest health adversely (Sharma et al., 2009; Mon et al., 2012). However, policy interventions would be required to avoid emissions from its use as fuelwood and to enhance wood processing, crafting and marketing skills of local communities.

Participatory land rehabilitation and its scope of REDD+

In Indian Himalaya where timber trade is banned and local people enjoy practically unrestricted rights of utilizing non-timber forest products free of any cost and privileges of getting timber required for subsistence on nominal cost from government forests (Singh et al., 2008), tree planting confers only indirect and longterm benefits to them. An income of US $ 37 per $family^{-1}$ $year^{-1}$ from carbon sequestration in degraded lands would be too low to mobilize tree planting by individuals or communities without any external support. Tree-crop mixed systems enabling an income of US $ 400–900 $family^{-1}$ $year^{-1}$ from the crop component could mobilize farmer-led rehabilitation initiatives and at the same time sequester as much carbon as the exclusive tree plantations. Exclusive tree planting in degraded lands is likely to succeed if local people are allowed income from timber (Newby et al., 2012), income from non-timber products are quite high (He et al., 2009; Adnan and Holscher, 2011) and landless/marginal farmers are provided all basic needs in return of their labor input (Shankar et al., 1998). For safeguarding the economic interests of the local communities from tree planting under REDD+ (Hayes and Persha, 2010), changes in the present policies, which enable local communities to develop tree-crop mixed systems in degraded lands, remove over-mature/diseased trees and to enhance their capacity of value addition and marketing of forest products, are required. The trend of narrowing down of the difference in carbon stocks at the two sites with age highlights the need of appropriate consideration of time scale while determining payments for ecological benefits from land rehabilitation.

4.0 Conclusions

The project aimed to assess challenges and opportunities of REDD+ for forest communities in Laos and Thailand, including lessons from past/ongoing forest conservation policies, provide much-needed scientific evidence on the potential co-benefits of traditional forest management practices and comparing it with alternative land-uses; and develop participatory community-based MRV mechanisms for REDD+ to enable local communities to incorporate carbon stocks into their forest management. In response to the project objectives, the project findings are summarized as follows:

4.1 Participatory assessment of challenges and opportunities

For the first time, the project followed a participatory methodology (working with local communities) to measure present carbon stocks and past and future likely changes; assess biodiversity and livelihoods in various land use - land cover types at a village landscape level. The research results show not only forests, but also other land uses contain rich carbon stocks, including biomass and soil organic carbon. Maximum carbon storage approaching 300 ton C/ha in the study site was found in conservation-headwater forest which are never cultivated, with minimum use in harvesting of timber and other forest products. Carbon storage declined with increasing intensity of land use, from communally managed utility forests (with 60% of the carbon in conservation forest), to shifting cultivation fields, to permanent crop field (growing mixture of perennial and annual crops), to paddy fields (with only 18% of the carbon in conservation forest). As a major land use, the shifting cultivation combining crop fields and forest fallows holds rich carbon and biodiversity, supporting local livelihoods. Time-averaged carbon content in a 7-year cycle of shifting cultivation in the study site in Thailand is as high as 96.95 ton/ha, higher than 65.34 ton/ha in permanent fields and 49.44 ton/ha in paddy fields. There were 56 species of crops in shifting cultivation. Among others 17 varieties of upland rice were cultivated in shifting cultivation. The traditional community forest management at the study site has conserved as wide as 52 % of the village land for forests, including conservation, utility, community and cemetery with rich carbon stocks of 272.65 ton/ha, 173.59 ton/ha and 154.31 ton/ha respectively. If actions, such as REDD+ are taken to support local livelihoods for forest conservation, the cycle of forest fallows might become longer to encourage full regeneration of forests with increasing carbon storage. Otherwise, the cycle of forest fallows would become shorter with decreasing carbon storage. In spite of remarkable achievements in forest conservation, "Community Forest Legislation" has not yet become law in Thailand. This absence of any legal basis is an obstacle to recognize achievements made so far by highland communities and to promote their conservation activities. Shifting cultivation is still discouraged for expansion of cash cropping with negative impact on carbon stock and biodiversity in mountainous areas.

Similarly, time-averaged carbon intensity in shifting cultivation in the study site in Laos is not so much different from the carbon intensity in teak plantations as the former has richer soil carbon stocks to make up lower biomass above ground. Teak plantations have lower biodiversity and higher soil erosion compared to fallows. The past land allocation policy at the study site led to zoning of significant fallow areas (old fallows) for forest conservation. As a result, shifting cultivators had to intensify cultivation within smaller areas zoned for agriculture, leading to short fallows with low rice yield. Teak production is a profitable land use in the project site. The opportunity cost for protecting forests from converting to teak plantations (\$0.795/t CO^2) much higher than that for (upland rice\$0.016/t CO^2). Along with discriminate policy against shifting cultivation, the combination of the low rice yield and the profitable teak production has promoted increasing conversion of short fallows into teak plantations with negative impacts on biodiversity and soil conservation. Without REDD+ and other conservation policies, old fallows might be opened for cultivation, leading to loss of carbon stocks. Implementation of REDD+ and other conservation policies might encourage conversion of young fallows or cropping fields to old fallows, leading to growth of carbon stocks.

In the associate study site in India, oak forest and home garden had significantly higher carbon content as compared to other land use - land cover types. Pine forest had similar total carbon content as compared to irrigated agriculture but significantly higher as compared to rainfed agriculture, abandoned agricultural land and scrub. Home garden also holds rich biodiversity, including 17 tree species, 16 herb species and 12 crops. Expansion of homegardens can more than compensate the losses of carbon occurring through forest degradation leading to deforestation over a period of time. Conversion of oak forests to pine forests for revenue followed 37% reduction in carbons stocks. Conversion of rainfed agricultural land to irrigated land will increase soil carbon stocks together with high food production. The carbon measurement found out that the estimation of soil carbon was influenced by soil depth. Estimation of litter biomass should also take into account seasonality. Age of tree plantations was found to influence the rate of carbon sequestration. During the first-fifteen years of rehabilitation, the abandoned agricultural land site (AAL) site accumulated aboveground C at a rate 150% higher compared to the scrubland/highly degraded forest land (HDFL) site. While changes in all aboveground C pools during 16-20 year period were insignificant at the AAL site, there was a significant but quite slow increase in the tree and shrub C pools at the HDFL site.

4.2 Potential co-benefits of traditional forest management practices

The project findings from the participatory assessment indicate potential co-benefits of traditional forest management practices for carbon storage, biodiversity conservation and livelihoods. Land use intensification or shortening of forest fallow has been the main strategy to cope with population pressure. With support of REDD+ and other efforts for forest conservation, the cycle of shifting cultivation might be maintained and even extended to allow full regeneration of forests for carbon sequestration, conservation of biodiversity, soils and water, and enhancement of local livelihoods. Cropping systems with short rotations and commercial crop plantations without carefully managed understory pose a much greater threat to soils than cropping systems under shifting cultivation with long rotations. Converting land from traditional slash-and-burn production systems to commercial cash crops such as maize, cassava can result in substantial increases in sediment yields. Favouring the conservation of fallow-like areas within the landscape would therefore assist in controlling soil detachment and inter-rill erosion. To meet this challenge, adequate land use management and practices need to be defined. Among them, the conservation of riparian areas, planned management of understory, strictly controlled burning, or sufficiently long fallow period within the shifting cultivation cycle associated with no tillage practices during cultivation should be promoted. The community forest management has also allocated and maintained a high percentage of the village land for long-term forest conservation with multiple benefits, such as timber, NTFPs as well as water sources.

Shifting cultivation systems can be sustainable. Rates of sediment generation under the shifting cultivation systems are well within the bounds of natural replacement. As long as the fallow phase on the rotation is long enough (8-15 years), and the cropping phase is short (1-3 seasons), these systems can rejuvenate and remain highly productive. A key to sustaining shifting cultivation systems is the relative low population density of most upland areas. Depopulation of uplands associated with urbanization and out-migration for off-farm opportunities will help traditional shifting cultivation systems to remain sustainable. For these reasons, a review of current policies encouraging the eradication of slash-and-burn farming systems is warranted. Promotion of commercial cash cropping systems for maize, cassava should be tied to appropriate conservation methods that minimize sediment generation. Many simple, inexpensive methods are readily available. However, conservation policies using these technologies and approaches need to be formulated and enforced. These may include incentive-based mechanisms such as payments for environmental services (PES) or a National Soil Conservation Act enforceable through a legal framework and institutions (e.g., conservation and extension services). This becomes even more critical in the context of climate change, when severe extreme events are predicted. Watersheds respond rapidly to changes in land use. Re-vegetation of catchments either naturally or through plantations will result in declining dry season water yields. This has significant implications for people in communities and industries who depend on these flows. Ideally, provisions will be made to ensure the supply of water in light of land uses in upper catchments. Such provision might include small water storage and supply infrastructures as well as land uses that are diversified to match upland landscapes. As land-use changes are often initiated by changes in property rights or market incentives, such instruments will require an ex-ante impact assessment before being implemented.

Carbon market is volatile and highly risky. It is dangerous to rely on carbon market only for forest conservation. Other opportunities for forest conservation should be mobilized. The current regional emphasis on hydropower generation could be undermined by high erosion rates and reservoir siltation. Hydropower developers could protect their investments through partnerships with upland communities that offer economic incentives for forest conservation, and the use of conservation agricultural practices in upland watersheds. Agroforestry system is another important opportunity to harness various livelihood benefits beyond potential carbon income. The present study in India shows that tree growth was better in tree crop mixed system with manure and irrigation applied primarily to benefit crops in abandoned agricultural lands than exclusive plantations in highly degraded forest lands, the two plantation systems did not differ in total carbon sequestration over a period of 20 years and the income from carbon sequestration was negligible compared to that from crops*. B. rugulosa, G. optiva, C. australis and F. glomerata* seem to be more suitable for planting in abandoned agricultural lands where amelioration of soil moisture and nutrient stress is feasible*, A. lebbeck, S. sebiferum and P. pashia* in distant highly degraded forest lands where such amelioration is not feasible and *A. nepalensis and P. cerasoides* in either situation. In biodiversity hotspots like the Indian Himalaya, where land holdings as well as area of degraded lands available to local people are small, income from timber is prohibited, natural regeneration of degraded lands is ineffective and people remain economically marginal, there is an urgent need of policies (i) safeguarding economic interests of local people from tree planting in degraded lands and (ii) enhancing scientific knowledge on multipurpose species to strike a better coupling and trade-offs of direct and indirect, short term and long term and local and global benefits from land rehabilitation.

4.3 Develop capacity for community-based MRV

Through the south to south and the south to north cooperation, the project developed a participatory methodology (see Appendix) and built national capacity for REDD+. The field assessment involved local communities as well as local officials to develop local capacity. The research results were shared with local communities and authorities to understand, manage and monitor forest carbon storage and respond to the REDD+. Good land use practices, such as understory management, controlled burning, were demonstrated for local communities to enhance carbon stocks, protect biodiversity, and enhance productivity. Community-based MRV is cost-effective in ground based measurement, and beneficial to the remote sensing technology-based MRV. Moreover, local communities can expand their objectives of forest management beyond traditional scope of forest products to include carbon enhancement. The project findings were presented to policy makers and reseaerchers at national and international levels. The project networking with partners in Yunnan of China and Myanmar facilitated development of the new international project on Sustainable Forest Rehabilitation and Management for the Conservation of Trans-boundary Ecological Security in Montane Mainland Southeast Asia– Pilot Demonstration Project of Lao PDR, Myanmar and China/Yunnan (SFR-MMSEA).

5.0 Future Directions

Ecosystem services (ES) are not well recognized. There is a need to strengthen assessment and communication of the multiple values of ecosystem services to raise public awareness at all levels. The scope of ES should be broadened to include multiple values of ES, not limiting to carbon or biodiversity values. Payment for ES should be also broadened to support multiple values of ecosystem services, not limiting to carbon. Thus, local communities could benefit from multiple values of integrated ecosystem management. There are many opportunities to integrate enhancement of carbon stock, other ecosystem services and livelihood improvement for co-benefits of the REDD+. Carbon stocks in non-forests and below-ground should be also appreciated to achieve the integrated ecosystem management at landscape level. Nevertheless, the future studies are necessary to build on history-tested traditional knowledge for integrated ecosystem management.

Institutional barriers remain a big challenge even if ES is recognized. The global mechanism for implementation of the REDD+ remains in discussion in spite of many pilot efforts. Watershed service is well recognized, but the cooperation between upstream and downstream communities is often lacking. Inappropriate land tenure is also limiting options for ES-based land management. While timber tree planting is encouraged in Thailand, farmers are not allowed to harvest and sell the timber trees. As a result, farmers concentrate on non-timber forest products only and do not like to plant timber trees in their farms even if tree planting could enhance ES. Cooperation among different sectors is necessary to promote sustainable forest management. So far, PES, such as REDD+, is still minor compared to other livelihoods or policy supports. It is important to link PES with other rural development policies. Development of alternative livelihoods is also very important to reduce local pressure on natural resources. Development of alternative livelihoods will need innovations and new business models in marketing of ES. Capacity building of local communities is also essential to support ground-based MRV. Synergy of remote sensing and community participation will make MRV more cost-effective.

References

Adnan, M., Holscher, D., 2011. Medicinal plants in old-growth, degraded and regrowth forests of NW Pakistan. Forest Ecology and Management 261, 2105–2114.

Albrecht, A., Kandji, S.T., 2003. Carbon sequestration in tropical agroforestry systems. Agriculture, Ecosystems and Environment 99, 15–27.

Anderson, J.M., Ingram, J.S.I. (Eds.), 1993. Tropical Soil Biology and Fertility: A Handbook of Methods. CAB International, Wallingford, UK.

Antle, J.M., Stoorvogel, J.J., Valdivia, R.O., 2007. Assessing the economic impacts of agricultural carbon sequestration: terraces and agroforestry in the Peruvian Andes. Agriculture, Ecosystems and Environment 122, 435–445.

Bhadauria, T., Kumar, P., Kumar, R., Maikhuri, R.K., Rao, K.S., Saxena, K.G., 2012. Earthworm populations in a traditional village landscape in central Himalaya, India. Applied Soil Ecology 53, 83–93.

Brown S. 2008. *Assessment of the Advantages and Limitations of Ground-Based Surveys and Inventories.* UNFCCC Workshop on Methodological Issues Relating to REDD in Developing Countries 25-27 June. Tokyo, Japan. http://unfccc.int/files/methods_and_science/lulucf/application/pdf/080625_tokyo_brown.pdf.

Bruun, et al, 2009. Environmental Consequences of the Demise in Swidden Cultivation in Southeast Asia: Carbon Storage and Soil Quality. Hum Ecol (2009) 37:375–388

Cairns M A, Brown S, Helmer E H and Bumgardner G A. 1997. Root biomass allocation in the world's upland forests. *Oecologia*, 111: 1-11.

Champion, S.G., Seth, S.K., 1968. A Revised Survey of the Forest Types of India. Manager of Publications, Government of India, Delhi, India.

Chave J, Andalo C, Brown S, Cairns MA, Chambers JQ, Eamus D, Folster H, Fromard F, Higuchi N, Kira T, Lescure JP, Nelson BW, Ogawa H, Puig H, Riera B, Yamakura T. 2005. Tree allometry and improved estimation of carbon stocks and balance in tropical forests. *Oecologia.* 145(1):87-99.

Davidson, E.A., Ackerman, I.L., 1993. Changes in soil carbon inventories following cultivation of previously untilled soils. Biogeochemistry 20, 161–193.

Davidson, R., Gagnon, D., Mauffette, Y., Hernandez, H., 1998. Early survival, growth and foliar nutrients in native Ecuadorian trees planted on degraded volcanic soil. Forest Ecology and Management 105, 1–19.

Deans, J.D., Diagne, O., Nizinski, J., Lindley, D.K., Seck, M., Ingleby, K., Munro, R.C., 2003. Comparative growth, biomass production, nutrient use and soil amelioration by nitrogen-fixing tree species in semi-arid Senegal. Forest Ecology and Management 176, 253–264.

Dhyani, S.K., Tripathi, R.S., 1999. Tree growth and crop yield under agrisilvicultural practices in north-east India. Agroforestry Systems 44, 1–12.

Diemont, S.A.W., Martin, J.F., 2009. Lacandon Maya ecological management: sustainable design for subsistence and environmental restoration. Ecological Applications 19, 254–256.

Dixon, R. K., Brown, S., Solomon, R. A., Trexler, M. C., and Wisniewski, J. 1994. Carbon pools and flux of global forest ecosystem. Science 263: 185-190.

Farwig, N., Sajita, N., Bohning-Gaese, K., 2009. High seedling recruitment of indigenous tree species in forest plantations in Kakamega Forest, western Kenya. Forest Ecology and Management 257, 143–150.

Fonseca, F., Figueiredo, Tomas de, Martins, A., 2011. Survival and growth of mixed forest stands installed in Mediterranen Region: effects of site preparation intensity. Forest Ecology and Management 262, 1905–1912.

Gaur, R.D., 1999. Flora of the District Garhwal North West Himalaya (with ethanobotanical notes). Transmedia Publication, Srinagar (Garhwal), India.

Gibbs HK, Brown S, Niles JO and Foley JA. 2007. Monitoring and estimating tropical forest carbon stocks: making REDD+ a reality. *Environ. Res. Lett*. 2 045023 (13pp).

Gilmour, D.A., King, G.C., Applegate, G.B., Mohns, B., 1990. Silviculture plantation forest in central Nepal to maximize community benefits. Forest Ecology and Management 32, 173–186.

Guo, L.B., Gifford, R.M., 2002. Soil carbon stocks and land use change: a meta nalysis. Global Change Biology 8, 345–360.

Hairiah K, Dewi S, Agus F, van Noordwijk M, Rahayu S, Velarde SJ. 2010. *Measuring Carbon Stocks Across Land Use Systems: A Manual*. Bogor, Indonesia. World Agroforestry Centre (ICRAF), SEA Regional Office, Brawijaya University and ICALRRD (Indonesian Center for Agricultural Land Resources Research and Development) at www.worldagroforestrycentre.or/seaHajjar, R., Jarvis, D.I. and Gemmill-Herren, B. 2008. The utility of crop genetic diversity in maintaining ecosystem services, Agriculture, Ecosystems and Environment, Vol. 123 No. 4, pp. 261-270.

Hayes, T., Persha, L., 2010. Nesting local forestry initiatives: revisiting community forest management in a REDD+ world. Forest Policy and Economics 12, 545– 553.

He, J., Zhou, Z., Weyerhaeuser, H., Xu, J., 2009. Participatory technology development for incorporating non-timber forest products into forest restoration in Yunnan, Southwest China. Forest Ecology and Management 257, 2010–2016.

Houghton, R.A., 2007. Balancing the global carbon budget. Annual Review of Earth and Planetary Sciences 35, 313–347.

Jackson, M.L., 1962. Soil Chemical Analysis. Blackwell, Oxford, UK. Jackson, N.A., Wallace, J.S., Ong, C.K., 2000. Tree pruning as a means of controlling water-use in an agroforestry system in Kenya. Forest Ecology and Management 126, 133–140.

Jimenez, J.J., Lal, R., Leblanc, H.A., Russo, R.O., 2007. Soil organic carbon pool under native tree plantations in the Carbbean lowlands of Costa Rica. Forest Ecology and Management 24, 134–144.

Johnson, E.A., Miyanishi, K., 2008. Testing the assumptions of chronosequences in succession. Ecology Letters 11, 419–431.

Kamau D M, Spiertz JHJ and Oenema O. 2008. Carbon and nutrient stocks of tea plantations differing in age, genotype and plant population density. *Plant Soil* 307:29–39.

Knapp, B.O., Wang, G.G., Walker, J.L., Cohen, S., 2006. Effects of site preparation treatments on early growth and survival of planted longleaf pine (Pinus palustris Mill.) seedlings in North Carolina. Forest Ecology and Management 226, 122– 128.

Kuntadter, P., Chapman, E. and Sabhasri, S. 1978. Farmers in the Forests: Economic Development and Marginal Agriculture in Northern Thailand. Honolulu: The University of Hawaii Press for East-West Center.

Kurnianto S. and Murdiyarso D. 2010 *Forest carbon database: a Web-based carbon stock data repository and exchange system.* CIFOR, Bogor, Indonesia. 16p.

Laclau, P., 2003. Biomass and carbon sequestration of ponderosa pine plantations and native cypress forests in northwest Pantagonia. Forest Ecology and Management 180, 317–333.

Laganière, J., Angers, D.A., Parè, D., 2010. Carbon accumulation in agricultural soils after afforestation: a meta-analysis. Global Change Biology 16, 439–453.

Lamb, D., Gilmour, D., 2003. Rehabilitation and Restoration of Degraded Forests, IUCN, Gland, Switzerland and Cambridge, UK and WWF, Gland, Switzerland,110pp.

Lamb, D., Erskine, P.D., Parrotta, J.A., 2005. Restoration of degraded tropical forest landscapes. Science 310, 1628–1632.

Lasco RD. 2002. Forests carbon budgets in Southeast Asia following harvesting and land cover change. *Science in China* (series C), Vol. 45: 55-64.

Lee, E.W.S., Han, B.C.H., Corlelt, R.T., 2005. Natural regeneration in exotic tree plantations in Hong Kong, China. Forest Ecology and Management 212, 358–366.

Liang, L., Shen, L., Yang,W., Yang, X., Zhang, Y., 2009. Building on traditional shifting cultivation for rotational agroforestry: Experiences from Yunnan, China, *Forest Ecology and Management* 257 (2009) 1989–1994

Liang L., Sengtaheuanghoung O., and Takehashi S. 2010. Land use change, cause, and consequence in Montane Mainland Southeast Asia: A case study in Northern Laos, in *Meeting Climate Change Challenges in Transboundary Basins: Role of Sciences*, CECAR Series No.4, UNU-ISP, Tokyo, Japan, ISBN: 978-92-808-8027-4

Maikhuri, R.K., 1993. Evaluation of some multipurpose trees in traditional agroforestry of Garhwal Himalaya. Nitrogen Fixing Tree Research Report 1, 11–13.

Maikhuri, R.K., Saxena, K.G., Rao, K.S., 1995. Experiences in developing a village agroforestry project in Garhwal Himalaya, India. International Tree Crops Journal 8, 213–221.

Maikhuri, R.K., Semwal, R.L., Rao, K.S., Saxena, K.G., 1997. Rehabilitation of degraded community lands for sustainable development in the Himalaya: a case study in Garhwal Himalaya, India. International Journal of Sustainable Development and World Ecology 4, 192–203.

Maikhuri, R.K., Semwal, R.L., Rao, K.S., Singh, K., Saxena, K.G., 2000. Growth and ecological impacts of traditional agroforestry tree species in central Himalaya, India. Agroforestry Systems 58, 257–272

Mascaro, J., Hughes, R.F., Schnitzer, S.A., 2012. Novel forests maintain ecosystem processes after the decline of native tree species. Ecological Monograph 82, 221–228.

Mertz, O. 2009. Trend in shifting cultivation and the REDD mechanism. *Current Opinion in Environmental Sustainability*. Volume 1, Issue 2, December 2009, Pages 156-160

Mokany K, Raison J R, and Prokushkin AS, 2006. Critical analysis of root-shoot ratios in terrestrial biomes. *Global Change Biolology* 12: 84-96.

Mon, M.S., Mizoue, N., Htun, N.Z., Kajisa, T., Yoshida, S., 2012. Factors affecting deforestation and forest degradation in selectively logged production forests: a case study in Myanmar. Forest Ecology and Management 267, 190–198.

Mulyoutami, E., Rismawan, R., Joshi, L., 2009. Local knowledge and management of simpukng (forest gardens) among the Dayak people in East Kalimantan, Indonesia. Forest Ecology and Management 257, 2054–2061.

Myers, N., Mittermeier, R.A., Mittermeier, C.G., da Fonseca, G.A.B., Kent, J., 2000. Biodiversity hotspots for conservation priorities. Nature 403, 853–858.

Newby, J.C., Cramb, R.A., Sakanphet, S., McNamara, S., 2012. Smallholder teak and agrarian change in Northern Laos. Small-scale Forestry 11, 27–46.

Ogawa, H., K. Yoda, K. Ogino and T. Kira. 1965. Comparative ecological studies on three main types of forest vegetation in Thailand. II. Plant Biomass. Nature and Life in Southeast Asia 4 : 49-80.

Panta, M., Kim, K., Joshi, C., 2008. Temporal mapping of deforestation and forest degradation in Nepal: applications to forest conservation. Forest Ecology and Management 256, 1587–1595.

Paul, K.I., Polglasc, P.J., Nyakuengama, J.N., Khanna, P.K., 2002. Change in soil carbon following afforestation. Forest Ecology and Management 168, 241–257.

Piotto, D., Craven, D., Montagnini, F., Alice, F., 2010. Silvicultural and economic aspects of pure and mixed native tree species plantations on degraded pasturelands in humid Costa Rica. New Forests 39, 369–385.

Potvin, C., Mancill, L., Buchmann, N., Monteza, J., Moore, T., Murphy, M., Turner, B.L., Wilcke, W., Zeugin, F., Wolf, S., 2011. An ecosystem approach to biodiversity effects: carbon pools in a tropical tree plantation. Forest Ecology and Management 261, 1614–1624.

Rao, K.S., Pant, R., 2001. Land use dynamics and landscape change pattern in a typical micro watershed in the mid elevation zone of central Himalaya, India. Agriculture, Ecosystems and Environment 86, 113–124.

Rao, K.S., Maikhuri, R.K., Saxena, K.G., 1999. Participating approach to rehabilitation of degraded forest lands: a case study in high altitude village of Indian Himalaya. International Tree Crops Journal 10, 1–17.

Rerkasem, K. 2000. Chiang Mai Activity 1999-2000. UNU-PLEC Annual Report. Chiang Mai University. 52 p.

Rerkasem K., Yimyam N., and Rerkasem B. 2009. Land use transformation in the mountainous mainland Southeast Asia region and the role of indigenous knowledge and skills in forest management. In Rerkasem K., Yimyam N., and Rerkasem B., 2009. *Forest Ecology and Management* (257): 2035–2043.

Rytter, R.-M., 2012. The potential of willow and poplar plantations as carbón sinks in Sweden. Biomass and Bioenergy 36, 86–95.

Saxena, K.G., Rao, K.S., Sen, K.K., Maikhuri, R.K., Semwal, R.L., 2001. Integrated natural resource management: approaches and lessons from the Himalaya. Conservation Ecology 5, 14.

Schroth, G., 1999. A review of belowground interactions in agroforestry, focusing on mechanisms and management options. Agroforestry Systems 43, 5–34.

Semwal, R.L., Maikhuri, R.K., Rao, K.S., Singh, K., Saxena, K.G., 2002. Crop productivity under differently lopped canopies of multipurpose trees in central Himalaya, India. Agroforestry Systems 56, 57–63.

Semwal, R.L., Maikhuri, R.K., Rao, K.S., Sen, K.K., Saxena, K.G., 2003. Leaf litter decomposition and nutrient release patterns of six multipurpose tree species of central Himalaya, India. Biomass and Bioenergy 24, 3–11.

Shankar, U., Lama, S.D., Bawa, K.S., 1998. Ecosystem reconstruction through 'taungya' plantations following commercial logging of a dry, mixed deciduous forest in Darjeeling Himalaya. Forest Ecology and Management 102, 131–142.

Sharma, G., Sharma, R., Sharma, E., 2009. Impact of stand age on soil C, N and P dynamics in a 40-year chronosequence of alder-cardamom agroforestry stands of the Sikkim Himalaya. Pedobiologia 52, 401–414.

Sharma, C.M., Baduni, N.P., Gairola, S., Ghildiyal, S.K., Suyal, S., 2010. Tree diversity and carbon stocks of some major forest types of Garhwal Himalaya, India. Forest Ecology and Management 260, 2170–2179.

Sheikh, M.A., Kumar, M., Bussman, R.W., 2009. Altitudinal variation in soil organic carbon stock in coniferous subtropical and broadleaf temperate forests in Garhwal Himalaya. Carbon Balance and Management 4, 1–6.

Singh, K.A., Rai, R.N., Patiram, Bhutia, D.T., 1989. Large cardamom (Amomum subulatum Roxb.) plantation – an age old agroforestry system in Eastern Himalayas. Agroforestry Systems 9, 241–257.

Singh, K., Maikhuri, R.K., Rao, K.S., Saxena, K.G., 2008. Characterizing land-use diversity in village landscapes for sustainable mountain development: a case study from Indian Himalaya. Environmentalist 28, 429–445.

Singh, S.K., Pandey, C.B., Sidhu, G.S., Sarkar, D., Sagar, R., 2011. Concentration and stock of carbon in the soils affected by land uses and climates in the western Himalaya, India. Catena 87, 78–89.

Smukler, S., and Palm, C. 2009. Agriculture and Climate Change: An Agenda for Negotiation in Copenhagen For Food, Agriculture, and the Environment Monitoring, Reporting, and Verification Methodologies for Agriculture, Forestry, and Other Land Use, International Food Policy Research Institute (IFPRI), Focus 16 Brief 8, May 2009.

Sokal, R.R., Rohlf, F.J., 1981. Biometry. The Principles and Practice of Statistics in Biological Research. W.H. Freeman & Company, New York, USA.

Sood, K.K., Mitchell, C.P., 2009. Identifying important biophysical and social determinants of on-farm tree growing in subsistence-based traditional agroforestry systems. Agroforestry Systems 75, 175–187.

Suraswadi, P., Thomas, D. E., Pragtong, K., Preechapanya, P. and Weyerhaeuser, H. 2004. Northern Thailand: Changing smallholder land use patterns. Agriculture Ecosystems and Environment 104: 355-384.

Takeuchi K, Brown RD, Washitani I, Tsunekawa A, Yokohari M. (eds) 2002. Satoyama: the traditional rural landscape of Japan. Springer, Tokyo.

Thapa, B., Sinclair, F.L., Walker, D.H., 1995. Incorporation of indigenous knowledge and perspectives in agroforestry development. I. Review of methods and their application. Agroforestry Systems 30, 249–261.

Tiwari, M., Singh, S.P., Tiwari, A., Sundriyal, R.C., 2003. Effect of symbiotic associations on growth of host Coriara nepalensis and its facilitative impact on oak and pine seedlings in the Central Himalaya. Forest Ecology and Management 184, 141–147.

Tsutsumi, T., Yoda. K., Sahunalu, P., Dhanmanonda, P., and Prachaiyo, B. 1983. Forest: felling, burning and regeneration. In K. Kyuma and C. Pairitra (eds.). Shifting cultivation. (pp. 13-26). Tokyo.

van Breugel, M., Hall, J.S., Craven, D.J., Gregoire, T.G., Park, A., Dent, D.H., Wishnie, M.H., Mariscal, E., Deago, J., Ibarra, D., Cede~no, N., Ashton, M.S., 2011. Early growth and survival of 49 tropical tree species across sites differing in soil fertility and rainfall in Panama. Forest Ecology and Management 261, 1580–1589.

van Noordwijk, M., Minang, P.A., Dewi, S., Hall, J., Rantala, S. 2009. Reducing Emissions from All Land Uses (REALU): The Case for a whole landscape approach. *ASB PolicyBrief* 13. ASB Partnership for the Tropical Forest Margins, Nairobi, Kenya. Accessible at http://www.asb.cgiar.org/pdfwebdocs/ASBPB13.pdf

van Oudenhoven, F.J.W., Mijatovic, D., and Eyzaguirre, P.B. 2010. Bridging managed and natural landscapes: The role of traditional (agri)culture in maintaining the diversity and resilience of social-ecological systems, in Bélair C., Ichikawa K., Wong B.Y. L., and Mulongoy K.J. (Editors) (2010).

Walker, L.R., Wardle, D.A., Bradgett, R.D., Clarkson, B.D., 2010. The use of chronosequences in studes of ecological succession and soil development. Journal of Ecology 98, 725–736.

Wangda, P., Ohsawa, M., 2006. Structure and regeneration dynamics of dominant tree species along altitudinal gradient in a dry valley slopes of the Bhutan Himalaya. Forest Ecology and Management 230, 136–150.

Wen-Jie, W., Ling, Q., Yuan-Gang, Z., Dong-Xue, S., Jing, A., Hong-Yan, W., Guan-Yu, Z., Wei, S., Xi-Quan, C., 2011. Changes in soil organic carbon, nitrogen, pH and bulk density with the development of larch (Larix gmelinii) plantations in China. Global Change Biology 17, 2657–2676

Yimyam, N., Rerkasem, B. and Rerkasem, K. 2005. Shifting agriculture in northern Thailand: Land use changes and alternative management for sustainable production and improvement of livelihoods. Paper presented at the international workshop on Shifting Agriculture, Environmental Conservation and Sustainable Livelihoods of Marginal Mountain Societies. Organized by the Jawaharlal Nehru University (JNU) and the United Nations University (UNU). 6-10 October 2005. National Institute of Rural Development (NIRD), North-Eastern Regional Centre, Jawaharnagar, Guwa hati, India.

Yimyam, N. 2006. Fallow regeneration and upland rice yield variation in a system of shifting cultivation with Pada (Macaranga denticulata (BL.) Muell. Arg) as the fallow enriching species in northern Thailand. Ph.D. Thesis. Chiang Mai University. 285 p.

Appendix

Annex 1: *Summary report of the inception workshop of the join UNU-CMU-NAFRI project on "Critical analysis of effectiveness of REDD: for forest communities and shifting cultivation, based on lessons learnt from conservation efforts in Laos and Thailand", 17-19 January 2011, Chiang Mai, Thailand*

1. Background

Chiang Mai University (CMU) and United Nations University Institute for Sustainability and Peace (UNU-ISP), with the support of the Asia-Pacific Network for Global Change Research (APN), jointly organized the project inception workshop "REDD+ for Forest Communities" in Chiang Mai, Thailand from 17 to 19 January 2011. The workshop included two days of in-house discussion and one day to visit the Thai project study site, Tee Cha Village in Sop Moei District, Mae Hong Son Province of the Northern Thailand.

The objectives of the workshop were

- Review the project goals and expected outcomes
- Discuss and finalize the project methodology
- Discuss and finalize the project workplan and responsibilities
- Initiate the field work in Thailand

Overview of the workshop

Monday 17 January 2011:

- Welcome remarks
- Overview of the project, objective and study site
- Session I: Community-based monitoring of land use and forest
- Session II: Community-based monitoring of land use and forest
- Session III: Payment for ecosystem services and livelihoods
- Session IV: Integration of policy

Wednesday 18 January 2011: Field visit to *Ban Tee Cha*

- Group meeting with staff and village headman
- Field walk observing village landscape and land use practices
- Meet with village group and local officials to discuss problems, ideas and history of forest management

Thursday 19 January 2011:

- Review and discussion of the work plan and responsibilities
- Budget

2. Participants

The workshop was attended by

Prof. Theera Visitpanich, Dean, Faculty of Agriculture, Chiang Mai University

Prof. Benjawan Rerkasem, Faculty of Agriculture, Chiang Mai University

Prof. K.G. Saxena, School of Environmental Sciences, Jawaharlal Nehru University (JNU)

Mr. Oroth Sengtaheuanghoung, National Agriculture and Forestry Research Institute (NAFRI)

Dr. Narit Yimyam, Highland Research and Training Center, Chiang Mai University (CMU)

Mr. Luohui Liang, United Nations University Institute for Sustainability and Peace

Dr. Shimako Takahashi, United Nations University Institute for Sustainability and Peace

Dr. Jintana Kawasaki, United Nations University Institute for Sustainability and Peace

Ms. Alva Lim, United Nations University Institute for Sustainability and Peace

3. Summary of the Discussion

1. Prof. Theera Visitpanich, Dean of the Faculty of Agriculture, Chiang Mai University warmly welcomed the participants to Chiang Mai. He highlighted the value of the project and that it complemented well with recent efforts the University is doing with regards to forest carbon stocks.

2. As Chair of the first session, Prof. Rerkasem emphasized Prof. Visitpanich's sentiments, and then invited all participants to briefly introduce themselves before beginning the presentations.

3. In the first presentation, Mr. Liang gave an overview of the new joint project between UNU-CMU-NAFRI with the support of APN, titled "Critical analysis of effectiveness of REDD+ for forest communities and shifting cultivation, based on lessons learnt from conservation efforts in Laos and Thailand". As explained in the programme and project concept, the project will be of 3 year duration, starting from 9 December 2010, and would include two project sites: one site in Laos and one site in Thailand; and two associate sites: one site in India and one site in China.

4. The aims of the Project are to:
(1) Assess the potential social, economic and environmental challenges and opportunities of REDD+ for selected communities in Laos and Thailand. Lessons will be drawn from past/ongoing forest conservation policies;

(2) Provide much-needed scientific evidence on the potential co-benefits of traditional agro-forestry practices and comparing it with alternative land-uses; and,

(3) Develop participatory community-based MRV mechanisms for REDD+. With our findings we hope to assist the pro-poor design and implementation of REDD+, improve the well-being of forests dependent communities and integrate traditional agro-forestry as a climate change mitigation agenda.

5. In simple terms, he explained that the core objectives of the project are to identify technological and policy options and develop national capacity that promote synergies and co-benefits of REDD+ in the management of community forest and agroforest systems in shifting cultivation areas. Specifically, the synergies and co-benefits, as well as trade-offs could include:

- Food and livelihood security
- Carbon storage enhancement from REDD+
- Biodiversity conservation
- Watershed services
- Enhancing adaptation to climate change

6. Mr. Liang also provided some of the key outputs to be expected from the research project, in particular: methodologies for comprehensive carbon storage assessment of short, medium and long forest fallows; quantified comparisons of carbon storage and sequestration of forest-agriculture

landscapes; data, research materials and methodologies on estimates of socioeconomic impacts, biomass and soil carbon, biodiversity, RS/GIS for Laos and Thailand; development of bottom-up processes in Measuring, Reporting and Verification Systems (MRV); and report and recommendations for prevention and mitigation of possible adverse impacts of REDD on forest communities and optimal integration of agriculture-forest management systems into REDD+. Finally, it is hoped that the project would lead to increased face-to-face engagements between local communities, policymakers and scientific community on REDD+ and shifting cultivation.

Lao Project Site: Laksip Village, Luang Prabang District, Luang Prabang Province

7. Mr. Oroth **Sengtaheuanghoung** presented an overview of the Laos project study site: Laksip Village, near Luang Prabang City in Luang Prabang Province in Northern Laos. Laksip village consists of 95 households and has a population of 450 people. The major ethnic group is the Khmu (89%), followed by the Lao Lum (9.5%) and the Hmong (1.5%). The main occupation of the villagers is the practice of shifting cultivation (62%) with rice, vegetables and livestock as the main source of on-farm income. However, rice yields (ton/ha) have been declining, particularly during 1990-2009 and the village is currently undergoing changes in cropping patterns away from rice and towards teak plantations; from around 10 hectares of teak plantations in 1995 to more than a 100 hectares by 2008. In the same period, the area of rice production has dropped from 60 hectares to a little over 20 hectares by 2008. More notably, the average fallow period for annual crops has dropped from 8 years to 3 years from 1970 to 2009 because land resources for shifting cultivation have been reduced through the policy implementation. Lack of viable methods to sustain rice yield in the reduced cycle of fallows, local people are converting their fallows to teak plantation and undertake off-farm job for cash income to purchase rice.

8. The categorization of land use in Laksip is as follows: *Conservation forests* (Evergreen, Mix deciduous, Dry Dipterocarpus forest) are areas designated for protection and conservation of natural resources (plant, wild life species, biodiversity), and for cultural, tourism and educational purposes;

9. *Protection forests* (Dry Dipterocarpus, Bamboo, and Old fallow forests >10 years) are areas designated as forest lands for the purpose of protecting watershed areas, rivers, roads, and controlling of soil erosion, land degradation, etc;

10. *Production forests* (Bamboo, Old Fallow) are defined as natural or planted forests for utilization purposes such as for harvesting timber and forest products to meet the social needs and livelihoods of local peoples; and

11. *Production land / Agricultural forests* (Teak plantations of ages > 10 years, 5-10 years, and < 5 years, Fallow land, and Annual Crop Fields) is defined as land that can be used for agricultural production purposes including tree, crop plantation and animal farming.

12. *Construction or housing lands* are areas where construction is permitted. *Construction or housing lands* are areas where construction is permitted.

Thai Project Site: Ban Tee Cha, Sop Moei District, Mae Hong Son Province

13. Dr. Narit **Yimyam** presented details of Tee Cha Village ('Ban Tee Cha' in Thai) in Sop Moei District, Mae Hong Son Province. It is located 246km from Chiang Mai in the mountains of Northern Thailand, the village lies at an altitude of 700-900 mean sea level (MSL).

14. The people of Tee Cha belong to the Karen ethnic minority group. There are 48 households with a population size of 172, and one primary school. All households are involved in subsistence farming based on short rotational shifting cultivation. Main sources of case income come from cash crop e.g. chilli, non-timber forest products e.g. mushroom, bee honey, bamboo shoot and bamboo worm, and wage labour e.g. longan picking.

15. The area experiences three seasons: rainy season (June-September), cool (November-February) and summer (March-May). Average annual rainfall is 2,104 millimetres. Soils are poor loamy clay with a low pH.

16. One of the challenges faced by the people of Tee Cha is land degradation from deforestation, and soil erosion and degradation. This has reportedly been a direct consequence of the forced shortening of the fallow cycle due to reduction of land resources for shifting cultivation through the policy implementation. This has been part of a long term development strategy by the government to replace opium production under shifting cultivation with alternative cash crops. Most recently, the Royal Forestry Department has introduced a law that enforces land restrictions over the practice of traditional shifting cultivation and expands forest conservation areas. As a result, fallow periods have been reduced from 10 to 7 years. In addition to this, other pressures from increased population, unsecure tenure and conservation demands have lead to increased tensions. In order to cope with the reduced cycle of fallow, local people are innovative to enrich soil through planting of pada in Thai (*Macaranga Denticulate),* a tree has led to maintenance of upland rice yield with enriching property. Rice yields and biomass in the fallow of dense *Macaranga* are higher than those in the fallow of sparse *Macaranga.*

17. Overall, government policies have shown to be the main drivers of land use change in Northern Thailand. With pressures on land and the absence of legal rights, traditional land tenures have changed to certain extent. Individual ownerships are becoming the common pattern in agricultural land. In Karen village, community still maintains traditional decision in managing land for upland rice. Natural forests are kept under community control in most of the highland villages, regardless of ethnic background and traditional land management practices.

18. The land use change, especially the reduction of fallow periods and expansion of cash cropping happening at two above project sites represent a general trend in the Mountainous Region of Mainland Southeast Asia (MMSEA) home to a rich bio-cultural diversity and source of the Mekong and other major rivers. The land use change has implications on biodiversity, carbon storage, watershed service as well as local livelihoods. The project is timely to assess carbon storages under different land use patterns and to help local community and government to identify synergy between biodiversity, carbon storage and local livelihoods in the implementation of REDD+.

Session I: Land use and carbon storage dynamics,

19. In this session, Prof. K.G. Saxena assessed land use/ cover change and its implication on carbon storage using a case study in India. In order to understand the change in time and space, land use/cover will need to be mapped at 2-3 points of time. Enhancing thematic details, including carbon stocks in the assessment may be achieved through integrating tools-topographic/revenue/forest maps as well as remote sensing data, GIS, and plot sampling. Plot sampling can be done through repeated measurements on a single site, paired sites or chronosequences where neighbouring sites experienced land use change at different times in the past.

20. Coupling of ecological and socio-economic system is necessary to appreciate trade-offs of carbon stock dynamics. Assessment of strengths and weaknesses of land use systems and practices will help find out win-win options to optimize ecosystem functions, ecosystem goods and services, reducing dependency, increase resilience/resistance of the social-ecological systems. High soil organic matter stores high carbon, but would not necessarily contribute to the soil quality due to low labile carbon or to the soil health due to abundance of pathogens. Thus, understanding thresholds is essential in assessing potential synergy between carbon storage and other ecosystem services. Nutrient transfer among different land uses, such as from forests to agriculture is important to understand the landscape process. Environmental science will need to be linked with policy and human dimensions so as to harmonize diverging goals of different stakeholders.

21. With regard to methods of assessment, Prof. Saxena explained four important components in

choice of methods: (a) Phytosociology concerning number, size, shape and distribution of quadrates; taxonomic resolution; growth forms/life forms and plant functional types (trees, shrubs and herbs - epiphytes; non-vascular plants), (b) Soil physical-chemical properties concerning bulk density, soil texture, pH, Cation Exchange Capacity (CEC), water holding capacity, total and/or available nutrients (major and/minor nutrients), plough layer or multiple layers covering the whole profile, (c) Carbon calculation concerning biomass component relations between above ground and below ground, allometry, conversion of biomass to C using 48-50% of oven dry biomass, (d) Land use - land cover dynamics concerning spatial and temporal scale of observation and mapping, classification scheme (Level I, II, III), interpretation tools, NDVI etc. Existing methods will need to be reviewed to develop a suitable methodology for the project.

22. In connection, Prof. Saxena discussed data quality. Accuracy of data depends on definition of variables, time of measurement and other factors. Choice of methods is affected by costs of measurement and accessibility of sampling plots affect. He also explained a few common indexes in assessment, such as (a) Carbon Pool Index (CPI) which is total C of a given land use/Total C of the reference land use, (b) Lability Index (LI) which is labile carbon content of a given land use/Non-labile carbon content of a given land use, (c) Carbon Management Index (CMI) = CPI * LI * 100, and (d) Landscape CMI' = sum of the products of multiplication of the CMI values of different land uses and their relative areas (%).

23. Using the case study on Ratgad Watershed in Central Himalaya India, Prof. Saxena illustrated that the main land use change from 1963 to 2005 was abandonment of some agricultural fields while forest areas remain unchanged. Intensity of carbon stock in home gardens is more than those in pine forests and close to those in oak forests. The total carbon in the watershed increased from 1964-2005. However, the total carbon increased from 1964-1998, but declined from 1998-2005.

Session II: Community-based monitoring of land use and forest

24. In this session, Dr. Shimako **Takahashi** started her presentation on community-based MRV with a brief review of REDD+ mechanisms. Expanding agriculture is often at expense of forest areas. A trade-off between agriculture and forestry has to be made, especially new recognition of high carbon stocks and other values in the forests. REDD+ provides payment to avoid forest conversion to agricultural and other land uses. The payment from REDD+ has to compete with incentives arising from forest conversion. Moreover, the REDD+ payment is based on reliable and credible system of monitoring, reporting and verification (MRV) to assess changes in forest carbon stocks. MRV should be cost-effective, but also compatible with a multiple levels of payment scheme at global, national, and local levels.

25. Forest area changes (number of hectare) and carbon stock change estimation/carbon density (carbon per hectare) will need to be monitored. The measurement is often based on remote sensing and ground verification. The national forest monitoring system, verification, and reference emission levels will need to take into account national circumstances. Transfer of scientific measurement to the MRV system will need to be fostered to develop robust and credible MRV system. MRV at community-level will need to build on interest and capacity of forest communities and indigenous people. Capacity development is required to enhance communities in MRV. In addition to carbon credits for good practices, other incentives should be considered to supporting alternative livelihood options, enhancing land tenure and local resource rights, intensifying productivity on non forest lands. Pressure to reduce deforestation needs to be spread across many levels to reduce the burden on forest communities.

Session III: Payment for ecosystem services and livelihoods

26. In this session, Dr. Jintana **Kawasaki**'s presentation was focused on concept of opportunity costs and trade-offs between forests and alternative land uses. The opportunity cost of forest land is defined as the difference between the benefits provided by the forest and the alternative land uses.

Benefits of conserving forest lands would include values of non-timber forest products as well as credits due to reduced emission from deforestation and forest degradation, and intangible values due to cultural services and biodiversity conservation. Benefits for alternative land use, for example, agricultural land uses would include values of agricultural crops and timber harvesting. The credits or payment from REDD+ as incentives for forest conservation will need to be comparable to the opportunity cost in order to avoid forest conversion. Dr. Kawasaki noted the presence of shifting cultivators is not necessarily the cause of deforestation as this still depends on the type of forest. Therefore, economic assessment is to examine economic profitability of the shifting cultivation and permanent cultivation, and on the economic adjustment process of how shifting cultivators might adopt fallow rotation system as a means to naturally improve agricultural productivity. Dr. Kawasaki has also proposed the work plan to assess opportunity costs. In Year one, assessment would cover the socio-economic characteristics of people and communities, including cost-benefits for agricultural production, and the ratio between on-farm and off-farm income, direct and indirect benefits of forest. In Year two, the investigation will examine and compare the opportunity costs of alternative land uses with the traditional agro-forestry practices, including values of carbon storage. In Year 3, appropriate strategy will be recommended for forest conservation to take into account social and economic benefits and beneficiaries of land uses.

Session IV: Integration of policy

27. In this session, Ms. Alva **Lim** reviewed the current policy-debate on REDD+ at the international level and discussed its Implications for our project. Kyoto Protocol only recognizes offsets from projects that create new forests, not from projects that protect existing ones. As a result of afforestation and reforestation policies global forest areas expanded, mainly, but global carbon stocks decreased because of tropical deforestation and degradation. Thus, REDD+ is important to main forest carbon. The negotiation on REDD+ to be included in the next commitment period (post-Kyoto 2012) is underway. The COP16 of UNFCCC at Cancun, Mexico, December 2010 has decided to encourages developing country Parties to contribute to mitigation actions in the forest sector by undertaking the following activities, as deemed appropriate by each Party and in accordance with their respective capabilities and national circumstances: (a) Reducing emissions from deforestation; (b) Reducing emissions from forest degradation; (c) Conservation of forest carbon stocks; (d) Sustainable management of forest; and (e) Enhancement of forest carbon stocks.

28. There is a debate on national criteria and procedures for establishing reference levels. Historical baselines need to adjust to 'national circumstances'. Historical baseline is estimated from past forest deforestation, forest degradation, carbon degradation (DDD) & resulting greenhouse gas (GHG) emissions over years. Business As Usual (BAU) baseline is projected emissions from DDD without REDD+ project. The reduced emission below the crediting baseline/Reference level as benchmark level (cap) would be entitled to receive credits. Reference level will be affected by national policies, including economic and rural development goals, land tenure, forestry policies, demographic policies, agricultural policies and energy policies.

29. Our project goes beyond REDD+ scope as it is currently negotiated not to cover soil carbon and non-forest land uses. The first step is to understand the current (pre-REDD+) situation and identify those land uses which are carbon rich and at high risk of conversion to other land uses. The second step is to project and map land use scenarios with or without REDD+, and compare net emissions from the land use scenarios with BAU baseline and the project reference level. For example, to receive carbon credits would require that fallow become longer in Tee Cha or the harvesting cycle of teak plantations become longer in Laksip. We also need to improve understanding of the drivers of deforestation/ degradation and local needs to develop other measures to address these root causes for forest conservation in addition to the carbon credits. Finally, Ms. Lim stressed that project outputs be fed into the national process.

Field visit to *Ban Tee Cha*

30. The field trip to Tee Cha Village, one of project sites in Northern Thailand offered a good opportunity for the workshop participants to appreciate different land uses with their ecosystem services in the village. The village land use pattern is composed of forests, agricultural land under shifting cultivation, permanent agricultural fields (paddy fields) and village settlements. Forests are further divided into conservation forest and headwater, community forests, utility forests and cemetery. The field trip started off with the group meeting with villagers who are used to work with Dr. Yimyam. These villagers then took participants to observe different land uses in the village.

31. The first land use observed was the utility forests where use of timber may be permitted. The Dipterocarpus forests are maintained in the utility forests. From point of the utility forests participants had observed agricultural land under different age of fallow at a distance. These fallows are largely covered by *Macaranga* bush to enrich soil in the reduced cycle as previous study revealed. Forests along the boundary of these fallows were protected to mark land property. Carbon stocks in the fallows may be determined according to the age of the *Macaranga* bush. The second land use observed was paddy fields. Part of paddy fields was already abandoned due to lack of water. The third land use observed was the community forests in which conversion to bamboo and coffee plantations are taking place. The fourth land use observed was the conservation forests and headwater where tree planting had been made to enrich the forests.

32. During the field trip, participants also observed village off-farm activities, such as local rice whisky making. Finally, participants and villagers wrapped up the field trip at the field demonstration site of the Royal Forest Department where various tree seedlings were prepared and distributed to encourage tree planting in the village. Villagers asked participants for advice on combating land degradation where *Macaranga* bush was sparse and the possible options for income generation. As *Cassia* trees have been already introduced to this village, villagers may try to plant *Cassia* trees in those fallows without much *Macaranga* and coppice them to enrich soils. As there are many orchids in the village forests and home gardens, identification and cultivation of some medicinal orchids may help villagers generate alternative incomes in addition to new cash crops such as Arabica coffee being experimented. Participants appreciated the villagers for their time to share their knowledge about forests in the village before departure. During the field trip, participants also observed village off-farm activities, such as local rice whisky making. Finally, participants and villagers wrapped up the field trip at the field demonstration site of the Royal Forest Department where various tree seedlings were prepared and distributed to encourage tree planting in the village. Villagers asked participants for advice on combating land degradation where *Macaranga* bush was sparse and the possible options for income generation. As *Cassia* trees have been already introduced to this village, villagers may try to plant *Cassia* trees in those fallows without much *Macaranga* and coppice them to enrich soils. As there are many orchids in the village forests and home gardens, identification and cultivation of some medicinal orchids may help villagers generate alternative incomes in addition to new cash crops such as Arabica coffee being experimented. Participants appreciated the villagers for their time to share their knowledge about forests in the village before departure.

Review and discussion of the work plan and responsibilities

33. Discussion on work plan started with review of an overall work plan for three years based on the project proposal prepared by UNU-ISP (See below). It was agreed that three main outputs will be achieved in Year One, including (1) Review and harmonization of carbon stock measurement with a manual, (2) Review of relevant policies on REDD+ and development of communication plan to participate in the policy process, and (3) Interim reports of carbon stock measurement at project sites in Thailand and Laos, and associate sites in India and China, including review of secondary data. UNU-ISP will be responsible for overall coordination of the project while CMU and NAFRI will manage field activities as well as national coordination. JNU will provide technical support to develop a manual on carbon stock measurement.

Project Work Plan: The main activities of this project will include

Year 1 Inception workshop to finalize agreement on study sites, project strategy and 3 year plan. National workshop and training on methodology for local communities and authorities. Remote sensing/GIS for land-use classification and tracking land-use change. Secondary data collection and census surveys;

Year 2 Household sampling surveys, field and laboratory work, including plot sampling for estimation of carbon storage intensity. National workshops for mid-term review and preliminary findings. Community academia engagements for bottom-up development of monitoring, measurement, reporting and verification (MRV) mechanisms; and

Year 3 Synthesis of project findings. Final international workshop to present findings to local officials, communities, researchers, policymakers and international community, develop policy recommendations, and future steps for collaboration.

Accordingly, the **project work plan will be as follows:**

Year 1 (2010/2011)	
Month/Year	**Detailed Activities**
December, 2010	Selection of project sites in Laos and Thailand, and project associate sites in India and China
January, 2011	Project inception workshop Thailand
March-May, 2011	Collection of secondary data
	Assessment of land use and ecological impacts of land use change by review of secondary data, including GIS data.
	Review of different methodologies for carbon stocks measurement at landscape level
	Review of forest policy of study countries
June, 2011	Project methodology workshop in Laos
July-September, 2011	Pre-test of methodologies for land classification, carbon stocks measurement at landscape level
November, 2011	Interim Report
Year 2 (2011/2012)	
January, 2012	International workshop in Thailand
January-May, 2012	Assessment of carbon storage in each project site
	Assessment of socio-economic community impact and opportunity costs of land use
June, 2012	National Workshop in Laos
July-September	Demonstration on good land management, including fallow enrichment for carbon sequestration
November, 2012	Interim report
Year 3 (2012/2013)	
December, 2012-April, 2013	Building local capacity in Measurement, reporting and verification (MRV)
May-July, 2013	Policy Analysis of forest resource management and REDD+
August, 2013	Final Project Workshop in Thailand
November, 2013	Final Report

34. The discussion finalized the work plan for Year I (See below). From March to June 2011, existing knowledge and information about the study sites with regards to the biodiversity, carbon stocks,

livelihoods, and traditional knowledge in forest, and soil management will be reviewed and knowledge gaps identified. The methodologies for measurement of carbon stocks (including biomass above ground, below ground, and soil organic matter) in the forested landscape in the contexts of national REDD process will be also reviewed. A methodology workshop will be held in June 2011 to harmonize methods across participating countries as the provisional project methodology. The provisional methodology will be then tested and finalized from July to September 2011. The pre-test will cover classification of land use and land cover, and sampling of plots in different land use and land cover categories. The land use and land cover mapping and carbon stock measurement in different land use/land cover categories will be carried out based on the approved project methodology from July to November 2011 and will continue in Year 2. From March to October 2011, all relevant policy for national REDD+ implementation will be reviewed and synthesized to help develop a communication plan for policy impact. After the work plan for Year One was finalized, the project budget was also agreed among project partners to implement the work plan for Year One. The project methodology workshop has been proposed to take place in Luang Prabang, Laos in June 2011. This forthcoming workshop will discuss the carbon stocks measurement at landscape level and to harmonize the national methods for a project methodology for comparable measurement across the study sites in Thailand and Laos as well as associate sites in India and China.

35. Finally, the workshop was closed with Dr. Takahashi's remarks to thank CMU's excellent organization of the workshop as well as valuable inputs of all workshop participants.

Detailed national work plan for Year I will:

Month/Year	Detailed Activities	Proposed Outcome
December, 2010	Selection of project sites (one site in Laos and one site in Thailand) and associate sites (one site in India and one site in China) through meeting with national coordinators, the meeting plan were: December 13, 2010 Selection of Project site in Laos; December 20-23, 2010 Project site in Thailand; and December 24, 2010 Associate site in India	Two project study sites and two associate sites
January 17-19, 2011	Project Inception Workshop in Chiang Mai, Thailand	The project goals and expect outcome of project, different project methodologies for each country, work plan, and responsibility
March-May, 2011	1) Data collection 2) Assessment of land use and impacts of land use change by using of GIS data base 3) Review and harmonization of methodologies for carbon stocks measurement at landscape level	1) Data sets for project sites including methodologies of carbon measurement, fallow management, land use of forest, forest community, forest policy, and etc. 2) Comparison of land use and impacts of land use change between forest land and agricultural land 3) Appropriate

		methodologies of carbon measurement across the region
June 27-29, 2011	Project methodology workshop in Laos	Different methodologies harmonized for carbon stocks measurement for each project site, and project work plan updated
July-September, 2011	Pre-test of methodologies for land classification, carbon stocks measurement at landscape level	Land use classification and carbon storage for each project site
March to October, 2011	All relevant policies for national REDD+ implementation will be reviewed and synthesized to help develop a communication plan for policy impact	A communication plan for policy impact
November 15, 2011	Preparation of project activity reports and detailed financial reports in Laos and Thailand, and summary reports in India and China	Tentative interim project report

Annex 2: *Summary report of project methodology workshop on "REDD+ for forest communities: Learning from forest conservation in Laos and Thailand", 19-21 June 2011, Luang Prabang, Laos and working manual for carbon stock estimation*

2.1 Summary report of project methodology workshop

1. Background

National Agriculture and Forestry Research Institute of Lao PRD (NAFRI) and United Nations University Institute for Sustainability and Peace (UNU-ISP), with the support of the Asia-Pacific Network for Global Change Research (APN), jointly organized the project methodology workshop "REDD+ for forest Communities" in Luang Phabang, Lao PDR from 19 to 21 June 2011 to bring together experts from UNU, Laos, Thailand and India and discuss the carbon stocks measurement at the landscape level. The workshop included two days of in-house discussion and one day to visit the Lao PDR project study site, Laksip Village which is located at ten kilometres from Luang Phabang City in the Northern Lao PDR.

The objectives of the workshop were 1) review different methodologies for carbon stocks measurement at landscape level, including the proposed methodology for each project site; 2) discuss and harmonize different methodologies as the project methodology; 3) initiate the field work in Laos; and 4) review project progress and plan forward.

Overview of the workshop

Sunday 19 June 2011:

- Welcome Remarks
- Overview of the project workshop and brief introduction to the associate project site in China
- Discussion of the work plan forward Session III: Proposed methods for carbon stocks measurement in Laos project site

Monday 20 June 2011: Field visit to Laksip Village

- Field walk observing village landscape and land use practices in both northern and southern parts of the Village
- Discussion of sampling methods in each land use practices for carbon stock measurement in the Village

Tuesday 21 June 2011:

- Harmonize and propose provisional project methodology with a special reference to Laksip Village site
- Discussion of the work plan forward

2. Participants

Name	Organization
Prof. Kazuhiko Takeuchi	UNU-ISP
Mr. Luohui Liang	UNU-ISP
Dr. Jintana Kawasaki	UNU-ISP
Prof. K.G. Saxena	Jawaharlal Nehru University
Prof. Kottapalli Sreenivasa Rao	University of Delhi
Mr. Oloth Sengtaheuanghoung	National Agriculture and Forestry Research Institute
Mr. Aloumsawath Chanphengxay	National Agriculture and Forestry Research Institute
Mr. Saysama Inthavong	National Agriculture and Forestry Research Center
Dr. Narit Yimyam	Chiang Mai University
Ms. Utumporn Chaiwong	Chiang Mai University

3. Summary of the Discussion

1. Mr. Oloth Sengtaheuanghoung, the Deputy Director of NAFRI-ALRC on behalf of NAFRI's Director-General warmly welcomed the participants to Luang Phabang and gave a brief outline of the workshop agenda.

2. The official welcoming remarks were given by Prof. Kazuhiko Takeuchi, Vice-Rector, United Nations University/ Director, Institute for Sustainability and Peace. He highlighted decisions of COP10/CBD and COP16/UNFCCC with regard to REDD+ and emphasized a particular need to integrate climate change and biodiversity policies, and to establish effective international frameworks on adaptation and REDD+ as well as that on mitigation.

3. Following the opening session, Mr. Luohui Liang, UNU-ISP, gave an overview of the workshop objectives in the context of the project works plan in 2011 and stressed that the project methodology need to conform to international standards as well as adapt to local circumstances of project sites.

4. The project work plan in 2011 is to:

(1) Different methodologies for carbon stocks measurement at the landscape level (i.e. to estimate carbon stocks above and below ground in different land uses in the landscape) need to be harmonized as the project methodology and applied in the project sites in Thailand and Laos, as well as the associate sites in India and China so that findings from different countries can be compared and synthesized at the regional level;

(2) Carbon stock at landscape level at all project sites will be measured along with land use mapping;

(3) Ongoing policy development on REDD+ in each country will be reviewed and synthesized to

develop a policy action plan so that project findings will be fed into the national process.

5. Mr. Liang explained the project concept and expected outcomes, including the methodology for the landscape level carbon stocks measurement, which is the main focus of this workshop. He also reviewed the 3 years of research design to identify co-benefits and synergy of forest carbon management and local livelihoods. He introduced two project sites where shifting cultivation is practiced: one site in Northern Laos and one site in Northern Thailand, and two associate sites: one site in North India and one site in Southwest China.

6. He also presented a brief introduction to the land use system in the Mangjing Village, the associate study site where tea production is the main source of income. There are two major types of tea production: one is traditional tea forests where tea is cultivated in natural forests and other is modern tea plantation on the terraces. These two types of tea production contrast in terms of carbon storage, biodiversity and sustainability. Recent appreciation of tea from the tea forests has helped revival of the traditional practice.

Session I: Carbon stocks measurement at landscape level with special reference to India

7. In this session, Prof. K.G. Saxena explained carbon stock estimation using a case study in India. Coupling of ecological and socio-economic system is necessary to appreciate trade-offs of carbon stock dynamics. Assessment of strengths and weaknesses of land use systems and practices will help find out win-win options to optimize ecosystem functions, ecosystem goods and services, reducing dependency, increase resilience of the social-ecological systems. Thus, implementation of national policies and measures and national strategies or action plans that could involve further capacity building, technology development and transfer, and results-based demonstration activities.

8. With regard to methods of carbon assessment, Prof. Saxena explained two measures: (1) measuring the stocks at two points of time; and (2) measuring the fluxes over a period of time.

9. Prof. Saxena discussed the following in details:

(1) In order to understand the change in time and spaces, land use/cover will need to be mapped through tools of RS/GIS. Plot sampling can be done through repeated measurement at different times. Through systematic sampling and stratified sampling, the assessment of carbon stock needs to cover carbon pools in aboveground biomass, roots, litter, and soil in different land uses in the village landscape.

(2) The assessment will also include participatory land use mapping and carbon inventory, identification and selection of land holdings having all land use/cover classes and covering the village landscape variability.

10. Aboveground biomass of woody plants (DBH.=>10 cm) is normally estimated through allometric model. The root biomass may be estimated as a percentage of the aboveground biomass. Biomass of understorey species with a DBH<10 cm is estimated by destructive sampling with a sample of material oven dried and weighed. Dead wood may be estimated to take into account the dropping of leaves. In conclusion, there is no universal standard for estimating biomass or carbon of a tree, which depends on local circumstances as well as availability of resources.

11. Prof. K.S. Rao discussed reduction of the emissions from deforestation and forest degradation (REDD+) with Indian case studies and potential REDD+ activities to increase carbon stocks or to avoid loss of carbon stocks in the forested landscape in the Indian Himalaya. . He explained diversity of the Himalayan ecosystems covers a wide range of mixed land uses under the categories of forests, settled farming, shifting agriculture and home gardens. Biomass measurement in these land uses often integrate different tools-remote sensing, on the ground verification, and stratified mapping.

12. Prof. Rao highlighted possible options for improvement of degraded ecosystems, including replaced ecosystem with creation of alternative ecosystem, and rehabilitated ecosystem with several components resembling original ecosystem. Recent conversion from traditional land use

system to intensive wet paddy field and tree crop plantation will have significant impact on biodiversity as well as carbon stocks in the landscape.

Session II: Proposed methods for carbon stocks measurement in Thailand project site

13. In this session, Dr. Narit Yimyam started his presentation on an overview of the land use system in the Thailand project study site: Tee Cha Village in Sob Moei District in Mae Hong Son Province. The land use system is composed of forests (conservation & head water forest, community forest and utility forest), agricultural land (shifting cultivation, permanent fields and paddy fields) and village settlement. He also explained tenure arrangement for each land uses.

14. Dr. Narit then explained the methodology the Thai team is using to measure carbon stocks in different land uses. Carbon storage in the forests was estimated as follow: Carbon storage = plant biomass x 0.5. Biomass of large tree (> 1.5 m high and diameter >15 cm girth at breast) was calculated by allometric equation: Tsutsumi et al. (1983) for hill evergreen; Ogawa et al. (1965) for dry dipterocarp, while small tree (>1.5 m high and diameter < 15 cm girth at breast) were measured by destructive sampling, i.e. cutting every plants at ground level in the area 2 m x 2 m. Plants were weighted directly and sub-sample of 3 kg was taken for oven dry at 80 ^{o} c for 48 hr for moisture content and biomass. Carbon stocks in agricultural land were also estimated by destructive sampling. Soil carbon storage was estimated based on the soil organic matter collected from the soil depth 0-30 cm. Carbon Storage (Cs) = 58% Organic matter x Soil mass in which Soil mass = Soil bulk density (g/cm^3) x Area (ha) x H Soil depth (cm).

15. With carbon storage of Thai forest above ground, Dr. Narit reviewed some previous studies and illustrated that it depended on type of forest. The total carbon in dry evergreen forest is about 70.29± 7.38 ton per ha, but hill evergreen is 142.32+3.36 ton per ha. He also explained amount soil carbon depend on type of land use such as 270 ton per ha for virgin forest, 200 ton per ha for second forest, and 80 ton per ha for crops. Results of this study will be compared with previous studies.

Session III: Proposed methods for carbon stocks measurement in Laos project site

16. In this session, Mr. Oloth Sengtaheuanghoung purposed the methods for the Laos study site. Using the case study on Nam Theun study site in Laos, two types of organic carbon stock could be distinguished: the above ground (including living biomass of tress, bamboos, lianas and dead biomass) in sample plots- 10 m x 10 m in size, and the below ground (roots). The assessment of the vegetation distribution was carried out on the basis of a 2,000 spot image in village with 1:35,000 map for ground check. The 9 sampling points per vegetation type were chosen. As result, the thickness of soil layers consider for the calculation of below ground organic carbon stock was not clearly defined that carbon stock was calculated down to 30 cm.

17. The methods for carbon stocks measurement in Laos project site: Laksip Village will depend on type of land use/cover. The currently total land area of Laksip is 1,746 ha consisting of three main land use types: forest land (including conservation forest, protection forest and production forest), production/agricultural land (crop production), and residential land. According to local terminology, forest land includes conservation forest, sacred forest, cemetery forest, and young forest while agricultural land includes old fallow forest, rotated fallow land, sifting cultivation, garden, and fish pond. For carbon stock measurement, conservation forest, sacred forest and cemetery forest are grouped as dense forest. The teak garden is divided into young teak 1-5 year old, medium teak 5-10 year old, and mature ld teak >10.

18. Biomass of large trees will be measured through allometric equation. Biomass of tree seedlings and other shrubs, herbs etc. will be determined by destructive sampling , i.e. cutting off the ground level. Plants were weighted directly and the data were med to estimate above ground biomass. Soil carbon stocks and fluxes in Laksip will be estimated based on soil organic matter. Mr. Oloth presented shifting cultivation could contribute to soil carbon storage. When plots were cleared and burned, 20 grams of carbon per kg of soil as biochar could get into soil profile.

19. Over 900 plant species are found in Laksip study site. Diversity indices were derived in order to compare the species richness, distribution and evenness in different land uses.

Field visit to Laksip Village

20. The field trip to the Laksip Village offered a good opportunity for participants to observe different land use and land cover and assist Lao researchers in designing the forthcoming field survey of landscape-level carbon stocks. The customary land use/land cover classification is used for stratification of the village landscape for sampling survey to better engage local communities in monitoring of carbon stocks in their land management.

21. The first land use observed was the production land. Annual cropping took place within a rotational shifting cultivation system. The main crop included upland rice for subsistence as well as maize and vegetable production (chilli, beans and parsleys)., Participants observed teak plantations in village. Teaks play very important role in contributing to household source of income. As it is in the rainy season, farmers have already sown upland rice. Rice usually is sown conventionally with dibbling stick with traditional rice varieties. Harvesting will start on October or early September. The second land use observed was the production forests where teak plantation area has been expanded.

22. During the field trip, participants also discussed on land use classification for carbon stock measurement, and laying sample plots-20 m x 20 m in natural forest and 10 m x 10 m in plantations and all other land use/cover classes. Number of plots in each land use will be based on (a) resource availability and accessibility, (b) relative area of different land use-more plots in more extensive land use, and (c) variation within land use.

Reviews and discussion of the work plan and responsibilities:

23. With reference to Laksip village, Prof. Saxena finalized land use classification and methodology on carbon stock measurement as follows:

(1) Forest

- Dense forest -Conservation, Sacred forest, Dense forest, and Cemetery forest
- Open forest-Young forest

(2) Shifting cultivation

- Shifting cultivation abandon fields-old fallow land
- Shifting cultivation current fallow-rotated fallow land
- Shifting cultivation cropped field – shifting cultivation (Hai)

(3) Forest plantations-teak gardens(Suan maysak)- Teak 1-15 years

- Young teak 1-5 years
- Medium teak 5-10 years
- Old teak-more than 10 years)

(4) Horticultural plantations-banana garden (2-3 years)-pine apple garden (Suan Kuay, maknut)

24. Enumeration of mature live trees in 20 m x 20 m or 10 m x 10 m plots, Prof. Saxena suggested to start from one corner of the plot and also explain GBH and DBH and a few common indexes in assessment such as (a) Convert GBH to DBH, for dicot trees $Y = \exp\{-2.134+2.530 \times \ln(D)\}$ where Y = tree biomass/kg; D: DBH in cm (FAO, 2004), (b) Radius = 10/2 = 5 cm, (c) Circumference/ girth = 2 x 3.14 x 5 = 31.4 cm ($2\pi R$), (d) Basal are area = 3.14 x 5 x 5 = 78.5 cm^2 (πR^2), (e) Determine biomass of each tree, species, all live trees in plot.

25. Enumeration of saplings: girth < 10 cm and nest a quadrate of 5 x 5 m size within 20 x 20 m or 10 x 10 m quadrate. We can use tape for measuring girth or calliper for measuring diameter. The shrubs will use the quadrates laid for sapling enumeration through count number of individuals by species as: harvest 10% of individuals of species; take fresh weight of the harvested individuals (x kg); take a sample of fresh biomass (y kg); dry in oven at 8^{o} deg C for 48 hours.

26. The litter (dead plant material lying on the ground) biomass will be collected in the plots laid for herbaceous biomass estimation as follows: segregate litter into woody and non-woody fractions; take fresh weight in the field; take samples for determining dry weight; determine dry woody and non-woody litter biomass on per ha basis.

27. The soil will take soil of 0-30 cm horizon. One composite sample from each 20 m x 20 m or 10 m x 10 m plot will determine for bulk density, soil organic carbon by Walkley-Black method (room temperature), soil organic carbon on per ha basis (=%C x Bulk density x 30 cm x 100 cm x 100 cm = g/m^2 convert to ton/ha)

28. The root biomass will be estimated by using available regression to determine root biomass as a percentage of the aboveground biomass. The conversion to carbon stock will take 50% of oven dry biomass as carbon content in oven dried plant biomass. Prof. Saxena will also summarize the methodologies based on this workshop and previous study of India, and to draft a project manual for all researchers by the end of June.

29. The provisional carbon stock measurement of Laos study site will be then tested in 7-13 July 2011. The pre-test will cover land use classification, and lay sample plots. The Thai team (Dr. Narit and Ms. Utumporn) will provide technical support to the field survey in the Laos study site.

30. The policy reviews with policy action plans are expected to complete on November 2011.

31. Finally, the workshop was closed with Prof. Saxena's remarks to thank everyone for their effort and hard work in making the workshop and discussion fruitful and successful. Dr. Jintana Kawasaki, UNU-ISP, appreciated NAFRI for excellent organization of the workshop as well active contributions from participants.

2.2 Working manual for carbon stock estimation

Keeping in view the time frame of the project, resource availability and local people-focus of the UNU-APN-REDD project, it was agreed that village landscapes, covering an area of 1,000-5,000 ha would constitute the spatial scale of operation/observation in each site.

Village landscapes, very often superimposed over natural regions like micro-watersheds, will be appropriate for understanding existing land use practices in relation to climate change mitigation and learning from as well as educating marginal mountain farmers to new opportunities of economic development by maintaining/enhancing carbon stocks, biodiversity and tree cover. Nevertheless, an overview of regional/national scope of responding to REDD+ as international programme would always be in the background. Thus, the village landscape scale observations/data/methods will be put within the context of national/international programmes and activities relevant to REDD+.

The village landscape analysis would aim to answer the questions: (i) which land uses encompass high levels of carbon stocks and what are the rates of losses or gains in carbon associated with different land use/management changes? (ii) what are the factors driving conversion of high carbon stock land uses to low carbon stock land uses? and (iii) what opportunities are available for promoting conversion of low carbon stock land uses to high carbon stock land uses?.

Though all sites (Lao, Thailand, China, and India) sites are located in marginal mountain areas, sites vary in terms of biophysical, socio-cultural and policy factors. A synthesis of studies carried out in different sites is likely to facilitate exchange of good practices between countries and to avoid environmental costs incurred in one country in the past in the other countries at present/future in addition to recommendations and conclusions applicable on a larger regional scale.

The study would bring out for each site at least : (1) land use/cover map of the selected village landscape at 1:10,000 to 1:1,000 scale, (2) area of each land use/cover type, (3) pathways/trajectories of land use changes and factors driving them, (4) carbon density (tons C/ha) in each land use/cover type and (5) key land use decisions/factors favouring maintenance/enhancement of carbon stocks, biodiversity, sustainable land management and well-being of people.

Broad steps in methodology	Details	
1. Identifying and mapping land use/cover types in the landscape: stratification of landscape into different classes differing in terms of C stocks	The core aim of this step is to classify a landscape in land use/cover types more uniform in terms of attributes determining carbon stocks. The number of land use/cover classes would depend based on the nature and magnitude of heterogeneity within a given landscape, scale of mapping and technique of mapping. To illustrate, in the Laksip village in Lao PDR, the land use classes would encompass (i). Natural forests: dense (crown > 60%), (ii) Natural forests: open (crown cover 20-60%), (iii) Teak plantations: old (> 10-year-old), (iv) Teak plantations: middle-age (5-10-year-old), (v) Young plantations: young (< 5-year-old) (with or without intercropping of annual crops), (vi) Abandoned shifting agriculture, (vii) Current fallows:1-2-year old, (viii) Current fallows: 3-4 years old, (ix) Cropped fields: annual crops (without teak), (x) Cropped fields: perennial crops. If national forest cover maps are available, it may be useful to develop classification schemes close to the widely applicable national schemes. For example, if the national scheme considers 30-70% as moderately dense and > 70% crown cover as dense forest, it may be appropriate to adopt these limits for classification in village landscape too. Customary classification schemes need to be taken in account so as to better facilitate participation of local communities in mapping and monitoring land use/cover and carbon stocks. It would be useful if land tenure/right	

	system/management system is also mapped (e.g., a map depicting distribution of production, protection and conservation forests in Laksip). By superimposing land tenure/management system type map, one can find out which tenure/management system is more effective in enhancing carbon stocks. Based on participatory discussions, the land use/cover stages preceding the present ones and probable reasons of changes should also be identified. To illustrate, there could be three patches of permanently abandoned shifting cultivation land similar in terms of land cover but different in terms of land use histories, with depletion of soil fertility forcing abandonment in one patch, weed infestation in the second patch and land allocation policy forcing abandonment in the third patch. Area (ha) of each land use type/subtypes should be estimated. The country team can take final decision on the scale of mapping 1: 10,000 to 1: 1,000 and mapping technique (participatory mapping, interpretation of satellite data, interpretation of aerial photographs)	
2. Deciding size and number of plots for estimating carbon density in each land use/cover type:	The past studies suggest a minimum plot size of 400 m^2 (20 m × 20 m) in natural forests and 100 m^2 (10 m × 10 m) in plantation forests for enumeration of trees, of 25 m^2 (one 5 m × 5 m quadrat) nested in the central area of tree plot for shrubs and 1 m^2 (5 quadrats of this size, one each around central and corner points of the tree-plot. The plots should be located in the central portion of a land use patch. If a land use is represented by several patches, as many patches as possible (preferably all) should be sampled. If a size of a patch is smaller than the size of tree plot, the whole patch should be analyzed and its area recorded. Sampling intensity/number of plots would be guided by desired level of confidence level,	Details of statistical analyses (confidence, standard error, etc) will be placed in annexure: this is being prepared and will be circulated at a later stage

	usually the observed mean lying within 10-20% of true mean with 95% confidence interval. To illustrate, if we get a mean biomass value of 20 t/ha and standard error of mean of 1.2 t/ha based on observations recorded in 17 plots (n =17), we are 95% confident that true mean lies between 22.544 t/ha [20 + {2.12 (*t* value at *P* = 0.05 and df 16) × 1.2}] to 17.456 [20 - {2.12 (*t* value at *P* = 0.05 and df 16) × 1.2}]. 22.544 and 17.456 in the present case mean 95% confidence limits and the range 22.544-17.456 95% confidence interval. The number of plots to be sampled could be determined by finding out variability within a land use based on past studies and, in the absence of past studies, on a quick small scale sampling (say 3-5 plots) in a given land use: Number of desired sample plots (n) = $(t \times s/E)^2$ or E = 2 × s/square root of n; E, desired half-width of the confidence interval = mean ×0 .1 or 0.2 (10 or 20% precision); t = 2 (sample size is unknown); S = standard deviation. For example, if mean = 50 t/ha; S = 10 t /ha; desired precision = within 10% of the true mean; then E = 50 × 0.1 = 5, n = $(2 \times 10/5)^2$ = 16 plots. The project areas in the present case are such that quite reliable carbon stocks could be estimated based on observations in sampling at 4-8 plots in each land use/cover type. Nevertheless, all areas being located in difficult mountain terrains, number of plots would, apart from statistical considerations, be guided by, resource availability, accessibility. One may start with enumerations in 4-5 plots in each land use, determine standard deviation/coefficient of variation and increase number of plots in land uses with high degree of variation such that standard deviation is less than 30% of the mean.	
3. Estimating aboveground biomass of live trees (DBH > 5 cm or 16 cm CBH/GBH,i.e., 3.14 × 5 or basal area of 19.6 cm^2,	Mark location of a plot in map, Measure and note down the slope of the plot (for applying slope correction at the end), average height of trees and crown cover: (in case of plots laid in forests) Start from one corner of the plot	Start from one corner of the plot Note down the name of species (scientific and local name) and CBH tree by tree

i.e., 3.14 × 2.5 × 2.5)	Note down the name of species (scientific name, local name and local uses) and CBH/GBH (circumference or girth at breast height) tree by tree Take some measure to avoid duplication, e.g., by marking a tree after noting down its GBH Measure tree height if it figures as an independent variable in the regression equation decided to be used for biomass estimation. In most of the tree species in the project sites relationship of aboveground with DBH/CBH/basal area is likely to be as strong as with DBH^2 × height and hence measurement of height may not be needed. Country teams need to decide on the regression equation to be used. However, in case of palms and bamboos height is often more strongly correlated with biomass than DBH and hence height measurement for these species would be necessary. Drawing allometric regression equations (statistical relationships between easily measurable tree attributes with biomass drawn based on harvesting of trees covering the whole range of variation in tree size) for each site would provide the most accurate estimates of biomass as the nature and strength of biomass – DBH and/height relationship varies by species, climate, soil properties and management practices. However, this may not be feasible within the time and resource constraints imposed by the project on one hand and site/country-specific constraints on the other. A proper choice of available regression equations may provide estimates with reasonable accuracy, a viewpoint also reflected in guidelines issued by organizations like FAO, GEF and IPCC. The country team should choose the regression equations which have been derived by others but in climatic/ecological conditions quite close to the project site. Some of the relevant available equations have been compiled in Table 1, while Table 2, giving an example, illustrates a wide range of variation in aboveground biomass estimates derived from different regression equations.	Take some measure to avoid duplication –by marking trees after noting down the GBH Convert GBH to DBH or basal area depending on the requirement of regression equations: For dicot trees: $Y = \exp\{-2.134+2.530 \times \ln(D)\}$ where Y = tree biomass/kg; D: DBH in cm (FAO, 2004) Determine aboveground biomass of each tree in the plot Determine biomass of each species in the plot Determine biomass of all live trees in plot Determine biomass on per ha basis

	Determine aboveground biomass of each tree in the plot Aggregate individual tree biomass values by species in the plot to get aboveground biomass of a species in the plot Sum up biomass of all species to get total aboveground live tree biomass in the plot Apply slope correction: work out true horizontal length for the length of the plot along slope as Length along slope x Cos of angle of slope (degree). Slope corrected area of rectangular plot = Width x horizontal length Slope corrected area of a circular plot = 3.14 × actual radius x horizontal radius Determine biomass on per ha basis from the plot level values. For example if slope corrected area of the plot is 250 m^2, biomass of trees in the plot is 10 t, biomass per ha would be (10,000/250) × 10 = 400 t/ha	
4. Estimating aboveground biomass of dead trees	Determine tree wise, species wise and total biomass as in the case of living trees. Reduce biomass by 10% to account for the loss of leaves, twigs and branches (Delaney et al., 1998). Apply slope correction and determine biomass per ha	
5. Estimating biomass of lianas	As in case of trees, except for use of regression equations drawn for lianas	
6. Estimating biomass of saplings (individuals of tree species with GBH/CBH < 10 cm	Nest a quadrat of 5 m × 5 m size within 20 m × 20 m or 10 m × 10 m quadrat Start from one corner of the nested quadrat Using a caliper, measure basal diameter (diameter 10 cm above ground) of each individual identifying its species Pool all individuals not identifiable by species as	

	miscellaneous species Convert basal diameter to basal area 3.14 × (basal diameter /2) × (basal diameter/2) Using regression equation, determine biomass of each individual Determine species wise biomass of saplings in the plot Apply slope correction and determine species wise biomass of saplings on per ha basis Determine total biomass of all saplings on per ha basis	
7. Estimating shrub biomass	Enumerate shrubs in the quadrats used for sapling enumeration Count number of individuals by species and pool individuals not identifiable by species as 'miscellaneous species' Harvest 10% of individuals of a species Take fresh weight of the harvested individuals in the field: 1-3 kg fresh weight taken for oven drying Take a sample of fresh biomass Dry in oven at 80 deg C for 48 hours and determine dry weight Determine dry weight of species wise shrub biomass in the plot Determine species wise biomass on per ha basis Determine total shrub biomass on per ha basis	
8. Estimating herbaceous biomass	Herbaceous biomass Nest five quadrats, each of 1 m × 1m size, at each corner and the centre of 10 m × 10 m or 20 m × 20 m sample plots Harvest all vegetation, segregate by species and pool all individuals not identifiable by species as 'miscellaneous' species and separate the	

	harvested biomass into above and belowground components Take fresh weight of harvested individuals Take a sample of fresh biomass (around 500-1000 g) of each species, dry in oven and determine dry weight Determine species-wise biomass in the plot Apply slope correction and determine species-wise belowground and aboveground biomass on per ha basis Sum up species-wise belowground and aboveground biomass, getting total herbaceous biomass per ha	
9. Estimating root biomass of trees and shrubs	Use available regression equations to determine root biomass	
10. Estimating litter biomass	Collect litter in the plots laid for herbaceous biomass estimation Segregate litter into woody and non-woody fractions Take fresh weight in the field Take 200-1000 g samples for determining dry weight after keeping at 80 deg C for 48 hours Apply slope correction and determine woody and non-woody litter biomass on per ha basis Sum up woody and non-woody litter biomass and get total litter biomass on per ha basis	
11. Estimating carbon stock in vegetation	Carbon content-oven dry weight/biomass relationship varies as shown in Table 3. In most cases, 50% of oven dry weight is taken as carbon content. Country teams can decide this value	
12. Estimating carbon in soil	Keeping in view the operational constraints, soil organic content in upper 30 cm soil layer will estimated Take soil of 0-30 cm horizon: sample 0-10 cm, 10-20 cm and 20-30 cm layers separately and average for 0-30 cm layer depending upon suitability of local conditions	

	Obtain one composite sample from each 20 m × 20 m or 10 m × 10 m plot Determine bulk density following broadly the method outlined by Anderson and Ingram (1989) • Remove surface material from the spot where soil is to be sampled and level the spot • Drive a 5 cm diameter thin-sheet metal tube of known weight (W1) and volume (V) 5 cm deep into the soil surface • Excavate the soil from around the tube and cut the soil beneath the tube bottom • Trim excess soil from the tube ends • Dry the soil at 105 deg C in an oven for two days and weigh (W2) • Calculate bulk density as (W2-W1, i.e., weight of oven dry soil collected in the tube from the field)/V as g/cm^3 • The size of tube can be changed based on the local circumstances Determine soil organic carbon by Walkley-Black method as outlined in Anderson and Ingram (1989) • Air dry the soil samples (200-500 g of composite sample) at about 40 deg C • Sieve the soil through a 2 mm sieve, and gently rub the crumbs through the mesh leaving the gravels and roots/other debris. • Grind all the material to pass a 0.15 mm mesh • Weigh 0.1-0.5 g of ground soil and pour it in a 250 ml conical flask, noting down the exact weight of soil (W) • Add 5 ml of 1 M potassium dichromate solution (dissolve 49.04 g of dry potassium dichromate in 800 ml of distilled water in a 1,000 ml volumetric flask and make up the volume to 1000 ml), gently stir the solution, add 7.5 ml of concentrated sulphuric acid slowly and then stir the solution so that all soil particles are exposed to the solution • Keep the solution at room temperature	

	till the solution comes down to room temperature • After solution comes down to the room temperature, add 0.3 ml of indicator solution (0.1 g N-phenylanthranillic acid and 0.1 g sodium carbonate in 100 ml of distilled water) • Titrate the digest with 0.20 M ferrous ammonium sulphate (dissolve 78.390 g ferrous ammonium sulphate in 50 ml of concentrated sulphuric acid and dilute to 1000 ml with water) and note down the volume of the solution when end point, i.e., change of colour of solution from violet to green, (T) • Calculate organic carbon (%) as (T × 0.2 × 0.3)/W • Determine soil organic carbon on per ha basis = %C × Bulk density × 30 cm x 100 cm x 100 cm = g/m^2 and convert to t/ha)	

Table a2.1: Regression equations available for plant biomass estimation

Life form	Regression equation	Author and ecoregion
Trees and palms > 5 cm DBH	Y = species specific wood density* x exp (-1.499 + 2.148 ln (DBH) + 0.207 $(\ln(DBH))^2$ – 0.0281 $(\ln(DBH))^3$	Chave et al. (2005) for tropical forests
Trees	Y = -1.638 + 2.08 ln DBH	Pilli et al. (2006) building on the model of WBE model of West et al. (1999)
Anacardium excelsum	$\ln Y_c = -3.4931 + 2.4843 \ln(DBH)$ $\ln Y_c = -3.4577 + 2.4889 \ln(DBH)$ $\ln Y_c = -3.4278 + 2.4830 \ln(DBH)$ $\ln Y_c = -3.4877 + 2.5143 \ln(DBH)$ $\ln Y_c = -3.7179 + 2.1936 \ln(DBH) + 0.4132 \ln$ height (m) DBH in cm	Losi et al. (2005) Tree size 1.8 to 11.2 cm DBH for plantations in Panama
Dipteryx panamensis	$\ln Y_c = -2.6344 + 2.5170 \ln(DBH)$ $\ln Y_c = -2.6362 + 2.5339 \ln(DBH)$ $\ln Y_c = -2.2433 + 2.3661 \ln(DBH)$ $\ln Y_c = -2.6203 + 2.5327 \ln(DBH)$ $\ln Y_c = -3.3814 + 2.8645 \ln(DBH)$	Losi et al. (2005)
Trees	$Y(pine) = 0.084 \times DBH^{2.47}$ $Y(oak) = 1.91 \times DBH^{1.782}$ Y (fir) = basal area × height × taper factor × wood density × expansion factor	Ordonez et al. (2008) for montane forests in Central Mexico

Trees	ln Y_c = -2.7450 + 2.6244 ln (DBH) ln Y_c = -2.0619 + 2.3088 ln (DBH)	Shepherd and Montagnini (2001) for plantations in humid tropics
Dicot trees	Y = exp{-2.134+2.530 x ln (D)} where Y = tree biomass/kg; D: DBH in cm R^2 = 0.97	FAO (2004) for DBH < 80 cm in 1500-4000 mm rainfall regime
	Y = exp{-1.996 + 2.32 x ln (D)} where Y = tree biomass/kg; D: DBH in cm R^2 = 0.89	FAO (2004) for 5-40 cm DBH in 900-1500 mm rainfall regime
	Y = 10 (raise to the power) (-0.535 + $\log_{10}$ (3.14 r^2) Y = tree biomass/kg; r: DBH in cm R^2 = 0.94	FAO (2004) for DBH 3-30 cm in < 900 mm annual rainfall regime
	Y = exp {-2.4090 + 0.9522 x ln (DBH2) x height x wood density R^2 = 0.99	Winrock from Brown, Gillespie and Lugo, 1989) for DBH > 5 cm in 1500-4000 mm rainfall regime
	Y = exp {-3.1141 + 0.9719 x ln (DBH2) x height R^2 = 0.97	Winrock from Brown, Gillespie and Lugo (1989) for DBH > 5 cm in 1500-4000 mm rainfall regime
	Y = 34.4703 – 8.0671 DBH + 0.6589 DBH^2	Winrock from Brown, Gillespie and Lugo (1989) for DBH > 5 cm in <1500 annual rainfall regime
Dicot trees and bamboo	Y = -122.297+13.065 DBH (Dillenia indica) Y = -163.332 + 15.09 DBH (Shorea robusta) Y = -144.678 + 144.678 (DBH) (Schima wallichii) Y = -63.06 + 10.562 DBH (Castanopsis indica) Y = -91.137 + 10.887 DBH (Garcinia cowa) Y = -229.852 + 17.451 DBH (Gmelina arborea) Y = -233.191 + 18.276 DBH (Artocarpus chaplasa) Y = -115.659 + 9.998 DBH (Vitex peduncularis) Y = 4.435 + 5.219 DBH (Milusa roxburghinana) Y = -80 + 6.5 x (Sterculia villosa) Y = -16.987 + 4.20 DBH (Dendrocalamus hamiltoni)	Singh (1980) for sub-tropical humid forests
Cooconut palms	Y = 5.5209 tree age + 89.355	Kumar (2011)
Other palms like Arecanut and	Y = 4.5 + 7.7 height	Brown (1997)

Borassus flabellifer		
Bamboo (*Bambusa* sps.)	Ln Y = 4.437 + 2.576 ln (DBH)	Kumar et al. (2005)
Tropical pine	Y = 5.508 + 2.008 DBH	Das (1980)
Sal plantation	Ln Y = 2.0473 DBH – 1.4516	Singh and Ramakrishnan (1983)
Lianas ≥ 1 cm	$Y = 10^{(0.12-0.91 \log (BA))}$	Putz (1983) for lianas in Venezuela
Shrubs	$Y = 0.363 \ln (diameter_a \times diameter_b \times height) + 0.7829$ $diameter_a$ and $diameter_b$ are two perpendicular diameters of shrub crown	Ordonez et al. (2008) for montane forests in Central Mexico
Saplings ≥ 1 cm Basal diameter < 5 cm DBH	Y = exp[3.965 + 2.383 ln (BD)]	Kirby and Potvin (2007) tropical moist forests in eastern Panama
Tree snags ≥ 5 cm DBH	species specific wood density $[3.14 (DBH/2)^2 \times height \times 0.78]$	Nascimento and Laurance (2002) for Amazonian rainforest
Dead trees ≥ 5 cm	90% of total aboveground biomass of live trees	Delaney et al. (1998) in six life zones of Venezuela
Downed woody debris	Density of dead wood $[3.14 \times 3.14 \sum (d^2)/8$ transect length] × slope correction factor	Brown and Roussopoulos (1974) for small fuels
Root/shoot ratio	0.25	Cairns et al. (1997) for oak and avocado orchards
	0.26	Cairns et al. (1997) for pine
	0.26	Ordonez et al. (2008) for shrubs in Central Montane forests in Mexico
	0.10	Ordonez et al. (2008) for agriculture in Central Montane forests in Mexico
	0.18	Jaramillo et al. (2003) tropical dry forests of Mexico
For dicot trees: Y = exp{-2.134+2.530 x ln (D)} where Y = tree biomass/kg; D: DBH in cm (FAO, 2004)	Y = exp{-2.134+2.530 x ln (D)} where Y = tree biomass/kg; D: DBH in cm	

Root biomass of trees, palms and lianas ≥ 1 cm DBH	24% of aboveground biomass	Cairns et al. (1997)
Root biomass in forests	20% of above ground biomas	Santantonio et al. (1977)
Ratio of belowground to aboveground biomass in forests	0.2	MacDicken (1997)
Ratio of belowground to aboveground biomass	0.28, 0.19 and 0.61 for tree, shrub and herb component, respectively, in Acer forest in Himalaya 0.36, 0.31 and 0.9 for tree, shrub and herb component, respectively, in Betula forests in Himalaya 0.49, 0.50 and 0.89 for tree, shrub and herb component, respectively, in Rhododendron forests in Himalaya	Garkoti and Singh (1995)
Belowground biomass as percentage of total tree biomass	6% in early successional and 21% in late successional species in sub-tropical humid forests	Ramakrishnan et al. (1982)
Belowground: aboveground biomass ratio of annual crops	0.03 to 0.14	Kritika (unpublished) in Himayan region
Aboveground-belowground biomass regression pooling all vegetation components	Ln Belowground biomass = 0.5667 ln Aboveground biomass -1.1212 R^2 = 0.87	Mustafa (unpublished) in Himalayan region
Agroforestry trees	Ln Y = 0.645 Ln basal area- 0.33 (R^2 = 0.51 in abandoned agricultural land) Ln Y = 1.0601 Ln basal area – 2.0679 (R^2 = 0.67 in degraded forest land) Ln Y = 0.8714 Ln basal area – 1.3643 (R^2 = 0.70 pooled data)	Semwal unpublished data in Himalayan region

*if species specific wood density is not known, a generalized value of 0.54 g cm^{-3} for standing trees, 0.453 g cm^{-3} for sound downed deadwood and 0.319 g cm^{-3} for rotten dead wood

Table a2.2: Variation in biomass estimates of a tree with DBH of 14.66 cm (or basal area 168.47 cm^2) and actual biomass of 49 kg) derived from different regression equations

Regression equation	Author	Biomass estimate
Y = species specific wood density* x exp (-1.499 + 2.148 ln (DBH) + 0.207 (ln (DBH))^2 – 0.0281 (ln (DBH))^3	Chave et al. (2005)	184.0
Y = -1.638 + 2.08 ln DBH	Pilli et al. (2006)	51.8
ln Y_c = -2.7450 + 2.6244 ln (DBH)	Shepherd and Montagnini (2001)	147.7 (2 x Yc)
Y = exp{-2.134+2.530 x ln (D)} where Y = tree	FAO (2004)	105.6

biomass/kg; D: DBH in cm $R^2 = 0.97$		
Y = exp{-1.996 + 2.32 x ln (D)} where Y = tree biomass/kg; D: DBH in cm $R^2 = 0.89$	FAO (2004)	69.0
Y = 34.4703 – 8.0671 DBH + 0.6589 DBH^2	Winrock from Brown, Gillespie and Lugo (1989)	57.8
Ln Y = 0.645 Ln basal area- 0.33 ($R^2 = 0.51$ in abandoned agricultural land) Ln Y = 1.0601 Ln basal area – 2.0679 ($R^2 = 0.67$ in degraded forest land) Ln Y = 0.8714 Ln basal area – 1.3643 (R^2 = 0.70 pooled data)	Semwal unpublished data in Himalayan region	19.5 28.9 22.3

Table a2.3: Relationship of carbon content with oven-dry weight (biomass) used by some researchers in carbon stock estimations

Relation of carbon content and oven dry weight/biomass	Authors
● 50% of dry biomass	Brown, 1986; Montagnnini and Porras, 1998
● 45% of dry biomass	Whittaker and Likens, 1973
● 45% for litter, 43% for seedlings, 41% for grass, 50% for downed woody debris and 47% for trees, palms and lianas	Hughes et al., 1999
● A common value of 47.5%	Fujisaka et al., 1998; Kotto-Same et al., 1997
● A common value of 46%	Elias and Potvin, 2003
● 48% based on analysis of samples	Losi et al., 2003

Annexure 1: Statistical analysis: formula and examples (being prepared)

References

Brown S. 2008. *Assessment of the Advantages and Limitations of Ground-Based Surveys and Inventories.* UNFCCC Workshop on Methodological Issues Relating to REDD in Developing Countries 25-27 June. Tokyo, Japan. http://unfccc.int/files/methods_and_science/lulucf/application/pdf/080625_tokyo_brown.pdf

Cairns M A, Brown S, Helmer E H and Bumgardner G A. 1997. Root biomass allocation in the world's upland forests. *Oecologia*, 111: 1-11.

Chave J, Andalo C, Brown S, Cairns MA, Chambers JQ, Eamus D, Folster H, Fromard F, Higuchi N, Kira T, Lescure JP, Nelson BW, Ogawa H, Puig H, Riera B, Yamakura T. 2005. Tree allometry and improved estimation of carbon stocks and balance in tropical forests. *Oecologia.* 145(1):87-99.

Gibbs HK, Brown S, Niles JO and Foley JA. 2007. Monitoring and estimating tropical forest carbon stocks: making REDD+ a reality. *Environ. Res. Lett*. 2 045023 (13pp).

Hairiah K, Dewi S, Agus F, van Noordwijk M, Rahayu S, Velarde SJ. 2010. *Measuring Carbon Stocks Across Land Use Systems: A Manual*. Bogor, Indonesia. World Agroforestry Centre (ICRAF), SEA

Regional Office, Brawijaya University and ICALRRD (Indonesian Center for Agricultural Land Resources Research and Development) at www.worldagroforestrycentre.or/sea.

Kamau D M, Spiertz JHJ and Oenema O. 2008. Carbon and nutrient stocks of tea plantations differing in age, genotype and plant population density. *Plant Soil* 307:29–39.

Kurnianto S. and Murdiyarso D. 2010 *Forest carbon database: a Web-based carbon stock data repository and exchange system.* CIFOR, Bogor, Indonesia. 16p.

Lasco RD. 2002. Forests carbon budgets in Southeast Asia following harvesting and land cover change. *Science in China* (series C), Vol. 45: 55-64.

Mokany K, Raison J R, and Prokushkin AS, 2006. Critical analysis of root-shoot ratios in terrestrial biomes. *Global Change Biolology* 12: 84-96.

Annex 3: *Summary report training on "What are carbon stocks and how to measure the tree in forest" in Thailand*

The project was launched two training in Chiang Mai Province: 1) Training on ""What are carbon stock and how to measurement the tree in forest" for the farmers and local forest officer at Thailand site on 11-13 October 2012 at Tee Cha village; and 2) Training on "What are carbon stock and how to measurement the tree in forest" on 1-4 November 2013 at the Chang Khain Highland Research Station.

Objectives:

The main objectives of the workshop were:

- Training the local forest officer on the topic "What are carbon stock and how to measurement the tree in forest".
- Demonstration and practices how to measurement the tree in forest

3.1 Training on "What are carbon stocks and how to measure the tree in forest" at Tee Cha Village, 11-13 October 2012

Chiang Mai University, Conserve Office Area 16 of Chiang Mai and Department of Natural Parks Wildlife and Plant Conservation, jointly organized this training, total 35 participants came from villages and provincial forest office.

Training programme and demonstration:

Wednesday, 10 October 2012:	
10:00-15:00 hrs	Travel from Chiang Mai University to Tee Cha village
Thursday, 11 October 2012: Tee Cha Village	
9:00–9:30 hrs	Register: • Staffs of Chiang Mai University
9:30–9:40 hrs	Opening the training: • Mr. Noi Taekhwa (head of village)
9:40–10:00 hrs	Introduction to the training: • Dr. Narit Yimyam
10:00–10:30 hrs	Coffee/tea break

10:30–12:30 hrs	General village landscape and Land used • Dr. Narit Yimyam
12:30–14:00 hrs	Lunch
14:00–15:30 hrs	How to used the map to land used map • Dr. Narit Yimyam
15:30–16:00 hrs	Coffee/tea break
16:00–18:00 hrs	Field walk observing village landscape and land use practices **Dr. Narit Yimyam and staffs**
Friday, 12 October 2012: Tee Cha Village	
8:30–10:30 hrs	What are carbon stock and how to measurement the tree in forest? **Dr. Narit Yimyam** **Dr. Sittichai Lordkaew**
10:30-11:00 hrs	Coffee/tea break
11:00-12:30 hrs	What are carbon stock and how to measurement the tree in forest? (continued) **Dr. Narit Yimyam** **Dr. Sittichai Lordkaew**
12:30–14:00 hrs	Lunch
14:00–15:30 hrs	Practices the method how to measurement the tree in forest **Dr. Narit Yimyam and staffs**
15:30–16:00 hrs	Coffee/tea break
16:00–18:00 hrs	Practices the method how to measurement the tree in forest (continued) **Dr. Sittichai Lordkaew and staffs**
Saturday, 13 October 2012:	
8:30-10:30 hrs	Discussion **Staffs of CMU.**
10:30–11:00 hrs	Coffee/tea break
11:00-12:00 hrs	Discussion continued **Staffs of CMU.**
12:00–13:30 hrs	Lunch
13:30–14:30 hrs	Summarize **Dr. Narit Yimyam**
14:30–15:00 hrs	Coffee/tea break
15:00–15:30 hrs	Closing
15:30-20:00 hrs	Black to Chiang Mai University

The lists of participants in the 1st Training

No.	Name	Address (No. house)	Position

1	Mr.Mayo Phakdeephanphana	211	Farmer
2	Mr.Daloy Cheewaboonyasit	386	Farmer
3	Mr.Kaewloy Laksanasoonthon	293	Farmer
4	Mr.Tanee Dararueangrong	202/2	Farmer
5	Mr.Luyo Deeledporn	338/1	Farmer
6	Mr.Saucha Hlaemsingkhor	346	Farmer
7	Mr.Liyo Tuphor	391	Farmer
8	Mr.Peeda Katoo	367	Farmer
9	Mr.Tucare Thongsayporisud	294	Farmer
10	Ms.Lar Koktoo	45	Farmer
11	Mr.Dipo Thongthungnapha	356	Farmer
12	Mr.Padikae Chalidaphorn	338	Farmer
13	Mr.Nopporn Sawadthisa	381	Farmer
14	Ms.Anong Thongsayporisud	294	Farmer
15	Mr.Daeng Hlaemsingkhor	291	Farmer
16	Mr.Chaemui Thawinkhrongsak	337	Farmer
17	Mr.Dichai Koksor	211/1	Farmer
18	Mr.Kan Doyngam	366	Farmer
19	Mr.Nujae Hlaemsingkhor	312	Farmer
20	Mr. Phudthawong Thongthongnapha	356	Farmer
21	Mr.Somchai Kosor	211/2	Farmer
22	Mr.Phonsawan Koatoo	45	Farmer
23	Mr.Da Naetoo	380	Farmer
24	Ms.Suyo Naetoo	380	Farmer
25	Mr.Thongdee Sawadthisa	163/1	Farmer
26	Mr.Noi Taekhwa	71	local forest officer
27	Ms.Rongruedee Taekhwa	71	local forest officer
28	Ms.Wanida sawatthisa	163/1	local forest officer
29	Ms.Siriwilai Laksanasantho	363	local forest officer
30	Mr.Caredo Khaewa	354	local forest officer
31	Dr.Narit Yimtam	Chiang Mai University	Chiang Mai University's Staff
32	Dr. Sittichai Lordkaew	Chiang Mai University	Chiang Mai University's Staff
33	Mr.Peeranun Mapan	Chiang Mai University	Chiang Mai University's Staff

34	Mr. Puthapong Manokam	Chiang Mai University	Chiang Mai University's Staff
35	Mr. Vorrawit Sukkumpa	Chiang Mai University	Chiang Mai University's Staff

Note: All farmers live in Tee Cha village Moo 10, Sop Moei Sub-district, Sop Moei district, Mae Hong Son province

3.2 Training on "What are carbon stocks and how to measure the tree in forest" at the Chang Khain Highland Research Station, 1-4 November 2013

Chiang Mai University and Conserve Office Area 16 of Chiang Mai jointly organized this training. There were total 30 participants.

Training programme and demonstration:

Friday, 1 November 2013:	
9:00-12:00 hrs	Participants arrival to Chiang Mai University
12:00–13:00 hrs	Lunch
13:00–15:00 hrs	Group Travel to Chang Khain highland research station
15:00-15:30 hrs	Welcome and introduction Chang Khain highland research station **Dr. Narit Yimyam**
Saturday, 2 November 2013: Chang Khain Highland Research Station	
9:00–9:30 hrs	Opening the training: **Director of highland research and training center**
9:30–10:00 hrs	Introduction to the training: **Dr. Narit Yimyam**
10:00–10:30 hrs	Coffee/tea break
10:30–12:30 hrs	How to use the map to land used map **Assistant Prof. Teerapong Soawaphak**
12:30–14:00 hrs	Lunch
14:00–15:30 hrs	Practices the method how use the map to land used map **Assistant Prof. Teerapong Soawaphak**
15:30–16:00 hrs	Coffee/tea break
16:00–18:00 hrs	Field walk observing landscape and land use practices **Dr. Narit Yimyam and staffs**
Sunday, 3 November 2013:	
8:30–10:30 hrs	What are carbon stock and how to measurement the tree in forest? **Dr. Narit Yimyam**
10:30-11:00 hrs	Coffee/tea break

11:00-12:30 hrs	What are carbon stock and how to measurement the tree in forest? (continued) **Dr. Narit Yimyam**
12:30–14:00 hrs	Lunch
14:00–15:30 hrs	Practices the method how to measurement the tree in forest **Dr. Narit Yimyam and staffs**
15:30–16:00 hrs	Coffee/tea break
16:00–18:00 hrs	Forest plantation in the station **Dr. Sittichai Lordkaew and staffs**
Monday, 4 November 2013:	
8:30-10:30 hrs	Discussion **Staffs of CMU.**
10:30–11:00 hrs	Coffee/tea break
11:00-12:00 hrs	Summarize **Dr. Narit Yimyam**
12:00–13:30 hrs	Lunch
13:30–14:30 hrs	Closing
14:30–19:00 hrs	Departure of participants

The lists of participants in the 2nd Training

No.	Name	Position
1	Mr.Peeda Katoo	village forest committee from Tee Cha village
2	Ms.Anong Thongsayporisud	local forest officer from Tee Cha village
3	Mr.Nopporn Sawadthisa	village forest committee from Tee Cha village
4	Mr.Somchai Kosor	village forest committee from Tee Cha village
5	Mr.Phonsawan Koatoo	village forest committee from Tee Cha village
6	Ms.Rongruedee Taekhwa	local forest officer from Tee Cha village
7	Ms.Wanida sawatthisa	local forest officer from Tee Cha village
8	Ms.Siriwilai Laksanasantho	local forest officer from Tee Cha village
9	Mr.Caredo Khaewa	local forest officer from Tee Cha village
10	Mr.Kongdat Sac Lee	village forest committee from Chang Khain village
11	Mr.Manop Sac Taow	village forest committee from Chang Khain village
12	Mr.Dang Sac Lee	village forest committee from Chang Khain village
13	Mr.Damrong Sac Ma	village forest committee from Chang Khain village
14	Mr.Jumdee Sac Lee	village forest committee from Chang Khain village
15	Ms.Sumaree Sac Lee	village forest committee from Chang Khain village
16	Ms.Tavepong Sac Ma	village forest committee from Chang Khain village
17	Ms.Maree Sac Taow	village forest committee from Chang Khain village
18	Mr.Nipon Thongnapha	village forest committee from Thongluang village
19	Mr.Da Phadee	village forest committee from Thongluang village
20	Mr.Thongsuk Naphasavadee	village forest committee from Thongluang village
21	Ms.Seeyo Phadee	village forest committee from Thongluang village
22	Ms.Somjai Jaidee	village forest committee from Thongluang village
23	Mr.Thong Sawanapha	village forest committee from Thongluang village
24	Ms.Marenee Thongnapha	village forest committee from Thongluang village
25	Dr.Narit Yimtam	Chiang Mai University's Staff
26	Dr. Sittichai Lordkaew	Chiang Mai University's Staff
27	Ass. Prof. Teerapong Soawaphak	Chiang Mai University's Staff
28	Mr.Peeranun Mapan	Chiang Mai University's Staff
29	Mr. Puthapong Manokam	Chiang Mai University's Staff
30	Mr. Vorrawit Sukkumpa	Chiang Mai University's Staff

Note: The participants from in 3 villages;

Tee Cha village, Sop Moei Sub-district, Sop Moei district, Mae Hong Son province
Chang Khain village, Suthap Sub-district, Muang district, Chiang Mai province

Thongluang village, Mae Win Sub-district, Mae Wang district, Chiang Mai province

Annex 4: *The species type of plant found that in the different fallow year in short rotational shifting cultivation of Tee Cha village, Thailand*

Thai name	Karen name	Scientific name	Family	Type	Fallow year							
					0	1	2	3	4	5	6	>8
unidentified-(GC)-04	เนงคูเม่ง	unidentified-(GC)-04	unidentified-(GC)-04	U	0	0	0	0	0	0	1	1
unidentified-(GC)-06	เตงควี	unidentified-(GC)-06	unidentified-(GC)-06	U	0	0	0	0	0	0	0	0
unidentified-(GC)-07	โพบวีอดรี	unidentified-(GC)-07	unidentified-(GC)-07	U	0	0	0	0	1	0	0	0
unidentified-(GC)-08	โพลู่ซัง	unidentified-(GC)-08	unidentified-(GC)-08	U	0	0	0	0	1	0	0	1
หมามุ่ย	โผล่จือแซ	*Mucuna pruriens*	Papilionoideae	C	1	0	1	0	0	0	1	0
กูดดอย	กูดเกี๊ย,ก่ายบ่างซัง	*Pteris vittata*	Dryopteridaceae	F	1	0	1	0	0	1	0	0
เฟิร์น1	-	Fern-1	Fern-1	F	1	0	0	1	1	1	1	0
เฟิร์น2	-	Fern-2	Fern-2	F	1	0	0	1	1	1	0	0
ย่านลิเภา	ก้ายคู,ก่ายคุ	*Lygodium flxuosum*	Schizaeaceae	F	1	0	0	1	1	1	1	1
หญ้าปากควาย	-	*Digitaria violascens*	Gramineae	G	0	0	1	1	1	0	0	1
หญ้าคา	คียกะ	*Imperrata cylindica*	Gramineae	G	1	0	1	0	0	0	0	0
หญ้าขจรจบ	-	*Pennisetum pedicellatum*	Gramineae	G	0	1	0	0	0	0	0	0
ก๋ง	ก้าย	*Thysanolaena maxima*	Gramineae	G	1	1	0	0	0	0	0	1
หญ้าตีนนก	-	*Mollugo pentaphylla*	Molluginaceae	G	0	1	0	0	0	0	0	0
หญ้า-2	-	unidentified-15	unidentified-15	G	0	0	0	0	0	0	1	0
หญ้าปูนลวก	-	unidentified-17	unidentified-17	G	1	0	0	0	0	0	0	0
หญ้าหาน	-	unidentified-18	unidentified-18	G	1	0	0	0	0	0	0	0
unidentified-19	กังคุย	unidentified-19	unidentified-19	G	1	0	0	0	0	0	0	0

unidentified-20	แค่วคูโย๊ะดุ	unidentified-20	unidentified-20	G	1	0	0	0	0	0	0	0
unidentified-22	ดูก้ายดู	unidentified-22	unidentified-22	G	0	1	0	0	0	0	0	0
unidentified-24	นังกายคู	unidentified-24	unidentified-24	G	0	1	0	0	0	0	0	0
unidentified-25	นังคลั่งไล	unidentified-25	unidentified-25	G	0	1	0	0	0	0	0	0
unidentified-26	นังควยหมี่	unidentified-26	unidentified-26	G	0	1	0	0	0	0	0	0
unidentified-27	นังตะสีปะซอ	unidentified-27	unidentified-27	G	0	1	0	0	0	0	0	0
unidentified-28	นังทุยเชา	unidentified-28	unidentified-28	G	0	1	0	0	0	0	0	0
unidentified-29	นังน้อแดง	unidentified-29	unidentified-29	G	0	1	0	0	0	0	0	0
unidentified-30	นังเบเมะ	unidentified-30	unidentified-30	G	0	1	0	0	0	0	0	0
unidentified-31	นังปะทอ	unidentified-31	unidentified-31	G	0	1	0	0	0	0	0	0
unidentified-32	นังพลู	unidentified-32	unidentified-32	G	0	1	0	0	0	0	0	0
unidentified-33	นังมิซิ	unidentified-33	unidentified-33	G	0	1	0	0	0	0	0	0
unidentified-34	นังลือคา	unidentified-34	unidentified-34	G	0	1	0	0	0	0	0	0
unidentified-35	นังแวะด้าย	unidentified-35	unidentified-35	G	0	0	0	0	0	0	1	0
unidentified-36	นางจุบี	unidentified-36	unidentified-36	G	0	1	0	0	0	0	0	0
unidentified-38	โผ้ลจีบวย	unidentified-38	unidentified-38	G	0	1	0	0	0	0	0	0
unidentified-39	พลู้	unidentified-39	unidentified-39	G	0	1	0	0	0	0	0	0

หญ้าขนไก่	-	*Lepidagathis incurva*	Acanthaceae	H	0	0	0	0	0	0	0	0
ผักปราบ	-	*Commelina bengalensis*	Commelinaceae	H	1	0	0	0	0	0	0	0
สาบแร้ง	นางเนาะมือ	*Aguatum comyzoides*	Compositae	H	1	1	0	0	0	0	1	0
สาบเสือ	นางชะกุย หน่อชะยะ/	*Chromolaena odorata*	Compositae	H	1	1	1	1	1	1	1	1
ผักคราดหัวแหวน	-	*Sphaeranthus africanus*	Compositae	H	0	1	0	0	0	0	0	0
น้ำนมราชสีห์	-	*Euphorbia hirta*	Euphorbiaceae	H	0	1	0	0	0	0	0	0
งาขี้ม้อน	-	*Perilla frutesens*	Labiatae	H	1	0	0	0	0	0	0	0
ฝ้าย	-	*Gossypium herbaceum*	Malvaceae	H	1	0	0	0	0	0	0	0
Desmodium sp.-1	-	*Desmodium sp.-1*	Papilionoideae	H	0	0	0	0	0	0	0	0
Desmodium sp.-2	-	*Desmodium sp.-2*	Papilionoideae	H	0	0	0	0	0	0	0	0
งาขาว	-	*Sesamum orientale*	Pedaliaceae	H	1	0	0	0	0	0	0	0

Annex 5: *Photos of the project activities*

THAILAND

Figure a1 Tee Cha Village landscape and traditional land use systems

Figure a2 Genetic diversity of upland rice in Tee Cha Village

Figure a3 Diversity of swidden crops in shifting cultivation system

Figure a4 Plant species in various land use stages and field types

a.1. Vegetation a.2. Ground cover

a. Conservation forest

b.1. Vegetation b.2. Ground cover

b. Community forest

c.1. Vegetation c.2. Ground cover

c. Utility forest

d.1. Vegetation d.2. Ground cover

d. Permanent tree crops

Figure a5 Vegetation and ground cover of field type in traditional shifting

a. Conservation forest

b. Utility forest

c.Shifting cultivation Field

d. Permanent tree crops

Figure a6 Methodology of biomass measurement in field types

a. Conservation forest

b. Utility forest

Figure a7 Methodology of ground cover and soil data collection

Figure a8 Activities in training the farmers and local forest officers on 11-13 October 2012 at Tee Cha Village

Figure a9 Activities in training the local forest officers on 1-4 November 2013 at the Chang Khain Highland Research Station, Tee Cha Village

Annex 6: Funding sources outside the APN

A list of agencies, institutions, organisations (governmental, inter-governmental and/or non-governmental), that provided any in-kind support and co-funding for the project and the amount(s) awarded. If possible, please provide an estimate amount.

1. United Nations University Institute for Sustainability and Peace (UNU-ISP), Tokyo provided in kind and co-funding
2. Chiang Mai University (CMU), Thailand provided in-kind support
3. National Agriculture and Forest Research Institute (NAFRI), Laos provided in-kind support
4. Jawaharlal Nehru University (JNU), India provided in-kind support

Annex 7: List of Young Scientists

1. Dr. Jintana Kawasaki involved in project coordination, and socio-economic survey and analysis, a former researcher at UNU-ISP, now working at Institute for Global Environmental Strategies, Japan. Email: kawasaki@iges.or.jp
2. Ms Alva Lim involved in project development and planning, and policy dialogue, a former researcher at UNU-ISP, now working at Seeds of Life, Timor-Leste. Email: alvalim@gmail.com
3. Ms. Utumporn Chaiwong involved in field survey and analysis at the project site in Thailand, a former researcher at Chiang Mai University, now working at National Corn and Sorghum Research Center, Thailand. Email: poohchiko291@gmail.com
4. Mr. Vikha Vi Mektakoul involved in field survey and analysis at project site in Laos, Agricultural Land Use Planning Centre, Laos. Email: vikham_m@yahoo.com

Annex 8 Glossary of Terms

AAL abandoned agricultural land

APFNet Asia-Pacific Network for Sustainable Forest Management and Rehabilitation

CDM Clean Development Mechanism

CMU Chiang Mai University

ES Ecosystem services

GIAHS Globally Important Agricultural Heritage Systems

HDFL highly degraded forest land

IGES Institute for Global Environmental Strategies

JNU Jawaharlal Nehru University

MAFF Ministry of Agriculture, Forestry and Fisheries of Japan

MRV Measurement, Reporting and Verification

NAFRI National Agriculture and Forest Research Institute

NPV Net present value

OJCB On-the-Job Research Capacity Building for Sustainable Agriculture/Forestry in Developing Countries

PES Payment for environmental services

REDD+ Reducing Emissions from Deforestation and Forest Degradation in Developing Countries

RS/GIS Remote sensing/Geographic Information System

SFR-MMSEA Sustainable Forest Rehabilitation and Management for the Conservation of Trans-boundary Ecological Security in Montane Mainland Southeast Asia– Pilot Demonstration Project of Lao PDR, Myanmar and China/Yunnan

SLM-MMSEA Sustainable land management in the mountainous region of mainland Southeast Asia

SWFU Southwest Forestry University of China

UN-CECAR University Network for Climate Ecosystems and Change Adaptation Research

UNU-ISP United Nations University Institute for Sustainability and Peace, now United Nations University Institute for the Advanced Study of Sustainability (UNU-IAS)