FINAL REPORT for APN PROJECT
ARCP2009-09NSY-Skole

Developing Small-holder Agroforestry Carbon Offset Protocols for Carbon Financial Markets –Twinning Sustainable Livelihoods and Climate Mitigation

APN
Asia-Pacific Network for Global Change Research

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MICHIGAN STATE UNIVERSITY

Global Observatory for Ecosystem Services

Carbon 2 Markets

NRCT

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Project Reference Number: ARCP2009-09NSY-Skole
Final Report submitted to APN

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OVERVIEW OF PROJECT WORK AND OUTCOMES

Non-technical summary

Protocols and methods for quantifying sequestered carbon in plantation systems and simple landscapes have been developed under the UNFCCC Clean Development Mechanism Afforestation/Reforestation (CDM A/R); however, none exist for more complex agroforestry systems. This project aimed to develop small-holder agroforestry protocols for the Chicago Climate Exchange working directly with farmers and communities in Laos, Thailand, and Vietnam. The project included capacity building training and the development and preliminary implementation of small-holder agroforestry carbon pilot activities in each of the three countries to help address issues of climate change related to land use change and sustainable development. Working with national level agency personnel and University staff engaged in natural resource management, rural livelihoods, sustainable development and climate change science, the knowledge and understanding shared and developed as a result of the workshops and the pilot agroforestry carbon projects that are central to this activity, we believe, helps to foster increased capacity at the national and regional levels for conducting global change research leading to projects that support policies aimed at combating climate change.

Objectives

The main objectives of the project were:

1. Training and capacity building in developing agroforestry carbon offsets
2. Development of agroforestry carbon offset pilot projects in Laos, Thailand and Vietnam
3. Development of new agroforestry carbon offset protocols for the Chicago Climate Exchange greenhouse gas trading market.

Amount received and number years supported

The Grant awarded to this project was: US$ 40,000 for 1 Year 2009/2010

Activity undertaken

The project included six main activities: 1) a three-day workshop in Bangkok, Thailand on Agroforestry in Southeast Asia and opportunities for agroforestry carbon offset projects in Laos, Thailand and Vietnam; 2) the selection of agroforestry carbon offset pilot areas; 3) preliminary data collection for the pilot areas; 4) the continued development of an Internet-enabled carbon offset MRV system; 5) a one-day symposium “Climate Change, Forests And Farmers: Global Perspectives And Projects At MSU” at Michigan State University, and 6) a meeting with members of the Chicago Climate Exchange.

Results

The results of the project include the following: 1) workshop materials on agroforestry systems in Laos, Thailand and Vietnam and carbon offset protocol requirements; 2) Symposium material on forestry and agroforestry carbon mitigation opportunities, use of remote sensing in measurement and monitoring of terrestrial carbon offsets, and Web-enabled, MRV management applications; 3) Study sites identified; the selection of four agroforestry carbon offset pilot activities; 4) development of field survey instruments and preliminary biometric field data collection; 5) a prototype MRV for small-holder teak woodlots; and 6) a draft “Protocol for Biotic Carbon Sequestration in Small Scale Agroforestry in Developing Countries” under review by the Forestry Offsets Committee of the Chicago Climate Exchange. All material can be accessed through the project website at: http://www.goes.msu.edu/apn_arcp_2009_09/.

Relevance to APN's Science Agenda and objectives

This project is cross-cutting specific to the APN Science Agenda priority topics of (1) climate, (2) ecosystems and land use, and (3) the use of resources for sustainable development. This project supports regional collaboration of basic research for developing small-holder carbon offset protocols (goal 1). The project includes both scientist and policy-makers as part of our project team (goal 2). The project includes technical capacity-building in using remote sensing, GIS, and carbon models for implementing small-holder carbon offset projects, and in understanding carbon financial markets (goal 3).

Self evaluation

The project was delayed a number of months at the start due to unforeseen personal circumstances of the project manager. The workshop in Bangkok was initially scheduled for early December 2009, but did not take place until March 2010. This late start impacted the amount of field data collected at the selected pilot areas prior to the end date of the project (14-July- 2010). The development of these agroforestry carbon offset pilot areas, however, is still proceeding. The workshop in Bangkok, the Symposium at Michigan State University, and the meeting with key personnel at the Chicago Climate exchange were all quite successful. The development of pilot areas and the drafting of new protocols are still in progress (at the time of this report: 14-June-2010). The project has a working prototype of the Internet-enabled carbon offset management (MRV) system at www.carbon2markets.org.

Potential for further work

The participants and collaborators all feel there is great potential for further work in developing, testing and refining the measurement and monitoring protocols for small-holder agroforestry carbon offset projects. There is also a great need for implementing projects to support national efforts at climate mitigation and for engaging small-holders in such activities for their economic benefit and for the potential sustainable ecological benefits that can accompany agroforestry systems. There is also a need to scale-up activities through aggregation services of small-holder carbon-rich properties in cost effective ways that enable the sale of sequestered carbon on the market. These challenges still exist. The work undertaken for this project is a small step in the right direction.

Publications

Samek JH, Skole DL, Klinhom U, Butthep C, Navanugraha C, Uttaruk P, Laosuwan T, Dumrongsukit S, Sangkanukij P, Kulwong A. 2010. *Inpang Community Network Agroforestry Carbon Bank in Northeast Thailand*. In B. M. Kumar and P. K. R. Nair (eds.), In Carbon Sequestration in Agroforestry: Processes, Policy, and Prospects. Advances in Agroforestry, Springer. the Netherlands. (accepted for publication).

Acknowledgments

The collaborators wish to acknowledge the dedication and tireless commitment of Mr. Jay Samek (Forestry, Michigan State University), the project manager, to seeing this project through to completion after the untimely loss of his mother, Sharon Ann Samek in December 2009.

TECHNICAL REPORT

Preface

Protocols and methods for quantifying sequestered carbon in plantation systems and simple forest and agriculture landscapes have been developed under the UNFCCC Clean Development Mechanism Afforestation/Reforestation (CDM A/R); however, none exist for more complex agroforestry systems. This project aimed to develop small-holder agroforestry carbon offset pilot projects and draft new measurement and monitoring protocols for the Chicago Climate Exchange carbon market working directly with farmers and communities in Laos, Thailand, and Vietnam. The project included a capacity-building training workshop in Bangkok, Thailand, the identification of project areas, the development of a prototype MRV management applications, and preliminary field data collection.

Table of Contents

1.0 Introduction

The significance of tropical forests to climate change in terms of greenhouse gas source emissions from deforestation and forest degradation and in terms of the mitigation potential of forested landscapes are well documented in the IPCC Fourth Assessment Reports and other publications (Moutinho and Schwartzman 2005; Metz et al. 2007; Parry et al. 2007; Solomon et al. 2007). Pressures on tropical forest resources by local people may be alleviated through adoption of agroforestry (Smith and Scherr 2003; Angelsen and Kaimowitz 2004; Montagnini and Nair 2004). Agroforestry, the use of trees on farm, including the domestication of indigenous trees, provides a variety of potential income streams from both timber and non-timber products (Michon and de Foresta 1996; Leakey and Simons 1998; Simons and Leakey 2004). Agroforestry can also play an important role in sustaining a variety of ecosystem services (Jose 2009), including climate mitigation through carbon sequestration (Sharrow and Ismail 2004; Kirby and Potvin 2007; Nair et al. 2009). Furthermore, carbon itself is now a commodity trading on a number of greenhouse gas or “carbon” financial markets, in regulatory and voluntary mechanisms. Agroforestry, therefore, has the potential to both mitigate climate change and provide an additional income stream to farmers, beyond income generated from traditional timber and non-timber products.

Accurate measurements of reforestation and biomass accumulation in trees on agricultural land is important because these data are needed to understand the global magnitude and capacity for carbon sequestration, and to inform decision makers and policy makers on options for carbon management practices that can remove carbon from the global atmosphere. There is considerable uncertainty on the current land area in woody perennials on farms in developing countries and the global potential for managing carbon sequestration in tree-based agriculture. Some estimates from international organizations suggest there is a large amount of carbon sequestration already occurring in these managed landscapes (Verchot and Singh 2009). Recognizing that disperse small-scale agroforestry farms in developing countries are sequestering atmospheric carbon dioxide and therefore mitigating climate change, there are a number of challenges linking agroforestry farmers to the carbon markets, and to buyers willing to pay farmers for carbon offsets. Transaction costs to implement any forestry carbon offset project are non-trivial. These costs include identifying and demarking project boundaries, collecting field-based biometric data, carbon measuring and monitoring tasks, third party verification, and project reporting. Furthermore, the heterogeneous nature of agroforestry (spatial planting configurations and species diversity) adds greater complexity to biotic carbon accounting. Markets expect carbon offsets to be real, verifiable, and permanent, and carbon offset methods and protocols are designed to ensure these requirements. While there are a growing number of newly proposed forest carbon accounting methods and protocols, there are currently only a few that are market-accepted, and these do not include the broad range of agroforestry systems in practice in developing countries. For example, under the Kyoto driven regulatory market, the United Nations Framework Convention on Climate Change (UNFCCC) Clean Development Mechanism (CDM) approved methodologies only provide for Afforestation/Reforestation carbon offset projects (UNFCCC 2010). The largest voluntary carbon market, the Chicago Climate Exchange (CCX) currently only includes Afforestation/Reforestation and Sustainably Managed Forest Projects (CCX 2010).

The project objectives included the development of prototype small-holder agroforestry projects in Laos, Thailand and Vietnam, and the drafting of related agroforestry protocols that define the measuring, monitoring, and validation methods for market-ready carbon sequestration offsets. The protocols will be reviewed by the Technical Advisory Committee on Agroforestry in Developing Countries and the Forestry Offsets Committee of the Chicago Climate Exchange for comment. Approval of these protocols will make it possible for future agroforestry projects in developing countries to be registered on the CCX. To accomplish the development of agroforestry pilot projects and the drafting of protocols, this project included training and capacity-building of farmers, University staff, and government agency personal who are members of our project team.

2.0 Methodology

To meet the objectives of this project, collaborators assembled project teams and followed an implementation plan that included an initial workshop, site selection, the development of survey data instrument, data collection, and the development of an Internet-enabled carbon management application for Measurement, Reporting and Verification (MRV: sometime referred to as Monitoring, Reporting and Verification). The activities build on a small-holder teak woodlot agroforestry project in Thailand.

The teams assembled by the project co-leaders included the following key participants (Table 1).

Table 1: Project teams

Country	Name	Institution	Expertise
Laos	Dr. Sithong Thongmanivong	Faculty of Forestry, National University of Laos	Team leader – remote sensing, GIS, forest silviculture
	Mr. Hounphet Chantavong	Faculty of Forestry, National University of Laos	Rural economic development
	Mr. Khosada Voangsana	Faculty of Agriculture, National University of Laos	Soil science, rural development
	Mr. Khamphouvieng Phouisombath	National Agricultural and Forestry Extension Service	Rural development, forest ecosystems
	Mr. Linkham Duangsavan	National Agriculture and Forestry Research Institute, Policy Research Institute	Forest biometrics, climate policy

Thailand	Mr. Chetphong Butthep	National Research Council of Thailand	Team leader – climate policy
	Dr. Sura Pattanakiat	Faculty of Environment and Resource Studies, Mahidol University	Remote sensing, forest ecosystems
	Dr. Charlie Navanugraha	Faculty of Environment and Resource Studies, Mahasarakham University	Soil science, GIS
	Dr. Usa Klinhom	Faculty of Science, Mahasarakham University	Rural livelihood, traditional medicines
	Dr. Rittirong Junggoth	Faculty of Environment and Resource Studies, Mahasarakham University	GIS, economic planning
	Dr. Teerawong Laosuwan	Faculty of Science, Mahasarakham University	Remote sensing, GIS
	Mr. Pornchai Uttharuk	Faculty of Science, Mahasarakham University	GIS
	Mr. Nathawat Khlangsap	Trat Agroforestry Research Station, Kasetsart University	Agroforestry, rural development
Vietnam	Dr. Do Xuan Lan	Dept of Science Tech. and Environment, Ministry of Agriculture and Rural Dev.	Remote sensing, GIS, forest silviculture
	Dr. Phung Van Khoa	Vietnam Forestry University	Forest economics, payments for ecosystem services
	Vu Tan Phuong	Forest Science Institute of Vietnam	Forest biometrics, climate policy
	Ms. Nguyen Thi Hai Hoa	Dept of Science Tech. and Environment, Ministry of Agriculture and Rural Dev.	Forest science, rural development
	Mr. Ky	Department of Forestry	Forest silviculture, agroforestry
United States	Dr. David L. Skole	Department of Forestry, Michigan State University	Team leader - Carbon markets, climate policy, ecosystem science
	Mr. Jay Samek	Department of Forestry, Michigan State University	Project manager – remote sensing, GIS, social forestry
	Dr. Larry Leefers	Department of Forestry, Michigan State University	Forest economics, environmental policy
	Dr. Sophan Chin	Department of Forestry, Michigan State University	Dendrochronology, silviculture, forest ecosystem productivity
	Dr. David MacFarlane	Department of Forestry, Michigan State University	Forest measurements and modeling
	Mr. Oscar Castaneda	Department of Forestry, Michigan State University	IT systems, GIS
	Dr. Eric Kasten	Department of Forestry, Michigan State University	IT systems, spatial analysis
	Mr. Walter Chomentowski	Department of Forestry, Michigan State University	Remote sensing, GIS, forest ecosystems
	Mr. Mike Smalligan	Department of Forestry, Michigan State University	Silviculture, forest biometrics

The project activities began with a workshop in Bangkok, Thailand, hosted by the National Research Council of Thailand, focused on a review of agroforestry systems and practices in Southeast Asia and the requirements of carbon markets. The agroforestry carbon offset pilot area site selections were developed on preliminary criteria and as a result of the workshop discussions. Draft field survey instruments were edited to each pilot area's specific characteristics. Data collection is currently on-going in the pilot area sites. The MRV project management system is in development and a prototype project is currently on-line. This is a small-holder agroforestry teak (woodlot) project in Thailand that serves as a model for the initial agroforestry protocol (in review at CCX). The project implementation plan stages are shown in table 2.

TABLE 2: IMPLEMENTATION PLAN

Project Task/Activity	**Brief Description**
Initial workshop	Regional agroforestry review of diverse systems, carbon market requirements for offset trading
Site criteria → Site selection	Minimum area, permanence commitment, voluntary market
Survey instrument	Land use / cover history, land management, ownership rights
Data collection	Landscape and plot level – biometrics, species, age class, etc.
MRV development	Internet-GIS content management application
Protocol	Eligibility, quantification methods, leakage, monitoring, verification, QA/QC, reporting, permanence
Project idea note (PID)	Carbon sequestration offset project details; baseline carbon stock, ex ante sequestration estimates.

Workshop: The workshop was held in Bangkok, Thailand, 15 – 17 March 2010 (figure 1). Even in the midst of an uncertain political situation in Bangkok at the time, more than 40 people participated in the three-day event including colleagues from the Faculty of Forestry, National University of Laos; National Agricultural and Forestry Extension Service, Lao PDR; Ministry of Agriculture and Rural Development, Viet Nam; Vietnam Forestry University; Forest Science Institute of Vietnam; Mahasarakham, Mahidol, Kasetsart and Thammasat Universities in Thailand; Inpang Community Network, Thailand; Office of Natural Resources and Environmental Policy and Planning, Thailand; Thailand Greenhouse Gas Management Organization; and Michigan State University in addition to the host organization.

FIGURE 1: WORKSHOP PARTICIPANTS

The workshop focused on two important challenges for implementing small-holder, agroforestry carbon offset projects: 1) field level carbon measurements in diverse agroforestry systems, and 2) the development of agroforestry carbon offset protocols. Three keynote presentations addressing the challenges and opportunities for forest and agroforestry related climate mitigation projects were given to start the workshop:

- Dr. David Skole of Michigan State University,
- Dr. Natarika V. Cooper, Acting Director of the Policy and Strategy Office of the Thailand Greenhouse Gas Management Organization, and

- Ms. Araya Nuntapotidech, Director of the Regional Environment Office, Ministry of Natural Resources and Environment in Thailand.

FIGURE 2: EXAMPLES OF AGROFORESTRY "*FARMSCAPES*" IN THE REGION: (A) FOREST FARM, INPANG COMMUNITY NETWORK, SAKON NAKHON, THAILAND; (B) LITCHI FRUIT TREES INTERCROPPED WITH BEANS, BAC GIANG, VIET NAM; (C) PARA RUBBER TREES INTERCROPPED WITH BANANA, TRAT, THAILAND, (D) JATROPHA INTERCROPPED WITH PINEAPPLE, BOLIKHAMXAY, LAO PDR

Country teams gave presentations on agroforestry practices in their respective countries (figure 2) which highlighted the diversity of such systems in practice. It is recognized that there are trade-offs to be made in the use of field-based inventories of biomass and carbon in agroforestry systems and the need for scientifically robust and valid measurements required to reduce uncertainty in trading carbon as a commodity on markets (figure 3).

Each country also presented their understanding of the institutional linkages and requirements for registering a carbon offset farm or area and for realizing payments from carbon offset transactions in their respective countries. Country teams organized into breakout groups to develop field level data collection instruments for registering a farm or landscape areas and for establishing baseline carbon in the agroforestry "*farmscapes*", and to discuss the required components needed for developing agroforestry carbon offset protocols based on a subset of specific agroforestry project prototypes based on species diversity, age classes, end-use, and spatial complexity.

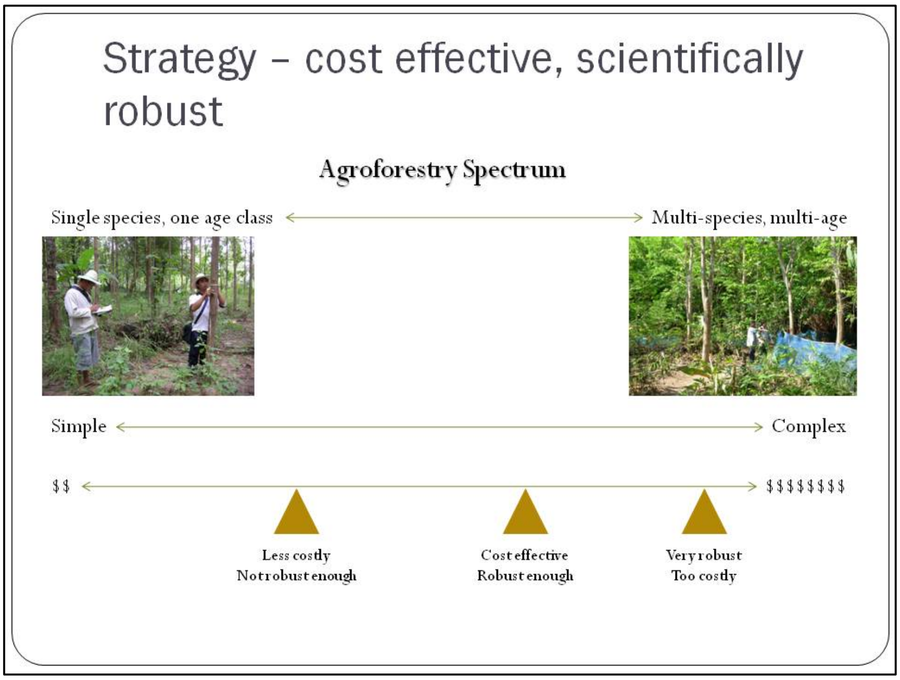


FIGURE 3: COST EFFECTIVE DATA COLLECTION FOR MARKET-ACCEPTABLE OFFSETS

The outcome of the workshop included initial identified of potential project pilot sites for data collection and implementation and a strategy for moving from farm-level data collection to realizing payments from agroforestry carbon offsets traded on a market.

Site Criteria and Selection: A set of initial conditions or criteria were established to guide the site selection process. An agroforestry carbon offset *project* is defined as a set of enrolled agroforestry (farm) properties. The properties may be contiguous or discrete and disaggregated. Property rights should be well established. Owners must agree to a 15 year permanence commitment. In addition to the properties containing woody perennials in the landscape, these properties would have to have been non-forest as of 1990. Target properties would be those that experienced a land use/cover change from annual crops only to the inclusion of woody perennials since 1990. Harvesting of woody biomass is allowed within project areas but the loss will be included as leakage. High priority should be given to geographically constrained sites that exhibit all the above characteristics in order to reduce costs associated with field work.

While individual farmers may be practicing agroforestry and establishing trees on their farms, the small amount of carbon sequestration at the farm level precludes them from entering the market. For example, one hectare of teak on average will sequester approximately 10 tCO_2e per year. The CCX trading platform trades what are call Carbon Financial Instruments or CFIs which are equal to 100tCO_2e. One requirement for the site selection, therefore, was to include a minimum of 300 hectares and set a goal of including at least 100 farmers (households). We also acknowledged at the outset that these would be offset generated for the voluntary market (as opposed to CER for any compliance market) and that there would be a minimum permanence requirement of 15 years. Assuming a sequestration rate of 6 tCO_2e per hectare per year an offset project which enrolled 300 hectares would sequester 1800 tCO_2e annually and 27,000 tCO_2e over a project period of 15 years. Assuming no leakage but a reserve pool of 30 % (8100 tCO_2e) held off the market until the 15 year project completion and a price of US$7.00 per tCO_2e would realize US$132,300.00 (or US$8820.00 annually).

FIGURE 4: PROJECT PILOT AREA AGROFORESTRY CARBON OFFSET SITES

The sites selected as an outcome of the workshop discussions and criteria are (figure 4):

- Laos: Nam Ton and Nam Sang Watersheds, Sangthong District, Vientiane Province – small-holder teak, rubber, and fruit tree
- Thailand: Inpang Community Network, Northeast Thailand – complex multi-species, multi-aged forest farms.
- Thailand: Trat Province – Small-holder rubber agroforestry and fruit trees.
- Vietnam: Kien Lao Commune, Luc Ngan District, Bac Giang Province – Litchi agroforestry

Survey Instrument and Data Collection: The survey instrument is designed to collect both carbon stock data (biomass, biomass accumulation over time) and greenhouse gas emissions from land use management practices or leakage. Carbon gain from biomass accumulation and carbon sequestration) minus leakage is the amount of marketable CO_2. Rather than develop a universal survey instrument to fit all agroforestry systems, we have used a general framework for data collection and revised as needed to meet the specific characteristics of the each project's agroforestry system. In addition to the biomass/leakage data the survey is used to explain carbon as a commodity to potential enrollees, ensure ownership and permanence commitment and record location information. For example a agroforestry project that includes small-holder tree crops such as teak or acacia (production species) would have a different survey design than a project with mixed fruit tree crops or very complex agroforestry tree-gardens; Species complexity as well as end-use of tree and tree products and land use management dictate to some extent the design of the field data survey instruments. Figure 5 is an example of the field survey instrument.

<u>MRV Application Development</u>: Use of innovate IT methods, infrastructure and geospatial tools and

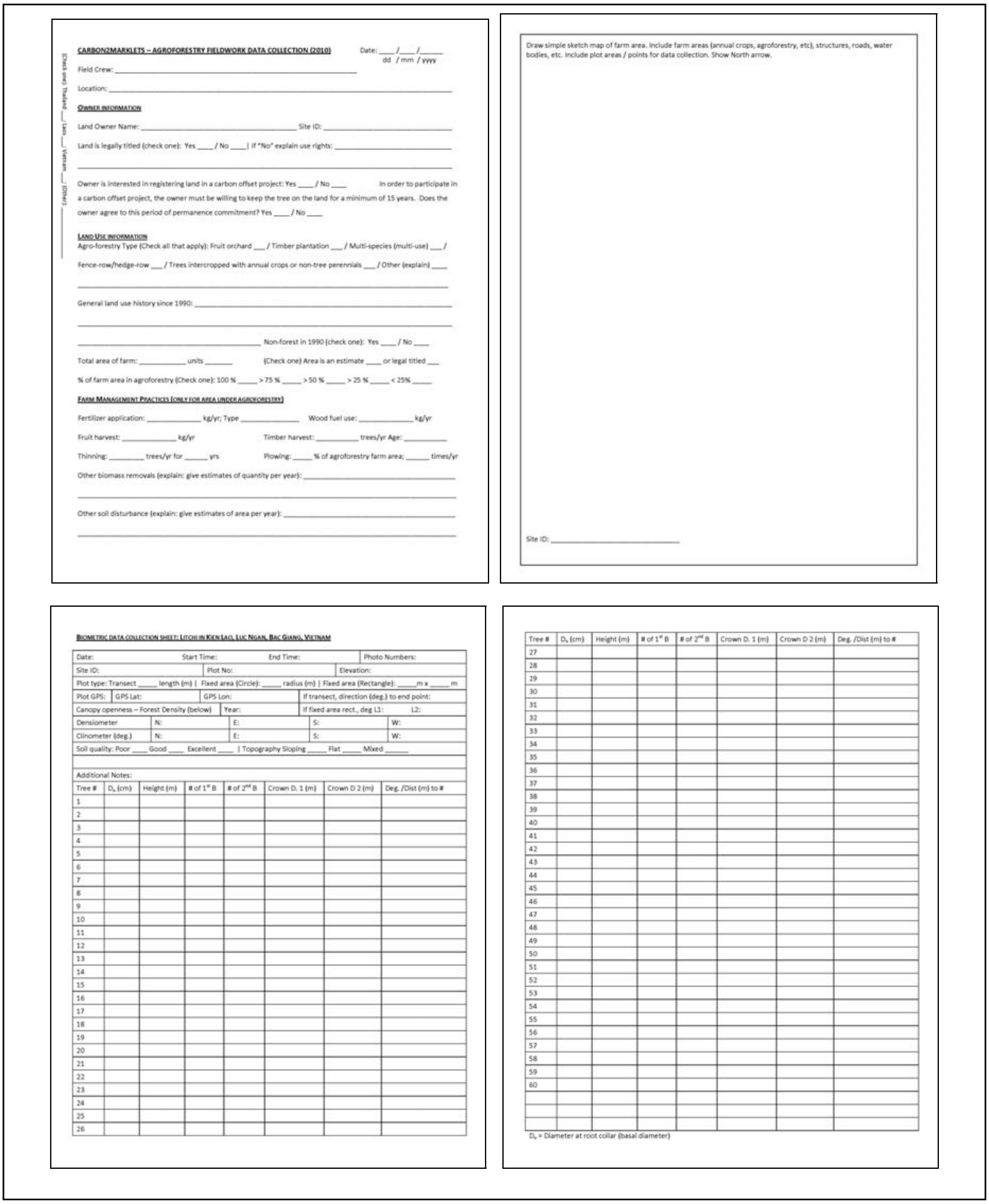


Figure 5: Field Survey Instrument for Bac Giang, Vietnam

technologies that form a carbon measurement, reporting and verification system (MRV), we believe, help reduce costs associated with developing terrestrial carbon mitigation projects and reporting carbon stocks and stock changes to carbon markets. To this end, we have developed a working prototype of the MRV system, an Internet-enabled carbon management application that supports individuals and communities in managing their carbon assets. The system aggregates individual properties and reports carbon stocks at the plot, property and project levels. Eventually we would like this system to link a projects carbon offset account directly to the carbon markets, like the Chicago Climate Exchange.

Our approach builds on advances in geospatial and other related technologies that form a transformative opportunity to create a cost-effective, measurement and monitoring system. We have developed an on-line MRV system by twinning emerging Internet technologies with earth observation and location-based technologies. The project's carbon MRV system builds upon the following current trends:

- Satellites are now offering global, near real-time data with high spatial resolution which allow for accurate land use, land use change and forestry tracking anywhere in the world.
- Satellite imaging is decreasing in cost as more extremely high-resolution imaging systems are launched into orbit – and internet-enabled GIS mapping is now available for integration of multiple types of geospatial data layers, including land cover, land ownership, population, infrastructure, and other features; and geospatial content management software is increasingly available.
- GPS enabling, location-based services are built and available on distributed internet GIS.
- Telecommunications, wireless hand-held devices and increasing internet connectivity enable information flow from the field to centralized databases;
- Increasing computing power is lowering the cost of managing large and complex data sets such as remote sensing images.

The carbon MRV system is comprised of five integrated components (figure 6): 1) a relational database management system, 2) a spatial data engine, 3) a map server, 4) a Google Map API extension and 5) a web server. The five components are integrated through custom engineered APIs and scripts. This carbon MRV system is platform independent and able to be accessed through the World Wide Web using any simple web browser. The system is scale-independent with the ability to manage multiple projects from farm- to regional levels. The five components that comprise the MRV system are described in detail below:

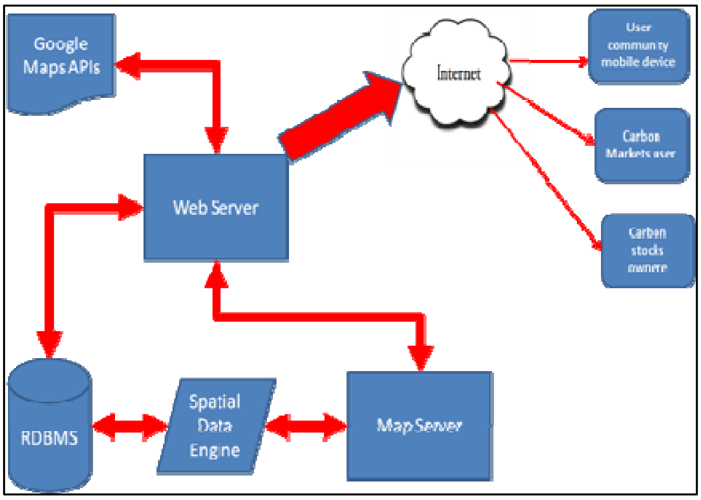


FIGURE 6: SCHEMATIC OF MRV IT COMPONENTS

Relational Database Management System (RDBMS): the carbon MRV system stores all data using Microsoft SQL server. Data include maps in vector format, satellite imagery in raster format and tabular data associated with the maps, satellite images and even data of higher dimension which includes time (to allow for change over time of the values of carbon stocks in a give location).

Spatial Data Engine: this component provides Spatial Indexes for the RDBMS optimized to store and query data related to objects in geographic space, including points, lines, polygons and satellite images. The spatial data engine also adds functionality to support spatial data types (to be able to send queries related to geo-spatial location attributes), enabling the ability for the web-GIS to generate queries that have a spatial component (e.g. find all the line segments that intersect a given point or set of points or a given line segment) in a timely fashion. Without a spatial engine, those queries would be time/CPU consuming and would not be practical in a web-GIS system.

Map Server: The map server component is a customized software environment that provides the elements necessary to build spatially enabled internet applications (web services) that have the ability to respond to spatial queries by creating customized maps on the fly. It also provides the ability to display satellite imagery and derived products. The map server is a set of programs that sit inactive in a computer waiting for requests to build maps or send information related to the maps (e.g. list the land owner with property that is crossed by a determined river). When a request is sent to the map server, it uses the parameters sent in the request to build its own request to the Spatial Data Engine and when the Spatial Data Engine returns the information, it builds a map and/or a string with the response. That response is sent to the web server where it is integrated with other elements. The map server in this MRV will be capable of generating responses in the most common web services protocols (KML, WMS, WFS, REST and SOAP). They all will be delivered in APIs built on JavaScript.

Google Maps APIs: The carbon MRV system uses the Google Map interface as a common, ubiquitous user-friendly portal to render project data using web-GIS. Its "look and feel" is very popular and most people know how to navigate its maps. It provides multiple geographic background layers, however our extension of the API allows for use of additional geospatial data sets and the ability to display current acquisitions of high-resolution data in support of project verification as a substitute of the Google Maps imagery. The ability to display maps that include satellite imagery becomes very important in remote areas where Google Maps has only imagery with low resolution. The interaction with Google Maps and the Map Server is executed through the customized JavaScript Extensions of the Google Maps API mentioned above. JavaScript provides an excellent medium for this systems because is a language that provides lightweight applications, since the code runs inside the browser immediately. There is no need to wait for big processes to happen on the server. The user does not need to install anything in order to run a program written in JavaScript, as all web browsers know how to interpret it.

Web Server: The web server component uses the Hypertext Transfer Protocol (HTTP) to portray project information and data in tabular and web-GIS formats over the World Wide Web. This is the component that puts the information coming from the Map Server, the RDBMS and the Spatial Data Engine together in a simple format that can be read with a simple web browser (e.g. Internet Explorer, Firefox, etc.) and does not demand high computer or network power.

The carbon MRV system functions as an on-line application with a suite of tools for developing and managing carbon mitigation offset projects. The system includes data storage and data back-up functionality; it provides data integration services of field-based biometry and remote sensing analysis for carbon stock and carbon projection calculations; and it also provides monitoring, reporting and verification services.

Data storage and data back-up: carbon mitigation offset protocols and methods specify data required for generating reliable estimates of carbon capture and carbon emissions avoidance. These data include project boundary areas, spatial and temporal land use and land cover change information, ownership, land management data, sample plot biometry, etc. The carbon MRV system stores all project data (tabular, GIS, GPS, and satellite remote sensing data) with multiple redundant back-ups for data safety and security.

Data integration for carbon calculation: The MRV tools are being developed to integrate the field-based biometry measurements at plot and inventory levels with assessments of biomass and carbon from new remote sensing analysis techniques and use alometric and spatially explicit carbon booking models to derive carbon stock. Ex ante projections of carbon sequestration in agroforestry offset projects can be reported using growth and yield models.

Monitoring, reporting and verification services: The carbon MRV system uses web-services, including advance web-GIS, to provide quantification of carbon stocks, monitoring for permanence, reporting and verification services. The MYV system can accommodate hyper-resolution satellite data (e.g. IKONOS, QuickBird) and ingest annual or bi-annual updated of field level inventories. These enable monitoring and verification services. The MRV system can generate on demand project reports that include required protocol modules (project boundary, land use history, eligibility, leakage assessments, permanence commitment, baseline carbon, ex ante projections, monitoring updates, etc.). These reports are in PDF format generated on the fly using the most current project level data stored in the MRV databases. The MRV system provides verification services through the on-line system by allowing verifiers to interrogate all data used in quantifying project level carbon stocks and projecting sequestration rates. These data include field level and individual tree level biometry data, alometric equations used to estimate biomass and carbon, calibration and validation data used for the remote sensing analysis, and documentation on enrollment, tenure and permanence commitments.

The carbon MRV system provides services to both carbon offset providers or managers and carbon offset buyers or the markets. Carbon offset providers or managers may include aggregators, local community organization, or individual land owners. Examples of carbon offset buyers or the markets include the Chicago Climate Exchange, climate investment funds, or direct investments on offsets from corporations and industries.

3.0 Results & Discussion

The project has established the pilot project area sites for implementing agroforestry carbon projects and for developing the protocols for the markets. Our early efforts as part of this project to complete work in Thailand with small-holder teak areas serves as the simplest agroforestry carbon offset system. Data is still being collected at the four additional pilot areas for ingest to the MRV application. Some initial data from all three pilot areas is reported below.

<u>Pilot area site descriptions (figure 7)</u>

Laos: Nam Ton and Nam Sang Watersheds, Sangthong District, Vientiane Province is approximately 70 kilometers northwest of the capital city, Vientiane. The region has under gone deforestation and forest degradation from timber logging in the late 1980s. The area is a mosaic of paddy field agricultural, shifting cultivation field and fallows, degraded shrub land, home gardens, cash crop gardens, and forest (conservation, protection and production). The site is also the location of the Model Training Forest (MTF) facility of the Faculty of Forestry, National University of Laos

Thailand: The Inpang Community Network in Northeast Thailand; this region includes Kalasin, Mukdahan, Nakhon Phanom, Sakon Nakhon, Nakhon Ratchasima and Khon Kaen Provinces. The Inpang network began in 1987 with a group of village leaders in Ban Bua Village, Tambon Kut Bak, Kut Bak District, Sakon Nakhon Province. In order to break the cycle of debt from cash-cropping, the farmers began to transform their farm landscapes from more costly, high-input, chemical dependent monocultures to diverse agroforestry systems that included rice for consumption as well as a wide variety of woody perennials. From a small group of twelve members, the Inpang network has grown to over 4000 members in five provinces in northeast Thailand, with linkages to many other farmer groups throughout Thailand. Inpang members grow hundreds of native woody perennial species as seedlings aimed at promoting the use of forest products from on-farm sources, rather than harvesting and collecting from the natural, protected forests in areas such as nearby Phuphan National Park.

FIGURE 7: PICTURES OF THE PROJECT PILOT SITES - A: TRAT, THAILAND (RUBBER WITH PINEAPPLE), B: INPANG NETWORK, NORTHEAST THAILAND (MIXED FRUIT TREE), C: BAC GIANG, VIETNAM (LITCHI), D: SANGTHONG DISTRICT LAOS (HOME GARDEN)

Thailand: Trat Province, Thailand, borders Cambodia to the east, Chantaburi Province to the northwest and the Gulf of Thailand to the South. Trat covers an area of 1,088.4 km^2. Agroforestry patterns in Trat province can be divided into 3 types, based upon the major land use patterns, which including agroforestry in rubber plantation, agroforestry in fruit garden and home garden. For agroforestry in rubber plantation, the species are intercropped such as *Aquilaria crassna*, *Acacia mangium, Hopea odorata*, *and Dipterocarpus alatus* etc. Most of agroforestry practices in fruit garden are mixed planting of fruit species. Some forest tree species are also enriched together such as *Aquilaria crassna,* and palm trees. For home garden practice which trees and crop are planted together around farmer's house, comprise of 3-5 layers. The trees in the upper layer provide wood for construction and fruit for food, in lower layer are medium sized fruit trees and in the lowest layer are medicinal and vegetation plants. Trat Agroforestry Research Station (TAFRS) under Kasetsart University Research and Development Institute (KURDI) was started agroforestry network (AFN) driving in Trat province since 2005. The activities of AFN are agroforestry knowledge transferring, distribute trees to planting in farmer' land and forest rehabilitation activity. In present, AFN is around 50 members and expanding member amount. In addition, AFN are planning to cooperative with community forestry (CM) groups in Trat province to promote agroforestry practices in CM.

Vietnam: Kien Lao Commune, Luc Ngan District, Bac Giang Province is located approximately 120 kilometers northeast of Hanoi and has an area of 56 km^2. The area is a mosaic of reforestation for both production and protection forest and agriculture dominated by Litchi (*Litchi chinensis*), paddy rice, cassava, maize, and soybean. The area under Litchi production in Luc Ngan District has steadily increased since the mid 1980s replacing annual crops such as cassava and maize and being planted on degraded hills.

Data analysis findings

Laos: Data collection is still on-going for this site. A key informant interview with a local farmer (figures 8) in Sangthong District who has developed a model agroforestry farm in cooperation with the Model Training Forest facility of the Faculty of Forestry, National University of Laos indicates there are more than 200 families in his village and approximately 80 have planted trees on their property to some extent; Between 60 – 70 households have planted teak, 100 trees or more each since 2003. The farmer himself has 1 rai (0.16 ha) in home garden agroforestry with seven different fruit trees (Mango, Guava, Longan, Coconut, Makham, etc.), 2 hectares of teak (3000 trees) and Eucalyptus (1000 trees with only a 50% survival rate) planted in 2004 and 2003 respectively. These were planted on old fallow-land that was overgrown with bamboo. He has an additional 1 ha of land in another nearby area that he would like to plant trees on, given some resources.

FIGURE 9: KEY INFORMANT INTERVIEW - SANGTHONG DISTRICT, LAOS

The Faculty of Forestry at the National University of Laos maintains a rich data set from a series of established plantations and forest enrichment block in their Model Training Forest in this study site. Figure 9 shows the location of these research "blocks" and the site of the key informant from above (as well as river and road networks. The research blocks are 1 ha each and data were established between 1998 and 2002.

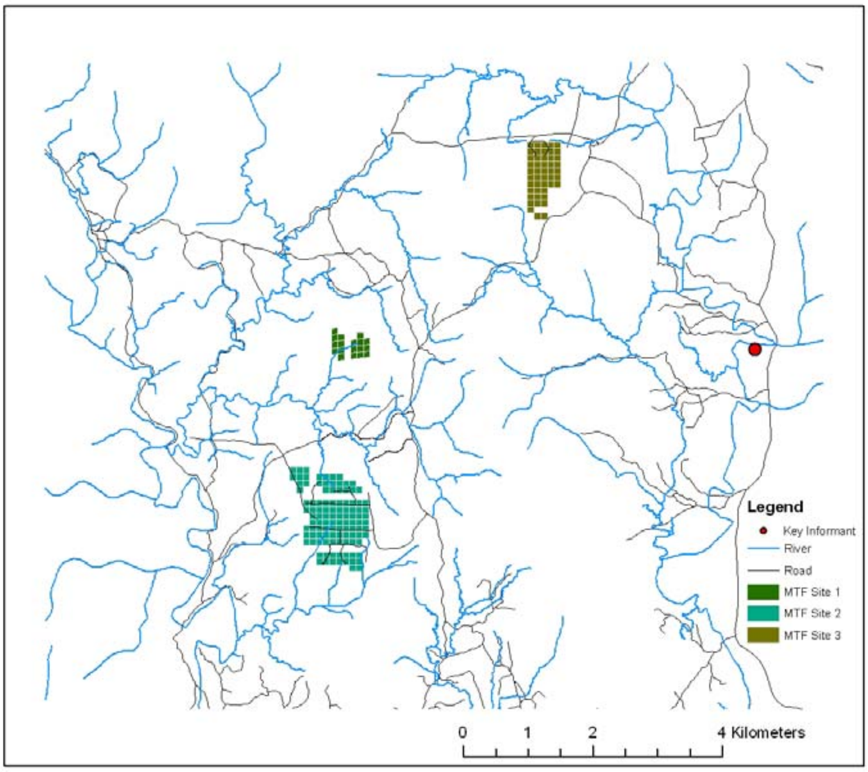


FIGURE 8: MAP OF MTF FOREST RESEARCH BLOCK

In total there are 170 1-hectare research blocks. Data for these areas includes species, type of planting (e.g. mixed plantation, single species plantation, line enrichment planting, gap enrichment planting, secondary natural regeneration, etc.) and growth rates. We will use these data to calculate and report potential carbon sequestration across all types of plantings to serve as models for the regions where families or local government units are engaged in agroforestry, tree planning, and forest rehabilitation interventions. Table 3 is an example of the data set showing information for three different research blocks: Line enrichment planting established in 1999, gap-enrichment planting established in 2001 and plantation established in 2000.

TABLE 3: EXAMPLE OF MTF RESEARCH BLACK DATA SET

	1	26	46
Plot No	1/1	6/1	12/3
Area (ha)			1
Location	Ban Nongboua	Ban Nongboua	Ban Nongboua
Elevation (m)	230	230	230
Topography	Rolling	Undulating	Flat
Slope gradient	<16%	<8	0
Crown cover before planting	<20%	40-70	0
Soil type	Ferric Alisol	Ferric Alisol	Ferric Alisol
Soil depth (cm)	75-100	>100	30-50
Top soil texture	Sand Clay loam		
Drainage	Well drainage	Well drainage	Well drainage
pH value	6.5	6.65	6.5
Erosion category	Sheet		
Erosion risk	Slight		
Forest function	Water Protection Forest	Water Protection Forest	Production forest
Stocking goal	Uneven-age, Multistorey Stand	Uneven-age, Multistorey Stand	Even aged pure stand
Production goal	High quality timber	High quality timber	Sawn timber
Utilisation	Heavy construction, Beams, Funiture, Veneer	Heavy construction, Beams, Funiture, Veneer	Matches, Packing, Ply, Veneer
Rotation Period (years/ diameter)	80-90	80-90	80-90/ >50 cm
Type of Rehabilitation	Line Enrichment Planting	Gap Enrichment Planlanting	Tree plantation
Species 1 (%)	Pterocarpus macrocarpus	Pterocarpus macrocarpus	Pterocarpus macrocarpus
Species 2 (%)	n/a	Vatica cinerea	n/a
Species 3 (%)	n/a	n/a	n/a
Date of establishment	May 1999	May 2001	May 2000
Seed source	Vientiane/ Laos	Vientiane/ Laos	Vientiane/ Laos
Planting stock [age / height]	Potted seedling [3 month / 30 cm]	Potted seedling [3 month / 30 cm]	Potted seedling [3 months / 30 cm]
No of trees / ha	250	480	1700
Planting space	15x2	2.5x3	3 x 2 m
Survival rate at first year (%)	98.4		
Taungya system applied during the first year of establishment	No	No	Yes
Key person involve	Phanvilay K., Bausavanh S., Weingart J.B., Brautigan D.	Vayakone S., Canthalangsy L.,Hacnorath Ph., Weingart G.B., Brautigam D.	Panhvilay K., Canthalangsy L.,Hacnorath Ph., Weingart G.B., Brautigam D.

Thailand: For the Inpang network project area a survey instrument was developed and translated to Thai in order to collect basic Inpang agroforestry data. The survey included ownership, location, farm size, land use history of farm area, and tree data - species, number of trees planted, age of trees, and use. 957 members responded. The data were input into an Access database organized in three related tables: ownership (name, address, size of farm area, land use history data), list of trees species (Latin and local names), and an agroforestry table (owner id, species planted, age of trees by species, number of trees

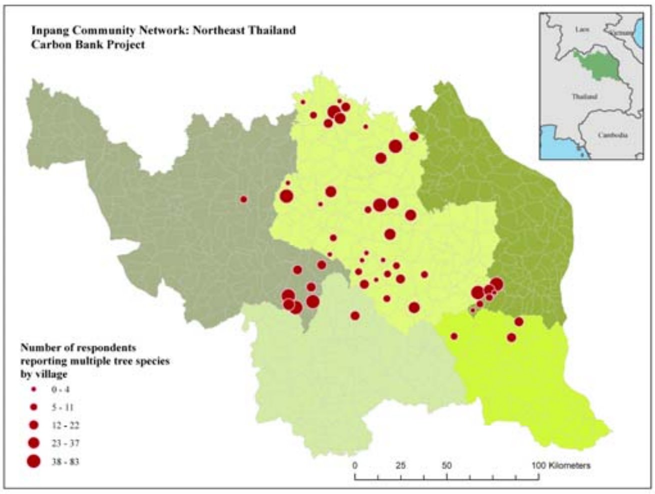


FIGURE 10: GIS FOR THE INPANG CARBON BANK PRELIMINARY DATA – DISTRIBUTION OF RESPONDENTS BY VILLAGE LOCATION REPORTING PLANTING MULTIPLE AGROFORESTRY SPECIES

planted by species, and use of tree species). These preliminary data are not sufficient for carbon accounting or registering agroforestry carbon offset projects. However, the data allow us to stratify the Inpang Carbon Bank diversity of agroforestry practices in multiple ways: geographically, by species diversity, and by the size of the area under agroforestry. Using the location information in the database we have developed an Inpang Carbon Bank GIS. Figure 10 shows how these data are used to stratify the Inpang Carbon Bank agroforestry areas and prioritize carbon offset project activities.

The data from the 957 Inpang respondents reveal that these farmers have planted or are managing a great diversity of tree species on their farms. Inpang respondents identify 254 different woody perennial species on their agroforestry farms. *Shorea obtusa* (Wall. ex Blume) is reported by the respondents to be the dominant species planted but total number of trees (table 4). Know in Thailand by the common Thai name "Teng", *Shorea obtusa* (Wall. ex Blume) is a member of the *Dipterocarpaceae* family, and is a valuable hardwood. Timber is not the only reason Inpang members plant and manage trees on their farms. Other dominate tree species in terms of numbers of trees planted (table 1) include *Hevea brasiliensis* (Willd. ex A.Juss.) for latex, *Dipterocarpus tuberculatus* (Roxb.) for fuel wood and medicinal herbs, and *Mangifera indica* (L.) for fruit.

TABLE 4: LIST OF TOP FIFTEEN SPECIES BY TOTAL TREES PLANTED REPORTED BY INPANG MEMBERS (N=957)

Species	Total Trees Planted	Households Planting
Shorea obtusa	146564	509
Dipterocarpus tuberculatus	129306	426
Hevea brasiliensis	99720	114
Xylia xylocarpa	93210	510
Ptercorpus macrocarpus	78456	491
Eucalyptus	59268	72
Sindora siamensis var. maritima	50741	246
Mangifera indica	38133	360
Tectona grandis	30769	116
Cratoxylum formosum	20034	135
Dimocarpus longan	17643	165
Lagerstroemia floribunda	15172	86
Tamarindus indica	13843	287
Terminalia alata	13327	140
Dipterocarpus obtusifolius	12762	123
Croton argyratus	12359	65
Afzelia xylocarpa	12293	73
Aporosa villosa	11645	73
Irvingia malayana	8198	83

Most of the Inpang agroforestry trees have multiple uses: timber, fuel wood, sap collection, fruit, medicinal herbs, animal fodder, cooking spices, and other uses. For example, one Inpang member, Khun Sawing Kudwongkaew, planted seven different tree species on approximately two hectares. In the mid-1990s she transformed this area, which had been annually planted in cassava for more than ten years, and as a result had very poor soil. Some of these species Khun Sawing planted create favorable habitat for growing edible mushrooms and for red ants. The ants build egg nests in the leaves of the *Xylia xylocarpa* trees. These egg nests are harvested for food and command a high value in the market, as do the mushrooms.

Thailand: Only preliminary data have been collected in the agroforestry project in Trat province. Twelve properties boundaries were collected using GPS in the field and biometric data collected in sample plots (figure 11). The properties include a variety of agroforestry systems: small-holder rubber plantations (monoculture), rubber intercropped with pineapple, rubber intercropped with ginger and rattan, rubber intercropped with banana and mangosteen fruit, rubber intercropped with agar wood and various fruit tree farms: mangosteen, longan, and rambutan. These agroforestry properties are of various ages and we have yet to analyze the biometric data. With some of the species, no alometric equations currently exist. Therefore we will use default IPCC Teir 1 model until new equations are developed.

FIGURE 11: GPS POLYGONS OF 12 AGROFORESTRY PROPERTIES IN TRAT PROVINCE, THAILAND

Vietnam: Litchi grown in this region of Vietnam are managed extensively. The tree is often multi-stemmed at the root collar with no single stem at DBH (figure 12). Growth rates are affected by soil quality associated with elevation and topography. Litchi grown at higher elevations with poorer soil nutrients and less water retention grow at a slower rate than do Litchi at lower elevations.

FIGURE 12: EXAMPLE OF MULTI-STEMMED LITCHI TREE

Data were collected in twelve Litchi sites Kien Lao Commune; six each in poor sold quality (higher elevations) and good soil quality (lower elevations) (table 5). Sample plots were in different age classes from Litchi planted in 1991 to 2008 (table 6). A total of 225 trees were sample and data collected included: diameter at the root collar, tree height, number of stems at root collar, number primary branches, number of secondary branches, crown diameter – two measurements, and crown height.

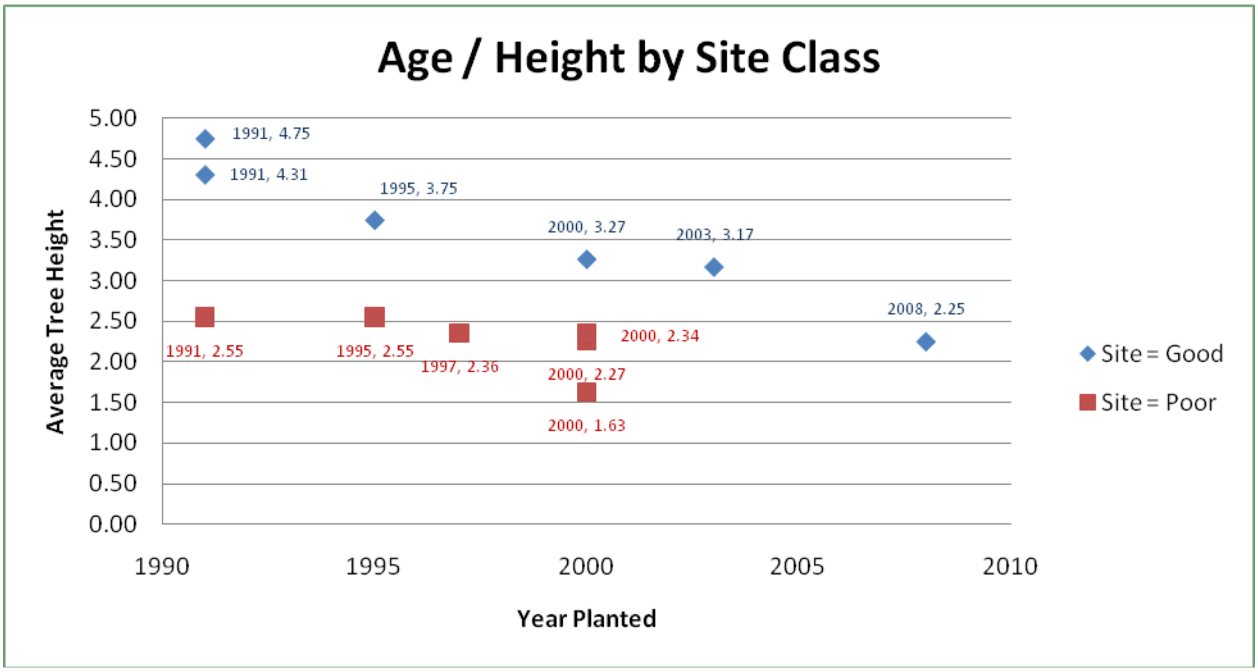
TABLE 5: SAMPLE SITES

Site	Year	Owner	Lat/Lon	Lat/Lon	Soil	Trees Sampled (N)
1	1991	La Van Manh	106 29 34.5	21 25 54.6	Good	15
2	2008	Lam Van Bang	106 29 36.8	21 25 56.5	Good	15
3	2003	Lam Van Bang	106 29 40.7	21 26 00.4	Good	15
4	1991	Ly Van Nien	106 29 32.6	21 25 56.1	Poor	20
5	1995	La Van Manh	106 29 24.4	21 25 59.8	Good	20
6	2000	Lam Van Sap	106 29 25.4	21 26 03.1	Poor	20
7	2000	Vi Van Van	106 29 25.1	21 26 07.3	Poor	20
8	1997	Hoang Van Truong	106 29 35.4	21 25 47.1	Poor	20
9	2000	Nguyen Sy Thanh	106 29 13.6	21 26 07.7	Good	20
10	2000	Tran Thi Dang	106 29 16.8	21 25 58.0	Poor	20
11	1995	Hoang Van Tha	106 29 14.6	21 25 57.6	Poor	20
12	1991	Tran Van Nham	106 29 33.5	21 25 52.9	Good	20
						N= 225

TABLE 6: SITES BY AGE CLASS AND SOIL QUALITY

	N=	YR1	YR2	YR3	YR4	YR5	YR6
Poor Soil	6	1991	1995	1997	2000	2000	2000
Good Soil	6	1991	1991	1995	2000	2003	2008

The plots in figure 13 show that both tree height and diameter at the root collar (D_o) vary by soil quality (site topography) across all age classes.



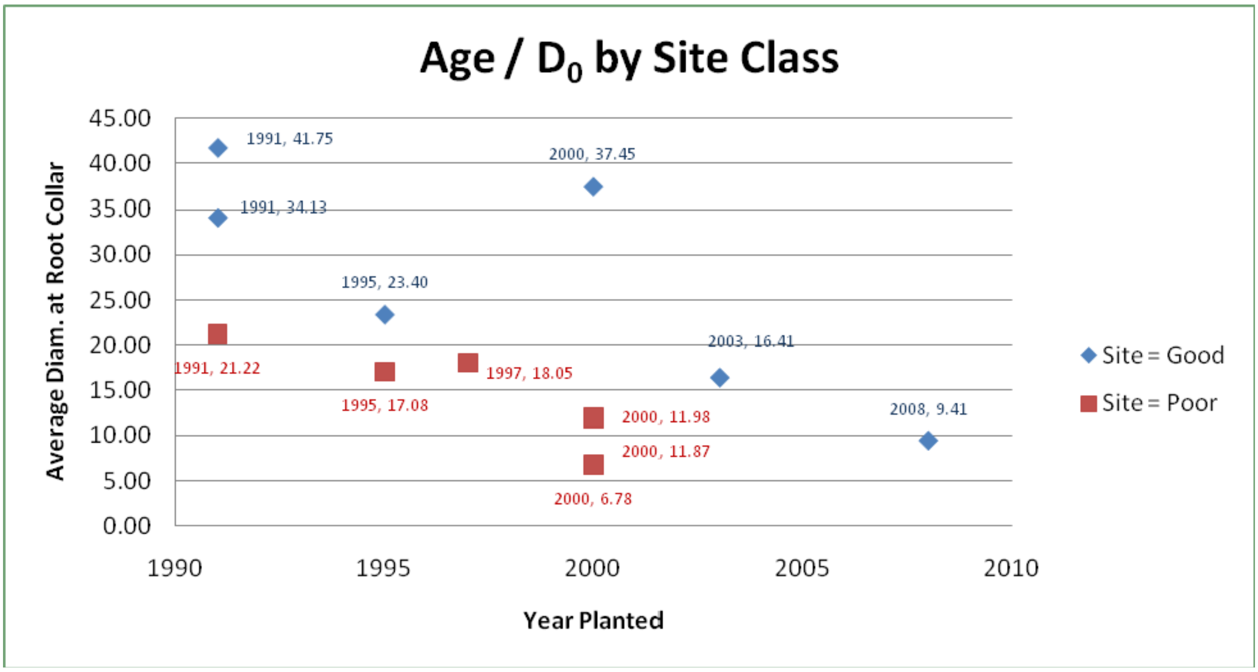


FIGURE 13: DATA PLOTS AGE/TREE HEIGHT (ABOVE) AND AGE/ D_o (BELOW) BY SITE CLASS

No alometric equation exists for the managed Litchi in Vietnam. The project will develop a series of alometric equations for Litchi in the two site classes using a destructive harvesting technique (Brown 1997, Parresol 1999, Pearson et al. 2005). Such equations relate a tree's physical characteristics to biomass from which carbon and carbon dioxide can be calculated.

The project will map litchi areas using GIS and high-resolution satellite data (IKONOS). On-screen digitizing enables desk-top mapping of these areas. Ownership of parcels will be derived in the field, but actual ownership boundaries are not required as the project will aggregate parcels to a single community carbon offset project. Figure 14 shows a subset of 1-meter multispectral IKONOS data for Kien Lao Commune. Features are easily discernable in the data, including the Litchi areas.

FIGURE 14: IKONOS DATA SHOWING LITCHI AREAS IN KIEN LAO COMMUNE

Carbon MRV Prototype: Small-holder teak – Thailand

The carbon MRV system at www.carbon2markets includes an agroforestry carbon offset project of small-holder teak areas in Thailand. This project has enrolled 98 Thai farmers, with 114 small-holder, teak agroforestry farms in the carbon MRV system. The project includes 44 teak areas owned by Inpang members, and 54 additional areas owned by non-Inpang farmers (10 in Uttaradit Province, 20 in Nakhon Sawan Province, and 24 in Nong Bua Lumphu Province). The average size of the teak areas are less than 3 hectares. The total area enrolled is 283.27 hectares. 170 permanent plots have been established and 13,021 teak trees tagged and DBH and height measurements recorded. Using an alometric equation developed for teak in Thailand (Petmark and Sahunalu 1980), we calculate the baseline carbon stock (2009) of the total enrolled area as 44,801 tCO_2e. Over a fifteen year commitment period the project will sequester an estimated 45,125 tCO_2e at a rate of 10.62 tCO_2e per hectare per year.

The project application is on-line at http://www.carbon2markets.org/thaiteak/.

Figures 15 and 16 show the carbon MRV application for the small-holder teak project in Thailand. All enrolled properties are displayed in the application down to the inventory plot and individual tree level details. Hi resolution satellite imagery show details of each property. Tabular data give summary information at the sample plot, property, project levels.

FIGURE 15: CARBON MRV SMALL-HOLDER TEAK PROJECT IN THAILAND

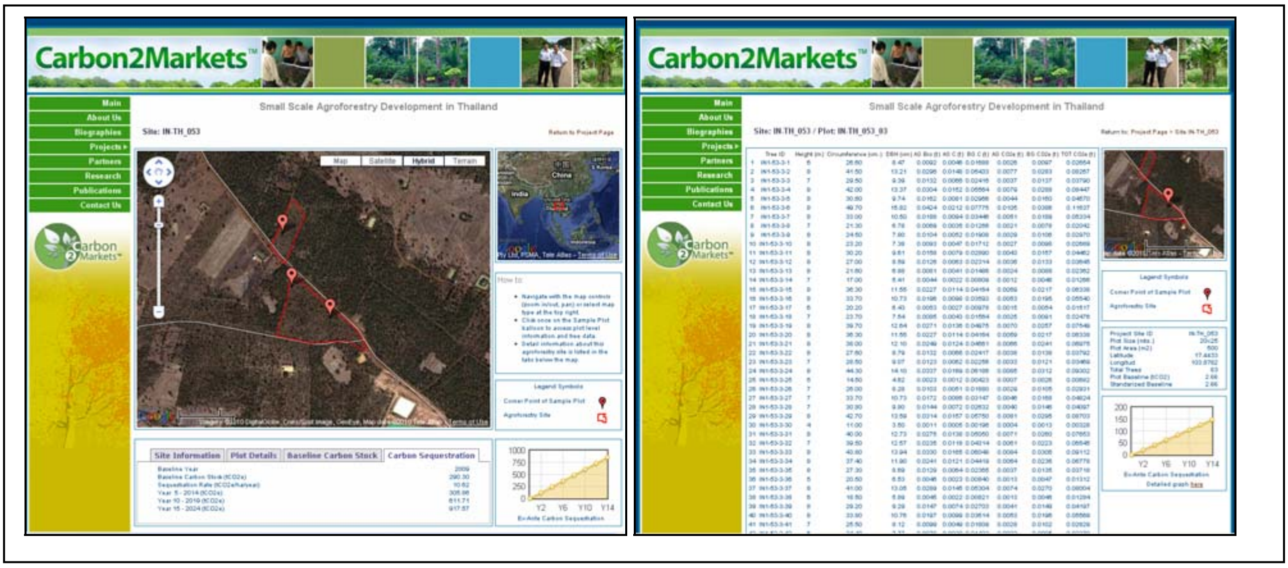


FIGURE 16: PROPERTY, PLOT AND TREE LEVEL DETAILS OF THE MRV APPLICATION

<u>Small-holder Teak Project Documentation</u>

Three important documents have been drafted for the Thai small-holder teak agroforestry carbon offset project: a *Protocol for Biotic Carbon Sequestration in Small Scale Agroforestry in Developing Countries*, a CCX project implementation document (PID), and a *Standard Operating Procedures: Field Measurements, Data Collection and Reporting* manual. All three of these documents are under review by the Chicago Climate Exchange. We include these documents in the appendix section of the report.

4.0 Conclusions

The project objectives including (1) training and capacity building in developing agroforestry carbon offsets, (2) the development of agroforestry carbon offset pilot projects in Laos, Thailand and Vietnam, and (3) the development of new agroforestry carbon offset protocols for the Chicago

Climate Exchange greenhouse gas trading market. The workshop in Bangkok, Thailand, the Symposium at Michigan State University and the meeting at the Chicago Climate Exchange were all valuable experiences for the participants in understanding the complex issues related to developing agroforestry carbon offsets and as benchmarks for the progress we have made toward our project goals. There is still a steep learning curve with respect to carbon financial markets and the requirements for mitigation projects. This learning curve is exacerbated by the very nature of the nascent markets and their continued evolution in light of new international agreement (e.g. Bali Road Map, Copenhagen Accord) and pending national legislation (particularly US legislation). Trading carbon as a commodity is further complicated in that there are both regulatory and voluntary markets. Pour project meetings, trainings with farmers, and field work always provide opportunities in which we discuss and exchange knowledge on the state of the markets and the development of our agroforestry carbon offset projects.

The identification of four pilot project areas and the development of the small-holder teak project in Thailand over the past 12 months is progress in realizing our goal of monetizing carbon sequestration in small-holder agroforestry "*farmscapes*" for climate mitigations and sustainable rural development. While some progress has been made in establishing the project areas there is more work to complete, including GPS of enrolled properties, the establishment of permanent plots to record tree measurements for carbon quantification, land use management data to quantify greenhouse gas emissions or leakage, acquisition of current hi-resolution remote sensing data for permanence and verification (we will acquire THEOS data for all project sites which has four 15-meter resolution multi-spectral bands and a 2-meter resolution panchromatic band), the development of new alometric equations for estimating biomass and carbon in certain species, and the ingest of data to the carbon MRV application. The team leaders in each of the countries are committed to making progress on these projects.

The carbon MRV system is currently fully functional as the prototype small-holder teak project in Thailand demonstrates (see: http://www.carbon2markets.org/thaiteak/). It is capable of integrating tabular database information with digital maps information in vector (point, line, and polygon) format and remotes sensing Earth Observation data in raster (pixel) format. The functionality of the system is being developed to include the ability to upload GIS/GPS project boundary data, to capture through on-line "drawing" tools project boundary data, and to upload repeat measurements of field based tree data (e.g. DBH and height). These new on-line services will help lower costs to implementing projects and to developing new projects.

The project documents for the Thai small-holder teak agroforestry carbon offset project serve as benchmarks for new agroforestry protocols for market-acceptable carbon offsets. With the great diversity of agroforestry practices it would be difficult to write a single protocol to fit all project types. The small-holder teak protocol, however, can serve as a template from which to revise and edit where needed. As advances are made in remote sensing analyses to quantify carbon in above-ground biomass new protocols will also be developed to include these techniques and tools.

5.0 Future Directions

Much still remains to be completed for the existing projects. A key focus of these efforts, however, is making entry to the carbon market for small-holders economically viable, by reducing the currently high barrier costs associated with project initiation, implementation, monitoring and verification. We envision the pathways for reducing costs to include: (1) the use of advanced Internet technologies (including Web-GIS) supporting all aspects of carbon offset project development and implementation, (2) advanced methods for quantifying carbon stocks and stock changes using remote sensing data (including multi-resolution, multi-spectral optical Earth

Observation satellite data and airborne or space-based Lidar data), and (3) the development of approved protocols for agroforestry carbon offset.

Much of the current costs associated with developing small-holder carbon offsets are associated with the need for a large number of field-based measurements. Using robust and scientifically valid remote sensing tools to quantify carbon will reduce the amount of field data needed for accurate accounting. Associated with the cost of field level data is the fact that small-holder carbon offset projects are comprised of numerous disaggregated properties. The use of GIS serves to aggregate these discrete parcels. But does not affect the costs associated with field-based measurements. Only remote sensing analysis can do this. A challenge associated with using remote sensing techniques for carbon quantification in agroforestry is the spatial nature and complexity of some agroforestry practices. Sparsely treed landscapes require high-resolution data.

To this end, one future direction for our work is relating tree crown dimensions to biomass. We are currently developing and testing a method of individual tree identification and tree density delineation using hyper-spatial resolution optical imagery (e.g. QuickBird, Worldview, IKONOS) (figure 17) and a method based on Geo-Object-Based Image Analysis (GEOBIA) (Hay and Castilla 2008). GEOBIA has several strengths, including: using image objects is akin to the way humans conceptually organize and comprehend images; image objects have useful statistical characteristics, texture and relationship to other objects; and presents the opportunity to use object-oriented methods and concepts borrowed from other disciplines. However, the development of robust and automated methods for partitioning remote sensing imagery into meaningful objects that can be used for remote measurement and monitoring is also challenging due to the increased complexity and detail afforded by hyper-resolution imagery. Leveraging the larger spatial extent afforded by image objects reveals the potential for using statistical, numeric and classification techniques to enable automated, robust and meaningful detection and measurement of trees found in the landscape. The boundaries of tree crowns may not be clear, contiguous edges and in many images crown boundaries may be fragmented into many noncontiguous pieces. Therefore, our technique focuses on extracting regions enclosed by a simple polygon for the delineation of tree crowns. There are four major steps to our method for detection and delineation of trees in the landscape. These steps are as follows:

Bootstrapping . The first step in the process is to "bootstrap" the detection of image objects by first using the spectral information afforded by single pixels to segment the image into larger, similar regions. This will identify areas on the image that contain forests and trees and segment these areas off from completely barren lands. This "bootstrapping" is the first step towards the detection of image objects and targets the separation of image segments that are spectrally similar to trees from those that are not. This initial classification serves to focus the remainder of the object detection process on image regions of interest.

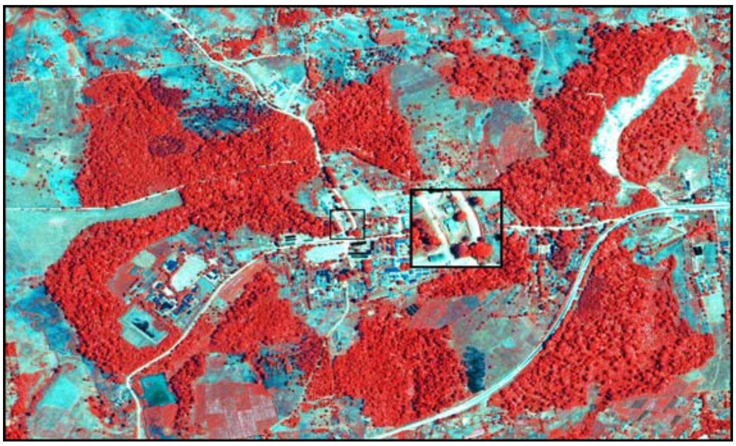


FIGURE 17: TREES ON FARMS NEAR A KAIMOSI FOREST FRAGMENT IN WESTERN KENYA. INSET SHOWS GREATER DETAIL OF INDICATED IMAGE REGION. IMAGE SHOWN WAS CREATED USING A PANCHROMATIC MERGE OF 3 QUICKBIRD BANDS COMBINED WITH THE TASSELED CAP TRANSFORMATION (GREENNESS) TO SHOW TREES AS BRIGHT RED. AT FULL RESOLUTION, THIS IMAGE HAS A 60 CM/PIXEL RESOLUTION.

Computing the gradient vector field. This step processes the image regions identified as containing forest and trees during bootstrapping using a numerical treatment. Specifically, the Laplacian operator is applied to the image gradient to produce a gradient vector field (GVF) as described by Xu and Prince (1997, 1998). Gradient ascent and descent algorithms (hill climbing) can then be used for the automated placement of object markers and subsequent detection and refinement of contiguous object boundaries. The GVF acts as a diffusion operator that diffuses the image gradient over a wider area, enabling the gradient ascent and descent processes to better locate object boundaries and to help smooth the image gradient such that gradient traversal can better avoid termination on local minima produced by canopy texture.

Peak detection. Using the GVF, the image is exhaustively searched for crown peaks using gradient ascent. These peaks are marked as starting points for the process of delineating tree crown boundaries during the next step. Duplicate markers are removed at the end of the search.

Boundary delineation. This step targets the delineation of tree crown boundaries within regions that have initially been classified as "trees." The goal is to refine crown boundaries using higher resolution panchromatic imagery to better delineate individual trees and to separate groups of trees into individuals. For this purpose we use active contours (Kass et al. 1988; Xu and Prince 1997, 1998). For each of the remaining markers located during peak detection a minimal polygon, comprising the eight pixel neighbors of the peak point as initial vertices, is constructed. For each vertex, gradient descent is performed by iteratively moving each vertex by an amount proportional to the change in the GVF. As the polygon grows, more vertices are added to better capture the shape of the tree crown. The process stops when each vertex has reached a minimum inflection point (crown boundary) or the maximum number of iterations has been attained. The number of vertices for each curve is reduced by removing intermediate vertices that lie on the same line and the polygon is recorded for later plotting or processing. As each tree crown is delineated it is removed from the image by masking the region it encompasses from subsequent processing.

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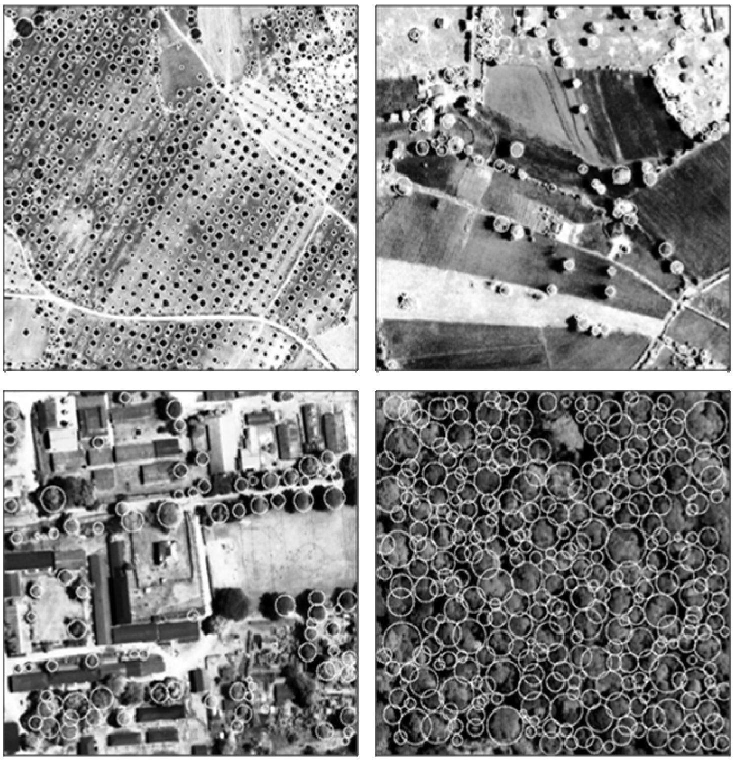

FIGURE 18: TREE DETECTION USING HYPER-SPATIAL RESOLUTION SATELLITE IMAGERY. TREES CIRCLED IN WHITE WERE DETECTED USING AN ALGORITHM DEVELOPED BY THE AUTHORS. A) IKONOS (1 M PAN) SHOWING DETECTION RESULTS FOR OLIVE TREES IN TURKEY. B) AND C) QUICKBIRD 2 (60 CENTIMETER PAN) SHOWING DETECTION RESULTS FOR SPARSE TREES IN THE WESTERN KENYA LANDSCAPE. D) QUICKBIRD 2 SHOWING DETECTION RESULTS FOR A CLOSED CANOPY FOREST IN WESTERN KENYA.

As shown in Figure 18, the method produces acceptable results over a set of landscapes with varying tree density. Accuracy and precision of the tree crown delineation is best for orderly agricultural plantings, like that shown in panel A, but also produces good results for sparsely planted woodlands and more densely planted regions.
Measurements computed using this method, such as crown size and diameter, can be correlated with field measurements and used to count trees, quantify woodland changes due to deforestation and reforestation and to construct general alometric equations for large regions.

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Appendix

Conferences/Symposia/Workshops

Workshop: Developing Agroforestry Carbon Offset Protocols for Carbon Financial Markets
Bangkok, Thailand, 15 – 17 March 2010

APN Workshop (ARCP2009-09NSY-Skole)
Developing Agroforestry Carbon Offset Protocols for Carbon Financial Markets
Bangkok, Thailand
15 – 17 March 2010
Venue: Windsor Suites Hotel
Local Host: National Research Council of Thailand

Agenda

Participating Countries: Lao PDR, Thailand, Vietnam, & the United States

14 Mar. 2010 (Sun)

11:20/17:50	Participants from Vietnam Arrive-Check in hotel/ Participants from Lao Arrive-Check in hotel

15 Mar. 2010 (Mon) **Keynote speakers & Presentations**

08:30 – 09:30	Registration
09:30 – 09.45	Welcome (Ms. Choosri Keedumrongkool, Director, Office of International Affairs, NRCT)
09.45 – 10.00	Opening Address (Mrs. Jintanapa Sobhon, Advisor on Social Science Research, NRCT)
10:00 – 10:20	Overview of Project Activity: background/goals (J. Samek, MSU)
10:20 – 10:30	Group Photo
10:30 – 11:00	*Morning break*

Session 1: Climate change mitigation; (Chair Dr. Charlie Navanugraha, Mahasarakham University)

11:00 – 11:20	Keynote 1: Dr. David L. Skole, Director of the Global Observatory for Ecosystem Services, Department of Forestry, Michigan State University (given by J. Samek)
11:20 – 11:40	Keynote 2: Dr. Natarika V. Cooper, Acting Director of the Policy and Strategy Office, Thailand Greenhouse Gas Management Organization (TGO)
11:40 – 12:00	Keynote 3: Dr. Araya Nuntapotidech, Director of the Regional Environment Office 10, Ministry of Natural Resources and Environment
12:00 – 13:30	*Lunch*

Session 2: Agroforestry practices (Chair: Dr. Usa Klinhom, Mahasarakham University)

13:30 – 13:45	Overview: J. Samek (Michigan State University)
13:45 – 14:00	Thailand: Nathawat Khlangsap (Trat Agroforestry Research Station)
14:00 – 14:15	Laos: Sithong Thongmanivong (Faculty of Forestry, National Univ. of Laos)
14:15 – 14:30	Vietnam: Do Phung Van Khoa (Vietnam Forest University)
14:30 – 14:45	Questions, comments, discussion
14:45 – 15:30	*Afternoon break*

Session 3: Institutional linkages for Carbon Offsets (Chair: Dr. Phongvipa Lohsomboon, TGO)

15:30 – 15:45	Overview: J. Samek (Michigan State University)
15:45 – 16:00	Laos: Sithong Thongmanivong (Faculty of Forestry, National Univ. of Laos)
16:00 – 16:15	Vietnam: Dr. Vu Tan Phuong (Forest Science Institute of Vietnam)
16:15 – 16:30	Thailand: Dr.Niramon Sutummakid (Thammasat University, Office of Economics Services)
16:30 – 16:45	Questions, comments, discussion
16:45 – 17:00	Logistics
18:30	Welcome Reception - hosted by NRCT at the hotel

วช. NRCT

APN Asia-Pacific Network for Global Change Research

MICHIGAN STATE UNIVERSITY

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16 Mar. 2010 (Tue)	**Project working group – full day (Agroforestry Carbon Field Work)**
09:00 – 10:30	Carbo2Markets: MRV and carbon offset registry/management system (J. Samek, MSU)
10:30 – 11:00	*Morning break*
11:00 – 12:00	Fieldwork and data collection for agroforestry carbon measurement (J. Samek, MSU) Breakout groups by country (Charge – review data collection FW sheets and protocols) • GPS and farm area data • Biometric data • AF management systems • Tenure-ownership-land use history
12:00 – 13:30	*Lunch*
13:30 – 14:30	Report back from breakout groups: recommendations & discussion (20 minutes each team)
14:30 – 15:30	Revisions on data collection data sheets
15:30 – 16:00	*Afternoon break*
16:00 – 16:30	Discussion and planning: Field work dates, proposed project sites, data management
18:30	Dinner at Leen On Tree Restaurant. We will meet in the hotel lobby and walk to the restaurant - very close by.
17 Mar. 2010 (Wed)	**Project Implementation**
09:00 – 10:30	Moving from "some" data collection to *REAL* projects and carbon offset market transactions Open discussion: requirements and gaps (J. Samek, MSU)
10:30 – 11:00	*Morning break*
11:00 – 12:00	Road map to project implementation; Future directions & possible funding support (All)
12:00 – 13:30	*Lunch*
13:30 – 14:00	Wrap-up (J. Samek, MSU)
Evening	Dinner on your own
18 Mar. 2010 (Thu)	
07:00	Lao participants depart hotel for airport (9:40 flight)
09:30	Vietnamese participants depart hotel for airport (12:20 flight)

Collaborating Institutions:

- Faculty of Forestry, National University of Laos, Lao PDR
- National Research Council of Thailand, Thailand
- Department of Science and Technology, Vietnamese Ministry of Agriculture and Rural Development, Vietnam
- Global Observatory for Ecosystem Services, Department of Forestry, Michigan State University, United States

Logistics

International and non-local participants staying at the Windsor Suites hotel will have breakfast in the hotel restaurant.

Please see Ms. Siritorn Dumrongsukit (Poom) or Ms. Patoo Sangkanukij (Pla) regarding workshop or hotel concerns.

Hotel Information:

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18-20 8 Sukhumvit Soi
Bangkok 10110 Thailand
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Workshop presentation available on-line at:
http://www.goes.msu.edu/apn_arcp_2009_09/workshop.html

Symposium: Climate Change, Forests And Farmers: Global Perspectives And Projects At MSU East Lansing, Michigan, U.S.A., 18-May 2010

SYMPOSIUM AGENDA

CLIMATE CHANGE, FORESTS AND FARMERS: GLOBAL PERSPECTIVES AND PROJECTS AT MSU
Tuesday, May 18, 2010
10:00 AM – 3:30 PM
Rm. 303 International Center

09:30 AM – 10:00 AM **Coffee and refreshments**

10:00 AM – 12:00 PM **Session I: Climate Mitigation Opportunities (CDM A/R, REDD, Carbon Benefits).**
(15-20 min. presentations)

1. Dr. David Skole: Climate Mitigation, Forests and Carbon Financial Markets
2. Mr. Chetphong Butthep: Thailand's National Climate Mitigation / Adaptation Strategy
3. Dr. Phung Van Khoa: Small-Scale CDM A/R Project in Vietnam - "Cao Phong Reforestation Project"
4. Mr. Walter Chomentowski: Global Rates of Tropical Forest Change for REDD
5. Dr. Sithong Thongmanivong: REDD in Laos
6. Mr. Michael Smalligan: Carbon Benefits Project: Kenya

12:00 PM – 01:30 PM **Lunch (International Center Food Court – 1st Floor)**

01:30 PM – 03:45 PM **Session II: Projects and Technology**
(15-20 min. presentations)

1. Dr. Madhab Karki: Nepal's experience in REDD through community forestry
2. Dr. Usa Klinhom: Inpang Community Network Carbon Bank
3. Mr. Jay Samek: Kien Lao Carbon Offset Project, Vietnam
4. Mr. Nathawat Khlangsap: Agroforestry Carbon Offset Opportunities in Trat Province, Thailand
5. Dr. Sura Pattanakiat: Remote Sensing Approach to Carbon in Teak Plantations in Thailand
6. Dr. Eric Kasten: High-Resolution Object Detection Classification
7. Mr. Oscar Castaneda: Carbon2Markets MRV System and Carbon Offset Management Application

03:45 PM – 04:00 PM **Coffee and refreshments**

The importance of forests and agriculture, of land-use and land-cover change, to climate change is recognized by scientists, governments and the international conventions. Researchers at the Global Observatory for Ecosystem Service (GOES), Department of Forestry at MSU have been working for more than ten years with scientists from SE Asia documenting changes in forest cover using remote sensing and geo-spatial technologies. We are deploying these same technologies and tools now to support climate mitigation in forestry and agroforestry systems. GOES is hosting a team of eleven visiting scientist from Laos, Thailand and Vietnam from May 12 – 19, 2010. GOES researchers and seven of the visiting scientist will give presentations on "Climate Change, Forests and Farmers" and on our collaborative projects in this symposium. This activity is supported, in part, by a grant from the Asia-Pacific Network for Global Change Research (APN ARCP2009-09-NSY-Skole titled, "Developing Small-holder Agro-forestry Carbon Offset Protocols for Carbon Financial Markets – Twinning sustainable livelihoods and climate mitigation". We recognize also, Dr. Charlie Navanugraha, Dean of the Faculty of Environment and Resource Studies, Mahasarakham University, Ms. Choosri Keedumrongkool, Director of the Office of International Affairs, National Research Council of Thailand, and Dr. Trieu Van Hung, the Director General, Department of Science, Technology and Environment, Ministry of Agriculture and Rural Development Vietnam who are not presenting at the symposium but are present.

International Colleagues from Thailand, Laos and Vietnam

1. Dr. Usa Klinhom, Professor of Biology, Faculty of Science, Mahasarakham University, Thailand
2. Dr. Sura Pattanakiat, Director of Geo-Informatics in Resource and Environment Research and Training Center, Faculty of Environment and Resource Studies, Mahidol University, Thailand
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MSU Researchers from the Global Observatory for Ecosystem Services, Dept. of Forestry

1. Dr. David Skole, Professor Forestry
2. Dr. Eric Kasten, Information Technologist, Systems Programming and Image Processing
3. Mr. Oscar Castaneda, Research Assistant, Systems Programmer and Web-GIS Databases
4. Mr. Walter Chomentowski, Research Specialist, Forest Ecologist, GIS and Remote Sensing
5. Mr. Jay Samek, Research Assistant, Social Forestry and Remote Sensing
6. Mr. Michael Smalligan, Forest Research

Special Guest from ICIMOD

1. Dr. Madhab Karki: Deputy Director General, International Centre for Integrated Mountain Development (ICIMOD)

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Project meeting with Chicago Climate Exchange (May 14, 2010)

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Protocol for Biotic Carbon Sequestration in Small Scale Agroforestry in Developing Countries (Draft)

Protocol for Biotic Carbon Sequestration in Small Scale Agroforestry in Developing Countries

A New Forestry Carbon Offset Protocol
Submitted to the Chicago Climate Exchange in association with the "Small Scale Agroforestry Development in Thailand" Project Implementation Document

Submitted by:

David L. Skole
Global Observatory for Ecosystem Services
Department of Forestry, Michigan State University

February 16, 2010

Table of Contents

Introduction

Agroforestry is the intentional inclusion of woody perennials within farming systems. While much of the world's agricultural lands are devoted to monocultures of annual crops, some farmers plant trees on their farm or they allow trees to remain on their land because they recognize that trees provide multiple benefits to their household. Some of the significant on-farm benefits that trees and agroforestry systems provide include fuel, living fences, building materials, fodder for livestock, nitrogen inputs, biological diversity, cultural services, economic diversification, and soil protection. Trees on farms also provide regional environmental services including hydrological benefits such as reducing soil erosion into rivers. Trees on farms also provide global environmental services by mitigating climate change as they sequester carbon dioxide from the atmosphere into long term storage in woody biomass. However, most climate change protocols, methodologies and standards are written to address trees in forests, not trees on farms. Forestry protocols for afforestation, forest management, and reduced deforestation of forested land do not address the specific barriers and opportunities for carbon sequestration in agroforestry systems on agricultural land. The global potential for agroforestry systems to contribute to mitigating climate change should be recognized and farmers who intentionally plant and manage trees on their farms should be allowed access to carbon financial markets.

The World Agroforestry Center estimates that 10.1 million km^2 of land classified as agricultural land (46% of all agricultural land globally) has greater than 10% tree cover (Zoomer, et al, 2009). However, there are significant barriers to establishing woody perennials that often prohibit farmers, especially small scale subsistence farmers, from implementing agroforestry systems. Taking agricultural land out of annual production to establish trees that may not produce income to the household for five or more years is an economic barrier that many farmers cannot overcome. The global carbon markets provide an early income stream that may allow farmers to overcome the financial barrier of transforming their high input, annual cropping systems into a more diverse agroforestry system that will eventually provide multiple benefits in multiple markets. Agroforestry systems also require both technical knowledge and access to locally appropriate tree seedlings that may not be available to subsistence farmers. Carbon offset projects can incorporate education about agroforestry systems and create access to nurseries that grow appropriate tree seedlings. Expanding agroforestry systems on small holder farms around the world can provide social, ecological, and economic benefits at the local, regional, and global scales. This document seeks to set forth a protocol to quantify the carbon sequestration benefits of agroforestry systems when farmers deliberately incorporate trees on their farms outside of land legally or practically classified as forest land.

Project Conditions for a Protocol for Small Scale Agroforestry in Developing Countries

Applicability

Agroforestry systems are not forests, even though they sometimes meet the UNFCCC definition of a forest. According to the IPCC GPG LULUCF, a forest is a minimum area of land of 0.05 – 1.0 hectares, with tree crown cover (or equivalent stocking level) of more than 10 – 30 percent, with trees with the potential to reach a minimum height of 2 – 5 meters at maturity *in situ*. Many agroforestry systems do meet that forest definition while remaining classified as agricultural land with a primary functional purpose of agricultural production of food or other crops. Small scale subsistence farmers cannot afford to forgo crop production for food and income and their agroforestry systems should be recognized as farming systems, not treated as forest lands.

This protocol is only applicable for land classified as agricultural land. Project activities cannot be implemented on land legally classified as forest land. Project activities must lead to the establishment of trees on farms that allow for the continuation of agricultural crops within the trees (ie. alleycropping) or adjacent to the trees (ie. windbreaks). Pre-project crown cover must have been less than the host country definition for a forest for at least ten years prior to establishing agroforestry trees. For example, Thailand's forest definition is land at least 0.16 ha, with 30 percent crown cover, and 3 meters tall. Project activities cannot lead to more than a 30 percent decrease in the total area of crop cultivation on individual farms.

Agroforestry systems by definition are managed trees, both planted and naturally occurring, in agricultural landscapes. This protocol combines elements of common afforestation and managed forest protocols but allows for some deviations appropriate for agroforestry systems on agricultural land.

Small Scale

This Protocol for Biotic Carbon Sequestration in Small Scale Agroforestry in Developing Countries is only applicable to farmers whose total land holdings, including both agricultural and forest land, is less than 100 hectares. This protocol is also limited to small scale projects where the annual sequestration of the entire project is less than 16,000 tCO_2e.

Location.

Project activities can be implemented in any non-Annex I nation. Farmers in Annex I nations are excluded from this protocol because they can readily overcome the financial, technical, social, and institutional barriers that often prevent farmers in non-Annex I countries from implementing agroforestry systems.

Eligibility

Agroforestry systems under this protocol must be recent, yet sustainably managed trees on farms. Projects are eligible only if agroforestry trees were planted on agricultural land (not classified as forest land according to host country definition) after January 1, 1990. Projects that establish agroforestry systems by clearing natural forests within ten years prior to the project start date are not eligible for this protocol. Agroforestry trees may be pruned, thinned or otherwise managed before and during the project.

Forest certification is not required for eligibility under this protocol. Agroforestry systems must be sustainably managed to permanently increase carbon stocks in soil and woody biomass resulting from growing trees on farms. However, agroforestry systems are agricultural systems with trees, not forests, so they do not require certification as sustainably managed forests that produce commercial timber products for the forest products industry. Farmers are encouraged to sustainably manage their agroforestry systems. Project developers are encouraged to educate farmers on the principles that are applicable to agricultural land use that are promoted by certification agencies like the Forest Stewardship Council or the American Tree Farm System. The permanence of carbon stocks must be demonstrated through annual reporting of project activities, periodic in-field verification of project activities, and ongoing monitoring with the use of high resolution remotely sensed imagery. Participating farmers will be required to commit to maintaining carbon stocks on their farms for at least 15 years beyond the life of the project.

Enrollment of Project Participants

Participating farmers may enroll at the beginning of the project start date. Additional farmers may join on an annual basis prior to the annual desk verification when project documents will reflect the additions to project area and carbon dioxide stocks. Participating farmers are not allowed to withdraw from the project during the crediting period to ensure the permanence of the sequestered carbon.

Additionality

This protocol assumes that agriculture is the primary land use for all project lands. Therefore, the establishment of agroforestry trees on farms is additional to the continuation of prior agricultural activities (Schoeneberger, 2009). However, project participants must demonstrate that the project would not have occurred anyway due to at least one of the following barriers:

I. Investment barriers such as a lack of access to credit
II. Institutional barriers that discourage planting trees on farms
III. Technological barriers including a lack of access to planting material
IV. Local tradition barriers including customs and market conditions
V. Prevailing practice barriers where project activity is "first of its kind"
VI. Ecological conditions barriers including degraded soil or grazing pressure

VII. Social conditions barriers including lack of local organizations

Emissions

Baseline emissions are considered insignificant and are therefore accounted for as zero. Greenhouse gas emissions as a result of the project are considered insignificant and are therefore accounted for as zero.

Carbon Pools

Carbon pools included in this protocol for measurement or estimation are above ground tree biomass, below ground tree biomass, and soil organic carbon.

Baseline greenhouse gas removals by sinks

The most plausible baseline scenario is the continuation of agricultural land use without agroforestry trees. Baseline greenhouse gas removals are assumed to be insignificant and are accounted for as zero.

Actual greenhouse gas removals by sinks

The following procedure for accounting for actual greenhouse gas removals by sinks is adapted from CDM AR-AMS0004 / Version 02 – "Approved simplified baseline and monitoring methodology for small-scale agroforestry - afforestation and reforestation project activities under the clean development mechanism." The procedure sets forth two primary methods of estimating carbon – 1) using biomass expansion factors (BEF) to convert merchantable volume to total biomass or 2) using allometric equations to directly estimate biomass from diameter at breast height (DBH) and/or total tree height.

Stratification of the project area may be carried out to improve the accuracy and the precision of the biomass estimates. Where required, stratification could be made according to tree species, age classes, or agroforestry management practices. Participants shall use stratified random sampling for establishing sample plots when planted vs. non-planted areas follow a regular pattern.

This protocol will also follow the three tier approach of UNFCCC to allow for increasing level of effort and accuracy as appropriate or economically viable. Project developers may use any one of three tiers when applying either allometric or BEF methods to estimate carbon. Tier 1 will use basic forestry data collected in the field and the default IPCC equations for the appropriate region and tree species to estimate biomass of individual trees and entire agroforestry systems. Tier 2 will use basic forestry data collected in the field and existing national allometric equations, volume equations, or BEF equations already developed within the host country to estimate the biomass of individual trees and entire stands. Tier 3 will use locally derived or newly created allometric equations, volume equations, or BEF equations for the agroforestry tree species in the project by destructively sampling multiple trees for regression analysis. Tier 3 will then use basic forestry data collected in the field and the local or newly created allometric or BEF equations to estimate biomass of individual trees and entire agroforestry systems.

The actual net greenhouse gas removals by sinks shall be estimated using the equations in this section. Equations from published scientific literature or equations created during the project development may be substituted as appropriate. When applying these equations for *ex ante* calculations of net anthropogenic GHG removals by sinks, participants shall provide estimates of the values of those parameters that are not available before the start of the crediting period and commencement of the monitoring activities. Participants should retain a conservative approach in applying these estimates.

The actual net greenhouse gas removals by sinks in year *t* are equal to:

$$\Delta C_{ACTUAL,t} = \Delta C_{PJ,t} \quad (1)$$

where:

$\Delta C_{ACTUAL,t}$	Actual net greenhouse gas removals by sinks in year *t*; t CO2-e yr-1
$\Delta C_{PJ,t}$	Project GHG removals by sinks in year *t*; t CO2-e yr-1

Project GHG removals by sinks are calculated as follows:

$$\Delta C_{PJ,t} = \sum_{i=1}^{t} \Delta C_{project,i,t} * 44/12 \quad (2)$$

$$\Delta C_{project,i,t} = [(C_{trees,i,t2} - C_{trees,i,t1}) / T] + \Delta C_{soil,t} \quad (3)$$

where:

$\Delta C_{PJ,t}$	Project GHG removals by sinks in year *t*; t CO2-e yr^{-1}
$\Delta C_{project,i,t}$	Average GHG removals by living biomass of trees and soil for stratum *i*, for year *t*; t C yr^{-1}
$C_{trees,i,t}$	Carbon stock in living biomass of trees for stratum *i*, at time *t*; t C
$\Delta C_{soil,t}$	Average annual change in carbon stock in soil organic matter for stratum *i*, for year *t*; t C yr^{-1}
T	Number of years between years t_2 and t_1

Estimation of carbon stock in living biomass of trees at the stratum level

The carbon stock in living biomass of trees for stratum *i* ($C_{trees,i,t}$) is estimated using the following approach: The mean carbon stock in above-ground biomass per unit area is estimated based on field measurements in permanent sample plots. The two methods available are the biomass expansion factors (BEF) method and the allometric equations method.

Method 1: Biomass Expansion Factors (BEF)

Step 1: Determine based on available data, e.g. volume tables (ex ante) and measurements (ex post), the diameter at breast height (DBH, at typically 1.3 m above-ground level), and also preferably height (H), of all the trees above some minimum DBH in the permanent sample plots.

Step 2: Estimate the volume of the merchantable timber component of trees based on available equations or yield tables (if locally derived equations or yield tables are not available use relevant regional, national or default data as appropriate). It is possible to combine Steps 1 and 2 if field instruments (e.g., relascope, laser hypsometer) that measure the volume of each tree directly are applied.

Step 3: Choose appropriate values for *BEF*. See section on Data and Parameters Not Monitored below for guidance on source of data.

Step 4: Convert the volume of the commercial timber component of trees into carbon stock in aboveground biomass via basic wood density *D*, the *BEF* and the carbon fraction using Eq. (4). See section on Data and Parameters Not Monitored below for guidance on source of data for wood density.

$$C_{AB,\,i,\,sp,\,j,\,l,\,t} = V_{i,\,sp,\,j,\,l,\,t} * D_j * BEF_{2,j} * CF_j \qquad \textbf{(4)}$$

where:

$C_{AB,i,\,sp,\,j,\,l,\,t}$	Carbon stock in above-ground biomass of tree *l*, of species *j*, in plot *sp*, in stratum *i*, for year *t*; t C
$V_{i,\,sp,\,j,\,l,\,t}$	Merchantable volume of tree *l*, of species *j*, in plot *sp*, in stratum *i*, for year *t*; m^3 $tree^{-1}$
D_j	Basic wood density of species *j*; t d.m. m^{-3}
$BEF_{2,j}$	Biomass expansion factor for conversion of merchantable biomass to aboveground tree biomass for species *j*; dimensionless
CF_j	Carbon fraction of dry matter for species or group of species type *j*, t C $(td.m.)^{-1}$

Step 5: Convert the carbon stock in above-ground biomass to the carbon stock in below-ground biomass via root-shoot ratio, given by:

$$C_{BB,i\,sp,\,j,\,l,\,t} = C_{AB,\,i,\,sp,\,j,\,l,\,t} * R_j \qquad \textbf{(5)}$$

where:

$C_{BB, i, sp, j, l, t}$	Carbon stock in below-ground biomass of tree *l*, of species *j*, in plot *sp*, in stratum*i*, foryear *t*; t C tree^{-1}
$C_{AB, i, sp, j, l, t}$	Carbon stock in above-ground biomass of tree *l*, of species *j*, in plot *sp*, in stratum *i*, for year *t*; t C tree^{-1}
R_j	Root-shoot ratio appropriate for biomass stock, for species *j*; dimensionless

See section on Data and Parameters Not Monitored below for selection of values of *R*.

Step 6: Calculate carbon stock in above-ground and below-ground biomass of all trees present in plot *sp* in stratum *i* at time *t* (i.e., summation over all trees *l* by species *j* followed by summation over all species *j* present in plot *sp*).

$$C_{tree,\, i,\, sp,\, t} = \sum_{j=1}^{Spg} \sum_{l=1}^{N_{j,i,sp,t}} (C_{AB,\, i,\, sp,\, l,\, t} + C_{BB,\, i,\, sp,\, j,\, l,\, t}) \qquad (6)$$

where:

$C_{tree, i, sp, t}$	Carbon stock in living biomass of trees on plot *sp*, of stratum *i*, for year *t*; t C
$C_{AB, i, sp, j, l, t}$	Carbon stock in above-ground biomass of tree *l*, of species *j*, in plot *sp*, in stratum *i*, for year *t*; t C tree^{-1}
$C_{BB, i, sp, j, l, t}$	Carbon stock in below-ground biomass of tree *l*, of species *j*, in plot *sp*, in stratum *i*, for year *t*; t C tree^{-1}
$N_{j,i, sp, t}$	Number of trees of species *j*, on plot *sp*, of stratum *i*, for year *t*
l	*1, 2, 3, ...* $N_{j,i,sp,t}$ sequence number of tree of species *j*, on plot *sp*, of stratum *i*, for year *t*

Step 7: Calculate the mean carbon stock in tree biomass for each stratum:

$$C_{tree,\, i,\, t} = (A_i / Asp_i) \sum_{Sp=1}^{Pi} C_{tree,\, i,\, sp,\, t} \qquad (7)$$

where:

C tree,i,t	Carbon stock in living biomass of trees in stratum *i*, for year *t*; t C
C tree, i, sp, t	Carbon stock in living biomass of trees on plot *sp*, of stratum *i*, for year *t*; t C
Asp i	Total area of all sample plots in stratum *i*; ha
Ai	Area of stratum *i*; ha
sp	*1, 2, 3, ...Pi* sample plots in stratum *i* in the project scenario
i	*1, 2, 3, ...* M_{PS} strata in the project scenario
t	*1, 2, 3, ...* t^* years elapsed since the start of the project activity

Method Two: Allometric Equations

Step 1: As in Step 1 of *BEF* method.

Step 2: Calculate the above-ground biomass for each individual tree of a species, using allometric equations appropriate to the tree species (or groups of them if several tree species have similar growth habits) in the stratum. In the absence of species-specific allometric equations use equations in accordance with guidance provided in section on Data and Parameters Not Monitored below.

Step 3: Estimate carbon stock in above-ground biomass for each individual tree *l* of species *j* in the sample plot located in stratum *i* using the selected or developed allometric equation applied to the tree dimensions resulting from Step 1, and sum the carbon stocks in the sample plot.

$$C_{AB,\,i,\,sp,\,j,\,t} = \sum_{l=1}^{N j,\,sp} CF_j * f_j\,(DBH, H) \qquad \textbf{(8)}$$

where:

$C_{AB,i,\,sp,\,j,\,t}$	Carbon stock in above-ground biomass of trees of species *j*, on sample plot *sp*, for stratum *i*; t C
CF_j	Carbon fraction of dry matter for species or group of species type *j*, t C (t d.m.)$^{-1}$
$f\,j\,(DBH,H)$	An allometric equation linking above-ground biomass of a living tree (t d.m.) to mean diameter at breast height (*DBH*) and possibly tree height (*H*) for species *j*, at time *t*; t d.m

Note: For *ex ante* estimations, mean *DBH* and *H* values should be estimated for stratum *i*, at time *t* using a growth model or yield table that gives the expected tree dimensions as a function of tree age. The allometric relationship between aboveground biomass and *DBH* and possibly *H* is a function of the species considered.

i	*1, 2, 3, ...* M_{PS} strata in the project scenario
j	*1, 2, 3, ...* S_{PS} tree species in the project scenario
l	*1, 2, 3, ...* $N_{j,sp}$ sequence number of individual trees of species *j*, in sample plot *sp*
t	*1, 2, 3, ...* t^* years elapsed since the start of the project activity

Step 4: Convert the carbon stock in above-ground biomass to the carbon stock in below-ground biomass via root-shoot ratio, given by:

$$C_{BB,\,i,\,sp,\,j,\,t} = C_{AB,\,i,\,sp,\,j,\,t} * R_j \qquad \textbf{(9)}$$

where:

$C_{BB,\,i,\,sp,\,j,\,t}$	Carbon stock in below-ground biomass of trees of species *j*, in plot *sp*, in stratum *i*, for year *t*; t C
$C_{AB,\,i,\,sp,\,j,\,t}$	Carbon stock in above-ground biomass of trees of species *j*, in plot *sp*, in

stratum *i*, for year *t*; t C

R_j Root-shoot ratio appropriate for biomass stock, for species *j*; dimensionless

See section on Data and Parameters Not Monitored below for selection of values of *R*.

Step 5: Calculate total carbon stock in the living biomass of all trees present in the sample plot *sp* in stratum *i* at time *t*.

$$C_{tree,i,sp,t} = \sum_{j=1}^{Sps} (C_{AB,i,sp,j,t} + C_{BB,i,sp,j,t}) \quad \textbf{(10)}$$

where:

$C_{tree,i,sp,t}$	Carbon stock in living biomass of trees on plot *sp* of stratum *i*, for year *t*; t C
$C_{AB,i,sp,j,t}$	Carbon stock in above-ground biomass of trees of species *j*, in plot *sp*, in stratum *i*, for year *t*; t C tree^{-1}
$C_{BB,i,sp,j,t}$	Carbon stock in below-ground biomass of trees of species *j*, in plot *sp*, in stratum *i*, for year *t*; t C tree^{-1}
i	*1, 2, 3, ... M* $_{PS}$ strata in the project scenario
j	*1, 2, 3, ... S* $_{PS}$ tree species in the project scenario
t	*1, 2, 3, ... t** years elapsed since the start of the project activity

Step 6: Calculate the mean carbon stock in living biomass of trees for each stratum, as per Eq. (7) - i.e., Step 7 of the *BEF* method.

Soil organic carbon

For strata that do not contain organic soils, *ex ante* and *ex post* $\Delta C_{soil,i,t}$ change is estimated from the following equation:

$$\Delta C_{soil,i,t} = A_i * \Delta C_{agroforestry,i} \text{ for } t \leq t_{equilibrium,i} \quad \textbf{(11)}$$

$$\Delta C_{soil,i,t} = 0 \text{ for } t > t_{equilibrium,i} \quad \textbf{(12)}$$

where:

$\Delta C_{soil,i,t}$	Average annual change in carbon stock in soil organic matter for stratum *i*, for year *t*; t C yr^{-1}
A_i	Area of stratum *i*; hectar (ha)
$\Delta C_{agroforestry,i}$	Average annual increase in carbon stock in soil organic carbon pool for agroforestry system in stratum *i*; t C ha^{-1} yr^{-1}
$t_{equilibrium,i}$	Time from start of the project activity until a new equilibrium in carbon stock in soil organic matter is reached for agroforestry system in stratum *i*; years

The default value of $\Delta C_{agroforestry\,i}$ = 0.5 t C ha^{-1} yr^{-1} and a $t_{equilibrium,i}$ of 20 years shall be used. Changes in carbon stock in soil organic matter are not monitored *ex post*.

Leakage

The displacement of people or activities is assumed to be insignificant and leakage is accounted for as zero. Projects should validate this assumption through one of several methods.

I. Show that project activities do not displace more than 30 percent of total land area cultivated for crops owned by participating farmers.
II. Show that project activities are located in regions with laws preventing conversion of natural forests to agriculture.
III. Show that project activities do not constrain supply to local agricultural markets.

Net anthropogenic greenhouse gas removals by sinks

The actual net anthropogenic greenhouse gas removals by sinks is the actual net GHG removals by sinks minus the baseline net GHG removals by sinks minus leakage. According to this simplified protocol for small scale agroforestry, both the baseline net GHG removals by sinks and the leakage are assumed to be insignificant and accounted for as zero. Therefore, the net anthropogenic GHG removals by sinks for each year are calculated as the actual net greenhouse gas removals by sinks in that year above the previous year's baseline stock of carbon dioxide.

Carbon Financial Instruments

A carbon sequestration baseline must be established within 12 months prior to the project start date. An inventory of the trees in the agroforestry systems must measure or estimate the baseline carbon dioxide equivalent stocks contained in the above ground tree biomass, below ground tree biomass, and soil organic carbon. Carbon Financial Instruments will be issued for the annual removal of every 100 tCO_2e.

Simplified Methodology for Monitoring, Reporting, and Verification

All data collected for monitoring, reporting, and verification must be archived electronically and stored for at least 5 years beyond the end of the crediting period. Participants should present in their Project Implementation Document an *ex ante* stratification of the project area or justify the lack of it. The stratification may change during the crediting period. Stratification should be used to achieve the targeted precision level of ±10% of the mean at a 90% confidence level.

Monitoring

Project activities will be monitored with remote sensing technology and geographic information systems (GIS) to show that carbon storage is occurring on project lands. This protocol seeks complete transparency by displaying project information on a website that is open to the public. All project activities, reports, inventories, ownerships, and imagery will be made available on the URL www.carbon2markets.org.

The Carbon2Markets application is an integral part of the measurement, monitoring, verification, and reporting for all project activities. All field level data, including GPS/GIS site polygons and permanent plot corner point data are stored and managed via the Carbon2Markets application. The application integrates Google Maps, Carbon2Markets archive of high resolution satellite data (IKONOS, QuickBird, GeoEye) with field GPS/GIS data and tree measurements stored in a relational database. Annual acquisitions of high resolution satellite data are used to ensure on-going project monitoring. The application serves as a reporting and verification tool to assure carbon buyers these assets are *real*, *verifiable* and *permanent*.

Reporting

Through "Forms" software on the Carbon2Markets website, carbon owners and carbon project managers can update annual field measurements and access reporting functions from the plot level inventory tree data, to the site level estimates of carbon stock, to the project level aggregate of carbon value over the next 20 – 50 years. Farmers are required to report annual changes in DBH and height of all trees located in any permanent sample plot located on their farm. Farmers are required to report any tree planting or harvesting activities and the acquisition or sale of land.

Verification

Projects will submit to annual desk audits of 100% of project documentation. Desk audits will verify project area, the reported species, management practices, compliance with project requirements, and reported carbon dioxide equivalents sequestered. Project activities will submit to in-field audits of at least 10% of participating farms every four years. Field audits will verify agroforestry practices and the quantification methodology of carbon dioxide equivalents. The

Carbon2Markets website will be updated at least quarterly for ongoing verification of project activities.

Quality Assurance and Quality Control

The following guidelines for quality assurance and quality control are adapted from the DOE 1605b Technical Guidelines for Voluntary Reporting of Greenhouse Gas Program Chapter 1, Emission Inventories, Part I, Appendix: Forestry. Measuring and monitoring requires planning for quality assurance (QA) and quality control (QC) to ensure that the reported carbon dioxide equivalents are reliable and meet minimum measurement standards.

QA/QC for Field Measurements. Collecting reliable field measurements is the foundation for quality assurance. Field workers must be fully trained in all aspects of field data collection. Project developers must create a Standard Operating Procedures (SOP) manual that describes each step of the field carbon measurements. These SOP manuals should detail all phases of the field measurements so that future personnel can repeat the measurements identically to previous times. The SOP manual must be filed with the project documents that show that QA/QC steps have been followed. Field crews should receive extensive training and should be fully aware of all procedures and the importance of accurately collecting data. An audit program for field measurements and sampling should be established to check data collection. Auditors will observe field crew members during data collection on a field plot to correct errors in techniques. Auditors will also conduct re-measurement of 10-20% of plots after the field crew has completed their work to compare audited data with original data. Any errors will be documented and corrected. Any errors discovered could be expressed as a percentage of all plots that have been re-checked to provide an estimate of the measurement error.

QA/QC for Laboratory Measurements. Standard operating procedures (SOP) should also be prepared by the project developer for any laboratory analysis required. All laboratory instruments should be calibrated using commercially-available certified standards or weights. Auditors will re-analyze/reweigh 10-20% of samples to produce an error estimate.

QA/QC for Data Entry. Accurate entry of data into the data analyses spreadsheets is required. Data will be reviewed to identify any unreasonable outlier. Communication between all personnel involved in measuring and analyzing data must resolve any apparent anomalies before final analysis of the monitoring data can be completed. If there are any unresolved problems with the monitoring plot data, the plot will be excluded from analysis. Errors can be reduced if the entered data are reviewed using expert judgment and comparison with independent data.

QA/QC for Data Archiving. Data archiving for maintenance and storage is an important component of any long term agroforestry carbon offset project. Data archiving should include original copies of the field measurement and laboratory data. All records should be maintained in original form and placed on electronic media to be stored in a secure location by the carbon measurements team. Offsite copies of all data analyses and models, final estimate of the amount of carbon sequestered, GIS products, and a copy of the measuring and monitoring reports should all be stored in a dedicated and safe place. Electronic copies of the data and reports should be updated periodically or converted to a format that could be accessed by any future software application.

Data and Parameters Monitored

The following parameters should be monitored at the start of the project and at least every four years after verification until the end of the crediting period. When applying relevant equations in this protocol for *ex ante* calculations of carbon sequestration, participants shall provide transparent estimations for the parameters that are monitored. These estimations shall be based on measured data or existing published data and participants must retain a conservative approach in selecting values that do not lead to overestimation of carbon sequestration.

Data: Project Area
Unit: ha
Description: The total area of the project activities incorporating agroforestry systems.
Source of Data: Measured with GPS, Remote Sensing data, and managed with GIS software.
Monitoring Frequency: At the start of the project and annually thereafter.

Data: Sample Plot Area
Unit: ha
Description: The total area of the combined sample plots within the project.
Source of Data: Measured in field with tape or GPS.
Monitoring Frequency: At the start of the project and when conducting return inventories annually by farmers and every four years by verifiers thereafter.

Data: Diameter at Breast Height (DBH)
Unit: cm
Description: Diameter of tree at 1.3 m from base of tree.
Source of Data: Field measurements of all trees >2.5 cm DBH within sample plots.
Monitoring Frequency: At the start of the project and when conducting return inventories annually by farmers and every four years by verifiers thereafter.

Data: Height
Unit: m
Description: Height of the tree, specified as total height or merchantable height.
Source of Data: Field measurements of all trees >2.5 cm DBH within sample plots.
Monitoring Frequency: At the start of the project and when conducting return inventories annually by farmers and every four years by verifiers thereafter.

Data and Parameters Not Monitored

The following parameters are found in published literature from local, national, or international sources. Project participants should be conservative when selecting values so as not to overestimate carbon sequestration.

Data: BEF
Unit: Dimensionless
Description: Biomass expansion factor for converting merchantable biomass to total above ground biomass for a given tree species
Source of Data: Local, national, or international species or group of species specific. International data can be found in Table 3A.1.10 of IPCC GPG-LULUCF 2003.

Data: CF
Unit: t C/t d.m. (ton of carbon per ton of dry matter)
Description: Carbon fraction of dry matter for a species
Source of Data: Local, national, or international species or group of species specific.
Default Value: 0.5 t C / t d.m. from IPCC GPG-LULUCF 2003.

Data: D
Unit: t d.m./m^3 (ton dry matter per cubic meter)
Description: Wood density for a give species.
Source of Data: Local, national, or international species or group of species specific. International data can be found in Table 3A.1.9 of IPCC GPG-LULUCF 2003.

Data: $f_j(DBH, H)$
Unit: t d.m.
Description: An allometric equation for species *j* linking diameter at breast height (*DBH*) and possibly tree height (*H*) to above-ground biomass of a living tree.
Source of Data: Local, national or international species specific equations derived from a large sample of trees across a wide range of diameters and heights. International default equations can be found in Tables 4A.1 to 4A.3 of IPCC GPG-LULUCF 2003.

Data: R
Unit: kg d.m. / kg d.m.
Description: Root to shoot ratio appropriate for biomass for a given species.
Source of Data: Local, national or international species specific ratios. International default ratios can be found in Table 3A.1.8 of the IPCC GPG-LULUCF 2003 or Table 4.4 of the IPCC AFOLU Guidelines 2006.
Default Value: A default value of 0.3 kg d.m. / kg d.m. may be used as a conservative generic root-shoot ratio for all trees.

Data: $t_{equilibrium}$

Unit: yr
Description: Time until a new equilibrium in carbon stocks in soil organic matter is reached for the second agroforestry system in stratum *i*, years
Source of Data: CDM AR-AMS0004/Version02
Default Value: A default value of 20 years shall be used.

Data: $\Delta\ C_{agroforestry}$
Unit: t C / yr
Description: Average annual change in carbon stock in soil organic matter for a given stratum in a given year.
Source of Data: CDM AR-AMS0004/Version02
Default Value: A default value of 0.5 t C/ha/yr shall be used.

Ex Ante Carbon Projections

Ex ante carbon projections may be modeled using standard forestry growth and yield models if applicable. However, common forestry models may not be suitable for estimating the growth and yield of agroforestry systems. *Ex ante* carbon projections may then be estimated using a conservative mean annual increment created during the project baseline inventory or published in applicable scientific literature. *Ex ante* carbon projections will be confirmed by field inventories of permanent sample plots at least every four years and modified as necessary.

Project Permanence

Project participants will agree to a commitment to keep trees on their farms for at least 15 years beyond the market period of the Chicago Climate Exchange to demonstrate their intent to maintain long-term storage of carbon in agroforestry trees. Participants will hold 20% of their Exchange Offsets as escrow in a Forest Carbon Reserve Pool to mitigate the non-compliance of individual farmers and biological risks beyond human control.

REFERENCES:

CCX. 2009. Chicago Climate Exchange Offset Project Protocol: Forestry Carbon Sequestration Projects.
http://www.chicagoclimatex.com/docs/offsets/CCX_Forestry_Sequestration_Protocol_Final.pdf

IPCC. 2003. Good Practice Guidelines for Land Use, Land-Use Change and Forestry. http://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf_contents.html

Schoeneberger, M.M. 2009. Agroforestry: working trees for sequestering carbon on agricultural lands. *Agroforestry Systems*. 75:27–37.

UNFCCC. 2009. CDM AR-AMS0004 / Version 02. http://cdm.unfccc.int/methodologies/SSCAR/approved.html

US DOE. 2006. Technical guidelines for voluntary reporting of greenhouse gas program. Chapter1, Emission Inventories. Part I Appendix: Forestry.

Zomer, R., Trabucco, A., Coe, R., and Place, F. 2009. Trees on Farm: Analysis of global extent and geographical patterns of agroforestry. http://www.worldagroforestry.org/downloads/publications/PDFs/WP16263.PDF

Project Idea Note: Small-Holder Teak Agroforestry, Thailand

CHICAGO CLIMATE EXCHANGE

Project Implementation Document

Entities are required to prepare a CCX Project Implementation Document for all Offset Projects being submitted to CCX for Approval. All Forestry Carbon Sequestration Projects are also required to complete Part 2. The completed form should be submitted to your CCX Account Representative or to offsets@theccx.com. Each proposed deviation request is subject to approval of either the CCX Offsets Committee or CCX Forestry Committee. CCX General Offset Program Provisions, the CCX Offset Project Verification Guidance Document and the CCX Offset Project Protocols can be downloaded by visiting www.theccx.com. Requests for further information or comments may be directed to offsets@theccx.com.

CHICAGO CLIMATE EXCHANGE

Project Implementation Document *Updated as of 8/20/2009*

PART 1.

Section 1: Contact Information

CCX Offsets Staff Account Representative:	
Name:	____

Entity Enrolling Offset Project	
Name:	Dr. David Skole
Organization:	Carbon2Markets, Michigan State University
Email:	skole@msu.edu
Address:	1405 South Harrison Road, Suite 101, East Lansing MI 48823 USA
Phone:	1-517 355-0181

Project Owner (if different than above):	
Name:	Tawatchai Kulwong
Organization:	Inpang Community Network
Email:	via Dr. Usa Klinhom, Mahasarakham University (usa.k@msu.ac.th)
Address:	Inpang Learning Center, Kut Bak District, Sakhon Nakon, Thailand
Phone:	____

Project Offset Aggregator (if different than above):	
Name:	____
Organization:	____
Email:	____
Address:	____
Phone:	____

Other Project Participant(s) (e.g. sub-aggregators):	
Name:	Mr. Chetphong Butthep
Organization:	National Research Council of Thailand, Office of International Affairs
Email:	butthep@msu.edu; poom_du@hotmail.com
Address:	196 Phaholyothin Road, Chatuchak, Bangkok 10900, Thailand
Phone:	+66-2940-6369, +66-2579-2690

Administrators of other GHG program(s) project is subscribed to:	
Name:	____
Organization:	____
Email:	____
Address:	____
Phone:	____

SECTION 2: PROJECT INFORMATION

1. Project Name:
Small Scale Agroforestry Development in Thailand
2. Date of PID Submission:
December 1, 2009
3. Version Number of PID:
Version 1
4. Project Start Date (e.g. commercial operation, tree planting dates, baseline inventory):
January 1, 2010 (Baseline inventory completed in 2009.)
5. Expected Project End Date:
December 31, 2024
6. Expected Project End Date:
December 31, 2024
7. Project Type
Biotic Carbon Sequestration in Small Scale Agroforestry in Developing Countries
8. Project Purpose
Sequester carbon in small-holder teak (Tectona grandis) agroforestry systems in Thailand.
9. Project Location: (geographic and physical information, maps, etc)
Individual farm parcels within six provinces in Thailand: Kalasin, Nakhon Phanom, Sakon Nakhon, Nakhon Sawan, Nong Bua Lumphu, and Uttaradit. See Appendix 1: Maps of geographic locations for farm parcels.
10. Provide any Photographs or Relevant Diagrams of the Project:
See Appendix 2: Photographs and parcel diagrams.
11. Protocol utilized (e.g. CCX, CDM, CAR, VCS); please include date of protocol and/or version number:
This project is proposing a new Biotic Carbon Sequestration in Small Scale Agroforestry Systems in Developing Countries referred to hereafter as "Small Scale Agroforestry Protocol".
12. Provide a justification for the choice of protocol / methodology and why it is applicable to the project:
The Small Scale Agroforestry Protocol will incorporate elements of the CCX Protocol for

Sustainably Managed Forest projects and the CDM AR-AMS0004 / Version 2: "Approved simplified baseline and monitoring methodology for small-scale agroforestry afforestation and reforestation project activities under the clean development mechanism." However, neither the CCX or nor the CDM protocols are adequate to for accounting carbon sequestration provided by small holder farmers, especially in developing countries, who are incorporating trees in their farming systems for multiple ecosystem and income benefits to both themselves and society. This project is submitted together with a new protocol for sustainably managed small scale agroforestry systems in developing countries. This project is an aggregation of 98 small-holder farmers in Thailand who began incorporating teak trees on farms as early as 1992. The teak areas are small, average 2.9 ha, and are an integral part of their farming systems and in some cases incorporate secondary annual and perennial crops in the understory. The small-holder teak areas in this project are managed sustainably. In general, the farmers intend to use long rotations (>30 years) and agree to re-plant teak or other tree species upon harvest. Most of the forest products generated by these small teak areas will eventually be used on-farm or in local markets, as long-lived wood products (house construction or furniture). These teak areas are not certified because they are not large scale, commercial forest operations. Although the farmers are abiding by the ten principles promoted by the Forest Stewardship Council, pursuing certification or even group certification is cost prohibitive to these low income farmers in rural Thailand. Rather, under the proposed new Small Scale Agroforestry Protocol, the project will implement measures to verify sustainable management of the teak areas to assure permanent carbon-storage for the duration of the project and beyond.

SECTION 3: ORGANIZATIONAL DESCRIPTION

13. Short description of the Project Owner and the Offset Aggregator (if applicable), their functions, relationship and work related to the project:
The project owner is the Inpang Community Network under the direction of Mr. Tawachai Kulwong. The Inpang Community Network is a self-organized farmer cooperative (formed in 1987) of more than 4000 farmers in Northeast Thailand. The Inpang Community Network provides training and services in sustainable farm management and sufficiency economy to farm communities and groups throughout Thailand and they operate a training center in Sakon Nakon Province, called the Life University. The Inpang Community Network is working cooperatively with the researchers at Mahasarakham University and the National Research Council of Thailand to coordinate this project with Inpang member farmers (in three provinces: Kalasin, Nakhon Phanom, Sakon Nakhon) as well as with farmers in three other provinces in Thailand: Nakhon Sawan, Nong Bua Lumphu, and Uttaradit. Inpang Network members and researchers at Mahasarakham University and the National Research Council of Thailand are working on farms to develop the project, establish site boundaries,

permanent sample plots, and tree measurements. Carbon2Markets and Michigan State University are providing technical backstopping and supporting the project through the deployment of an on-line project management application (www.carbon2markets) to ensure project transparency of the carbon accounting and provide geospatial tools for efficiently managing and monitoring sequestered carbon in these disperse small holder agroforestry systems.
14. Have contractual agreement(s) between the Offset Aggregator and Project Owner(s) been established? ***(If the project will be registered by an Offset Aggregator, CCX requires contractual agreement(s) between the Project Owner(s) and the Offset Aggregator. The requirements of the contractual agreements can be found within the CCX General Offset Program Provisions document and individual CCX Offset Project Protocols.)***
Contracts will be translated into Thai and will be signed with Thai farmers before March 31, 2010.

SECTION 4: PROJECT ELIGIBILITY

15. Please indicate whether or not the proposed project meets the eligibility requirements according to CCX General Offset Program Provisions and the project-specific protocol:
a. Is the Project Owner and/or Aggregator a CCX Member or Participant Member?
No
b. What is the GHG Emissions Profile of Project Owner? *(CCX requires each Project Owners to attest that it has reviewed the WRI/WBCSD GHG Protocol Corporate Standard and has determined that annual direct GHG emissions for the Project Owner are less than 10,000mt. If the entity emits greater than 10,000 Mt GHG emissions per year, the entity would only be eligible to enroll as a CCX Member, thus subject to the CCX Emission Reduction Commitment.)*
As per the Small Scale Agroforestry Protocol, the increase in emissions in the project above the baseline is insignificant and therefore accounted for as zero. The baseline GHG emissions of the group of 98 Thai farmers initially participating in this project proposal emit far less than 10,000 tCO_2e. The per capita CO_2 emissions in Thailand for 2006 were 4.30 tCO_2 (United Nations Statistics Division).
c. What entity owns the project's greenhouse gas mitigation rights and how has this ownership been established?
The Thai farmers own the land where the teak tree agroforestry systems are established and therefore own their greenhouse gas mitigation rights. However, Thai law does not currently

specify GHG mitigation rights.
d. Is the project required by any federal, state or local regulation or other legally binding framework?
The establishment of the teak on small area farms is not required by any federal, provincial, or local regulation.
e. Does the project meet the protocol's additionality criteria?
Yes, this project meets the additionality requirement of the proposed Small Scale Agroforestry Protocol. Because the primary use of the land is agricultural, the addition of trees on farm in an agroforestry system sequester carbon beyond what would occur under the continuation of annual-only agricultural activities.
f. If using a standardized protocol, please identify any anticipated deviations from the protocol. If deviations exist, complete the Deviation Request section of this document:
This project is not using a standardized protocol, but rather is submitted in conjunction with a new proposed Small Scale Agroforestry Protocol.

SECTION 5: PROJECT DESCRIPTION

16. Describe the social and environmental attributes of the project:
Forty-five percent (44 of 98) of the teak areas are owned by members of the Inpang Community Network. The Inpang Network is a self-created community membership organization established in 1987 that promotes the tenants of the "Sufficiency Economy." The Inpang Network members have transformed all or part of their farm landscapes from mono-culture crop cultivation to multi-purpose, multi-species agroforestry systems - which often include small tree farms (teak, eucalyptus, para rubber, etc.). The remaining fifty-five percent (54 of 98) of the teak areas belong to farmers located in three other provinces who have also transformed their degraded or fallow agricultural lands to agroforestry systems that include small teak areas. The social and environmental attributes of the project include: (1) household-level development and income generation for the rural poor. With the opportunity of selling sequestered carbon as a commodity, these farmers can benefit from two revenue streams, one from the sale of carbon and another from the sale of teak or the offset savings from not having to purchase timber for construction. This dual income benefit may also allow farmers to overcome investement barriers to establishing additional trees (teak or other) on their farms. The addition of trees on farms provides a diverse source of on-farm income, and could prove to be an important climate change adaptation strategy. The additional carbon financial benefit may also spur others to adopt agroforestry in place of

high-input annual-only agriculture practices.

(2) The environmental benefits of the tree farm systems occur at the local and global scales. The local level, on-farm, benefits include a more favorable microclimate, reduced soil erosion, and increased soil fertility. Since these are small tree farms that are functionally a part of the overall agricultural landscape, they also increase biological diversity. Unlike large plantations of single species, these small areas of teak contribute to a mosiac of annuals and woody perenials in a "patchwork," landscape with greater biodiversity. At the global scale, the establishment of trees on land previously under annual crop rotations or on degraded lands (non-forested since 1990 or before) mitigates climate change. Trees sequester carbon in biomass and actively remove atmospheric carbon dioxide.

17. Provide a historical description of project area, lands, forest stands, etc:

The project lands were not forested prior to being planted with teak. The land planted with teak trees was in annual agriculture production or in unproductive and degraded land. No agricultural or forestry activities were displaced as a result of this project (leakage is assumed to be zero). Changes in production of agriculture products are not in an equilibrium state. Farm-level changes to production are driven primarily by regional and global market changes and opportunities. Furthermore, Thai Law prohibits logging, therefore leakage into forest lands is not allowable.

18. Describe the baseline scenario of the project:

The baseline scenario in the absence of the project is the continuation of annual crops on agricultural land. Under annual agriculture cultivation, the baseline GHG removals by sinks are assumed to be insignificant and therefore calculated as zero.

19. Describe how project will achieve GHG emission reductions and/or removal enhancements:

This small scale agroforestry project will provide an economic incentive for Thai farmers to plant trees as part of their farming systems and to keep trees on their farms. The long-term management of trees on farm (>15 years) sequesters atmospheric carbon dioxide in biomass, thereby serves as a carbon sink achieving GHG removal enhancements.

20. Describe the project technologies, products, services and the expected level of activity for each:

The project's primary services are to build farmer capacity by providing education and training in climate change mitigation opportunities through agroforestry systems, basic forest-biomass measurements, and their participation in global carbon markets, managing carbon as a farm-level, household commodity. The project technologies include the deployment of a carbon sequestration project management system using internet-enabled GIS-Remote Sensing and database technologies that provide a suite of tools for carbon "growers" to manage and update field level data, aggregation tools for bundling small-holder carbon sequestration sites, and transparency tools for the "market" or carbon buyers of the methods used for measuring and monitoring the carbon sequestered from project to site levels. The on-line management system URL is www.carbon2markets.org.

21. Provide a summary environmental impact assessment when such an assessment is required by applicable legislation or regulation:
An environmental impact assessment for this project is not required by law in Thailand. However, where projects do require an EIA, this regulation resides with the Thailand Office of Natural Resources and Environmental Policy and Planning (ONEP).

22. Relevant outcomes from stakeholder consultations and mechanisms for on-going communication when such consultations have been conducted and/or are required by applicable legislation or regulation (include date of consultation(s), parties involved, topics discussed, relevant outcomes, date(s) of next consultations, if any):
The following stakeholder consultations have been conducted by Carbon2Markets/Michigan State University and multiple national- and local-level stakeholders in Thailand related to the development of this project and the development of forest carbon offset opportunities in Thailand in general. - December 2005 - initial meeting at the Office of Natural Resources and Environmental Protection and Planning (ONEP; the Thai CDM DNA), with representatives from National Research Council of Thailand (NRCT), the Thai Land Development Department (LDD), the Royal Forestry Department of Thailand (RFD), the National Research Council of Thailand, Mahidol University, Suranaree University of Technology, Kasetsart University, Mahasarakham University, and Carbon2Markets, Department of Forestry at Michigan State University in which we discussed possible opportunities for terrestrial, biotic carbon sequestration projects in the context of UNFCCC-CDM, voluntary carbon markets and sustainable rural development. -April 3 – 4, 2007: Meeting and Presentation at the Inpang Learning Center. Dr. Usa Klinhom (Mahasarakham University), Chetpong Butthep (NRCT) and Jay Samek (Michigan State University) meet with Mr. Tawatchai Kulwong and leaders of the Inpang Community Network at the Inpang Learning Center, Kudbak, Sakon Nakhon to open a dialogue about the possibilities of a project with members of the Inpang Community Network (ICN). The dialogue was informal and included an introduction to the ICN land management philosophy [sufficiency economy] by leaders from the ICN leaders as well as an introduction to carbon offsets by Mr. Samek, Dr. Klinhom, and Mr. Butthep. - August 10 - 12 2007: Carbon Offset, Fieldwork Training & Data Collection w/Inpang Comm. Network. A workshop and introduction to data collection for measuring biomass was given at the Inpang Learning Center attended by leaders and members of the ICN (including an active 20+ member youth group). The workshop was organized and supported by Mr. Butthep (NRCT), Dr. Klinhom (Mahasarakham University) and Mr. Samek (Michigan State University). The workshop included a presentation on Carbon Cycle Science, Carbon Markets, and Tools & Technologies for Measuring and Monitoring Carbon Sequestration. Data collection training was conducted August 11 (GPS, dbh measurements, tree heights, species identification, density and age, land use history, etc.). On August 15, the ICN youth group collected field data at four additional ICN member farms, using GPS, dbh tapes,

digital cameras, and a survey questionnaire /data sheet. - September 14 – 16, 2007: Extended Fieldwork Training & Data Collection w/Inpang Comm. Network. Dr. Klinhom and Mr. Butthep conducted an expanded data collection training workshop with more than 150 members of the Inpang Community Network. The training included recording biomass parameters (dbh, height, age) and land use / cover history for inclusion of family lands in the carbon offset project. - January 2009: Meeting, presentation and discussion with the Greenhouse Gas Management Organization (TGO): TGO agrees to support C2M project focused on the voluntary market. Michigan State University has an MOU with Mahasarakham University and will continue to coordinate with them and the National Research Council of Thailand regarding this carbon offset project. The next meeting in Thailand with NRCT and MSU-Thailand will be in February 2010.
23. Describe any other relevant project information:
The project will not require certification but will ensure sustainable management practices and the maintenance and permanence of the carbon offsets through annual field data collection, monitoring with annual high-resolution satellite data, desk-studies every two-years, and field verification every four years. Field data and remotes sensing data together with GIS boundaries will be available on-line through the offset management application at www.carbon2markets.org. These protocol checks in the monitoring, reporting and verification procedures will ensure farmers are employing sustainable forest management practices.

SECTION 6: QUANTIFICATION OF GHG EMISSIONS AND EMISSION REDUCTIONS

24. Brief description of quantification method. Explain any assumptions and chosen variables used in calculating GHG emissions:
Above ground tree biomass is quantified through direct measurement inventories. Below ground tree biomass is estimated using a default root to shoot ratio from the IPCC GPG LULUCF. Soil organic carbon in these systems acrues over time. We recognize this as a sink for carbon, but do not include this pool in the carbon accounting for this project. Project emissions are assumed to be insignificant and therefore, zero. The default scenario is that farmers will keep the teak trees on-site for a period of 30 years after the start of the project (2010). In the event that some areas are harvested, the contractual agreement is that farmers will re-plant these areas with teak or other trees, and the future estimated amount of carbon for the remaining period of time (2024 - date of harvest) will drop to zero, until restored to "sold levels" of carbon.
25. Provide estimated baseline emissions calculations for the crediting

period (stated in metric tons of CO_2e):
Baseline emissions are considered to be insignificant and are accounted for as zero.
26. Provide estimated project emission calculations for the crediting period (stated in metric tons of CO_2e):
GHG emissions as a result of this project are considered insignificant and are accounted for as zero, under a no harvest scenario for 15 years. The farmers involved in this project have not used chemical fertilizer at any time in the planting or management of the teak areas, nor do they thin or prune the stands.
27. Provide estimated project emission reductions and removal enhancements likely to occur from the project for the crediting period (stated in metric tons of CO_2e):
This project will sequester approximately 45,125 tCO2e between 2010 and 2024, under an assumed no harvest scenario for 15 years. Harvesting is allowed under the project, but only on condition of re-planting.
28. Identify any risks that may substantially affect the project's GHG emission reductions or removal enhancements:
Risks include biological events like insects or disease, abiotic events like fire or drought, and socioeconomic pressures under which a farmer will harvest all or a portion of the teak, and re-plant.

SECTION 7: MONITORING OF THE OFFSET PROJECT

29. Description of monitoring plan (Describe GHG data management systems and procedures, frequency of calibration of equipment, monitoring roles and responsibilities, etc):
The baseline inventories were conducted in 2008 and 2009. Monitoring reports to show permanence will be submitted annually based on annual updates of the field level inventories and the acquisition of available hi-resolution satellite data (QuickBird, IKONOS, GeoEYE1). Farmers, with guidance and oversight from the National Research Council of Thailand and Mahasarakham University, will collect and report the field level inventory updates. Carbon2Markets/Michigan State University will coordinate the acquisition of high-resolution satellite imagery and its use in the on-line management application (www.carbon2markets.org). Field verification will occur every four years with 3rd party verification of the reported forest inventories (planned for 2014, 2018, and 2022) and will include site visits by the 3rd party verfier as per the new protocol. The annual updates of the field data will be used to verify or adjust the estimated rate of sequestration derived from the initial baseline inventory.
30. Data and parameters monitored for each variable (not applicable to Forestry Carbon Sequestration Offset Projects):

(Complete the table below)

Data/Parameter:	Project area, sample plot area, tree diameter, tree height.
Unit:	Project area - ha; sample plot area - ha; tree diameter - cm; tree height - m.
Frequency of monitoring/reporting (including relevant project activities in each step of the GHG project cycle):	A full inventory of tree diameter and tree height within the permanent sample plots will be conducted annually and verified every four years (2014, 2018, 2022) in order to monitor and report changes in carbon sequestration within the project area. Annual high-resolution satellite data will be acquired for project areas to ensure permanence. These data as well as the field inventory data will be on-line and accessable via www.carbon2markets.org
Project period (including relevant project activities in each step of the GHG project cycle):	January 1, 2010 through December 31, 2024.
QA/QC checks:	Standard forest inventory QA/QC for field measurements, data entry and data archiving. QA/QC for field measurements: Standard Operating Procedures (SOP) manual and training of field staff in field measurement protocol for establishing permanent plots, tagging trees, measuring tree DBH and height; audit program managed by staff at Mahasarakham University and NRCT for hot, cold, and blind checks; 5 - 10 % of field data to be field checked and measurement error estimates calculated. QA/QC for data entry: data entry to xls database from field sheets or to on-line "forms" database from field sheets will be spot checked by second recorder after initial database entries are complete and DBH/height data will be plotted to identify possible outliers that are data entry mistakes. QA/QC for data archiving: Original copies of the field measurement data sheets will be maintained in original form and duplicates made - originals and duplicates will be stored in a secure location, by the carbon measurement implementers (Mahasarakham University and Carbon2Markets, Michigan State University; Redundant back-up copies of all electronic data and analyzed data used to generate the final estimate of the amount of carbon sequestered as well as GIS and Remote

	Sensing data products and all measuring and monitoring reports will be created and stored at Mahasarakham University and Carbon2Markets, Michigan State University.

Note: Verification procedure for each variable must be described according to Section 8.

SECTION 8: DEVIATION REQUESTS

Note: Complete this section ONLY if the proposed project deviates from a standardized protocol.

31. Protocol requirement(s) in question and description of the proposed deviation from protocol requirement:
____
32. Justification for requested deviation:
____
33. Describe any mitigative actions to be taken if the deviation results in a less conservative application of the CCX protocol:
____
34. Please provide any additional comments relevant to the deviation(s):
____
35. CCX has developed Verification Checklists for each standardized Offset Project Protocol. Verifiers are required to follow and complete these checklists when conducting project verification. **If the PID proposes any deviations from a standardized protocol, please follow the table below as a template to prescribe the corresponding Assessment Criteria for each proposed deviation:**

Verification Checklist Template:

Deviation Requirement	**Assessment Criteria**	**Verification Findings**

Insert Proposed Deviation	Insert Corresponding Assessment Criteria for Proposed Deviation	N/A

SECTION 9: VERIFICATION METHODOLOGY

36. Frequency and schedule of verification of the project:
As per CCX Offset Project Protocol: Forestry Carbon Sequestration for projects less than 10,000 acres, this project will be verified every four years for in-field forestry measurements and verified every two years for project area.
37. Please indicate whether or not the project will be verified according to a standardized protocol: (Yes or No):
Yes, this project will be verified according to the new protocol for Small Scale Agroforestry.
38. If the proposed project deviates from a standardized protocol, please provide a description of the proposed verification methodology (i.e. procedures to verify the project and procedures that will be taken to ensure reliable data collection for each data point):
This project will be verified according the specific guidelines of the Small Scale Agroforestry Protocol and the general requirements of the CCX Offset Project Protocol: Forestry Carbon Sequestration.

SECTION 10: ADDITIONAL INFORMATION

39. Other relevant project information:
The project will allow the addition over time of new teak areas that meet the eligibility requirements as described in the proposed Small Scale Agroforestry protocol. New areas will be allowed until the maximum total project areas reach an annual sequestration rate of 16,000 tCO_2e.

PART 2.

Section 11: Commercial Forest / Sustainably Managed Forest / Afforestation / Reforestation Project Proposal Summary

BACKGROUND	
Project Type	Biotic Carbon Sequestration in Small Scale Agroforestry in Developing Countries
Name of Company / Aggregator	____
Name of Project	Small Scale Agroforestry Development in Thailand.
Geographic Scope	Six provinces in Thailand: Kalasin, Nakhon Phanom, Sakon Nakhon, Nakhon Sawan, Nong Bua Lumphu, and Uttaradit
Entity's ownership of forest lands	Y/N
Number of hectares / acres	114 stands covering 283.27 hectares.
Species Types	Tectona grandis
Date of plantation of the lands included in the proposal	1992-2005.
Plantations established on unforested or degraded forest lands	Yes
Are all entity-owned lands included in proposal?	Yes
Entity hold sustainable certification on all owned lands?	No
Names of Certification Schemes:	Abiding by the principles of FSC Group Certification
Does crediting rate reflect (an. growth – yield) on annual basis?	Yes
INVENTORY (SEPARATE ANSWERS FOR EACH SPECIES)	
Is inventory conducted annually?	Yes
If not, what year(s) are inventories conducted?	All from 2008/2009 baseline period through 2024
How is sampling implemented?	Stratified, random, permanent sample plots
Measurement techniques	Fixed area
Inventory Intensity	Minimum 20x25 m (0.05 ha) sample plots, minimum 1 plot per stand, 1 plot per 1.6 ha
Proportion of trees in sample with height measurements:	100%
Proportion of trees in sample with dbh measurements:	100%
Statistical precision / error of inventory (at most 10%) at a 90% confidence level:	7.6 % error at 90% confidence level for the mean of 83.17 m3/ha
GROWTH-AND-YIELD (SEPARATE ANSWERS FOR EACH SPECIES)	
What is the name of the growth-and-yield model employed?	Ex ante calculations of carbon sequestration are calculated using a conservative mean annual increment.
For what years will output from growth-and-yield models be used to determine net change in carbon stocks?	Annually from 2010 through 2024
How is the net annual change determined?	Stand level accounting
CARBON QUANTIFICATION	
How is total volume transformed into CO_2?	CO2 = Merchantable Volume * Density * Biomass Expansion Factor * Carbon Fraction * 44/12. CO2 is also calculated using allometric equations to calculate

	biomass from tree height and diameter: CO2 = Mass * Carbon Fraction * 44/12 (1 + R)

Summary Carbon Quantification Table

Year	Total Owned Area* (ha)	Total Inventory Volume (m^3 / ha)	Avg. Volume / ha (m^3)	Volume Change (m^3 / ha)	Volume Change (tCO_2e / ha)	Volume Change (tCO_2e)
2002	____	____	____	____	____	____
2003	____	____	____	____	____	____
2004	____	____	____	____	____	____
2005	____	____	____	____	____	____
2006	____	____	____	____	____	____
2007	____	____	____	____	____	____
2008	____	____	____	____	____	____
2009	283.27	23,560 m3	83.17 m3/ha	5.97	10.62	3,007.68
2010	283.27	25,250 m3	89.14 m3/ha	5.97	10.62	3,007.68

* -- All Owned Area Must Be Included Each Year Under Ownership

SECTION 12: DESCRIPTION OF CARBON SEQUESTRATION QUANTIFICATION

40. Baseline measurement:

a. Inventory frequency:

Inventory annually starting with the 2008/2009 baseline period

b. Sampling techniques:

The inventory utilizes random sampling in permanent, fixed area 20m x 25m sample plots that were established in 2008/2009 in each of the 98 stands. There is a permanent sample plot for every 1.66 ha in the project. Every stand has at least one sample plot. Sixty-three percent of the stands (62 of 98) are less than 2 ha and have only 1 or 2 sample plots per stand. Thirty-three percent of the stands (32 of 98) are between 2-10 ha and average 2 sample plots per stand. The remaining 4 stands >10 ha average 4 sample plots per stand. A total of 13,021 trees were measured in 170 established permanent sample plots. This is a 3.1% sampling rate assuming 1,474 trees/ha on 283 ha.

c. Tree measurement techniques:

All trees greater than 2.5 cm in diameter at 1.3 m height are measured for diameter at breast height (DBH) and total height. DBH is reported in cm and total height is reported in m.

d. Volume calculation methodology:

Volume (m3) = Basal Area (m2) * Height (m) * 0.42 Source: FAO National Forest Assessment (http://www.fao.org/forestry/17109/en/)	
e. Statistical precision:	
7.6 % error at the 90% Confidence Level for the mean stem volume 83.17 m3/ha.	
f. Backup equations:	
The following equation for estimating total tree biomass: - Allometric equation used for above ground biomass: Petmark, P and P. Sahunalu (1980) Primary production of teak plantations. I. Net primary production of thinned and unthinned plantations at Ngao, Lampang. Forest Research Bulletin, Faculty of Forestry, Kasetsart University, Bangkok, Thailand. ---Above ground allometric equation ---Ws Stem biomass in kg LOG Ws = 0.9797*log(D^2H)-1.6902 ---Wb Branch biomass in kg LOG Wb = 1.0605*log(D^2H)-2.6326 ---Wl Leaf biomass in kg LOG Wl = 0.7088*log(D^2H)-1.7383 ---D Diameter at Breast Height in cm (DBH) ---H Height in meters ---AG_T_BIOt Total above ground tree biomass in kg Ws + Wb *Did not use the Wl in the total above ground biomass due to the high turn-over rate of carbon in Teak leaves. - Default IPCC GPG LULUCF equation for below-ground biomass ---EXP(-1.0587+0.8838 * LN(AG_T_BIOt))	
g. References and documentation:	
CDM AR AMS0004 / v2, IPCC GPG LULUCF 2003.	
41. Estimated baseline emissions calculations for the crediting period(stated in metric tons of CO_2e):	
Baseline emissions are considered insignificant and are accounted for as zero.	
42. Estimated project emission reductions and removal enhancements likely to occur from the project for the crediting period (stated in metric tons of CO_2e):	
This project will sequester approximately 45,115 tCO2e between 2010 and 2024.	

SECTION 13: DESCRIPTION OF ENTITY OWNED FOREST LANDS

43. Provide a description of other forest lands owned by the Project Owner(s). **Please include the following information:**
a. Forest land types:
Farmers enrolled in this project do not own other forest lands.
b. Number of hectares/acres:
zero
c. Location:
n/a
d. Current land use:
Current land use is agriculture.
e. Anticipated land use:
Anticipated land use is agriculture.
f. Certification on non-enrolled land:
n/a

SECTION 14: DESCRIPTION OF FOREST MANAGEMENT ACTIVITY

44. Social impacts of project forest land on the indigenous community:
The project areas are owned and managed by the indigenous community. These are agroforestry systems, trees on farm actively managed at the household level. The project include both economic and environmental benefits.
45. Harvesting cycle:
The planned rotation for teak in these agroforestry systems is greater than 30 years.
46. Description of thinning, clearing and other management activities:
No thinning or pruning occurs in the stands. Harvesting may occur within the project cycle (2010 - 2024) by some farmers who have agreed in the contract to replant the area in teak or other tree species. Currently there are no farmers who plan to harvest prior to 2024. If a harvest does occur, verification of replanting will be required. New calculations for the total annual increment of sequestered carbon will show the reduction from the harvested teak. The sequestration from the newly planted trees will not be allowed into the market, until restored to "sold levels".
47. Sustainable forest management certification information:
None

48. End use of the wood:
Teak is a high value wood product used for construction and other solid wood products like furniture. Most of the harvested teak will be used on farm or within the local community in construction or furniture as long-lived wood products. Teak is a dense hardwood with ranges between 700 - 900 kg per cubic meter. Teak is also extremely durable as a wood product. Components of teak make it resistant to rot and decay from bacteria and fungus as well as termite damage. Its high density means it does not easily warp, shrink or swell from environmental conditions. Teak, in these systems, therefore has a long-term decay function. Trees harvested on these small-holder teak areas sustain a long-term sequestration of atmospheric carbon dioxide and demonstrate permanence beyond the 15 + 15 year commitment.

Standard Operating Procedures: Field Measurements, Data Collection and Reporting

Biotic Carbon Sequestration in Small Scale Agroforestry Systems in Developing Countries

Standard Operating Procedures
Field Measurements, Data Collection and Reporting

Carbon2Markets
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Introduction

The following protocols are the standard operating procedures for field measurements, data collection and recording for carbon stock and sequestration in small-scale biotic agroforestry systems in developing countries. The protocol captures data and information required for calculating carbon in above-ground tree biomass. The data are used either in allometric equations or with tree volume and biomass expansion factors to estimate carbon stock at the tree and plot levels. Below-ground root biomass is calculated using standard root-to-shoot ratios. Other pools of carbon (soil organic matter, forest floor or litter, and dead wood) are assumed to be sinks in small scale agroforestry systems and are not calculated in this protocol.

The following steps are required for developing baseline carbon stock estimates and for annual reporting of carbon sequestration for carbon offset projects that meet the compliance standards of the Chicago Climate Exchange and other carbon markets. These procedures include QA/QC protocols for small-scale biotic agroforestry carbon offset projects.

Field Measurements for Biotic Carbon Calculations

Boundary delineation

The boundary of the project sites must be captured in geographic coordinates using:

1. A GPS receiver, or
2. Through on-screen GIS digitizing using high-resolution satellite data

Stratification

Project sites must be stratified according to one or more strata:

I. Agroforestry type:
    1. Small-holder tree farm (use: timber, NTFP, orchard)
        a. Single-species
        b. Multi-species
    2. Alley cropping
        a. With annual
        b. With perennials
        c. With annuals and perennials
    3. Riparian buffer
    4. Field border planting, windbreak, shelterbelt
    5. Live fence
    6. Multi-species, multi-aged, multi-structured

II. Species

III. Age Classes

Calculate Number of Sample Plots Needed

Every site will have at least one (1) sample plot. The suggested number of sample plots will be based on total area of the stand:

Stand Area (ha)	*Frequency of Plots*
<2	1
2 - 10	1 / 2 ha
10 - 50	1 / 5 ha
50 – 100	1 / 7 ha

Sites with high variability (species, age distribution, spatial planting, and/or growth rates) will require additional sample plots.

Also, can use the Winrock Terrestrial Sampling Calculator (Walker, S.M., Pearson, T., Brown, S. 2007) http://www.winrock.org/Ecosystems/files/Winrock_Sampling_Calculator.xls

Establishing Sample Plot Area

Sample plots are fixed-area, stratified, random and permanent.

1. Location of sample plot(s):
    a. Sample plots locations should be no closer than 25 meters from the edge of the agroforestry site.
    b. Sites that require more than one sample point are randomly placed and stratified based on area and/or site variability (agroforestry type, species, age distribution, spatial planting, and/or growth rates)

2. Sample plots size should be 500 m^2 (0.05 ha) and can be either rectangular (20m x 25m) or round (12.62m radius). All corner points or plot centers of the sample plots are to be flagged.

3. Record Location of Plot Corner/Center: For each sample plot, the geographic coordinates of the plot center or one corner must be recorded using a GPS receiver.

4. Biomass Tree Measurements and Information
    a. Tag all trees > 2 cm DBH (Project-Site-Plot-Tree ID)
        i. Project-Site = Alphanumeric – Numeric (e.g TH-IN-001)
        ii. Plot = Numeric
        iii. Tree = Numeric
        iv. Examples:
            1. TH-IN-001-1-1
                a. Project = TH-IN
                b. Site = 001
                c. Plot = 1
                d. Tree = 1
            2. NB1-022-3-78
                a. Project = NB1
                b. Site = 022

c. Plot = 3
d. Tree = 78

b. Record
   i. Species
   ii. Age
   iii. DBH or Circumference (cm): acceptable tools include – girth or circumference tape, calipers, DBH tape.
   iv. Height (m): acceptable tools include – laser hypsometer, clinometers, fixed-angle method, height pole.

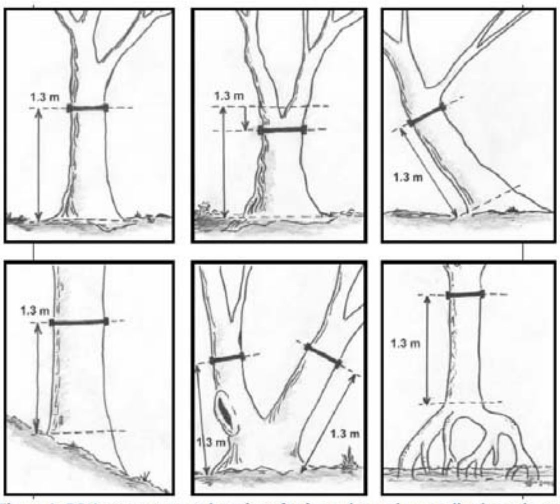

Figure 1: DBH measurement locations for irregular and normally shaped trees

Using a DBH tape

It is important that a dbh tape is used properly to ensure consistency of measurement:

- Be sure to have a staff or pole measuring 1.3m in length so the dbh location on the tree can be accurately identified, or use a sturdy stick (at least 2cm in diameter). Alternatively, each member of the team should measure the location of dbh (that is, 1.3m above ground) on their own bodies and use that location to determine the placement of the tape.
- Dbh tapes often measure diameter on one side and circumference on the other. It is important that all measurers know which measurements to record.
- If the tree is on a slope, always measure on the uphill side.
- If the tree is leaning, the dbh tape must be wrapped according to the tree's natural angle (not straight across, parallel to the ground).
- If the tree is forked at or below the dbh, measure just below the fork point.
- If it is impossible to measure below the fork, then measure as two trees. Traditional forestry dictates that forked stems be measured as two separate trees but when the focus is on biomass, it is more accurate to measure as a single tree wherever possible.

Data Collection and Recording

Use data sheets to record the following:

1. Location of site: Town/village, district, province, country (or other political units as defined in the country where the sites are located)
2. Project and Site ID Number
   a. Project ID = Alphanumeric (up to 5 digits)
   b. Site ID = Numeric
3. Ownership Information
   a. Name
   b. Contact information: Address
   c. Land titled, tenured , or other legal proof of ownership/use rights
4. Date of tree/plot inventory: MM/DD/YYYY (Gregorian calendar date format)

5. Land use / cover history: description of land use and land cover as far back as 1990 if possible. Important to note especially:
    a. Land use / cover prior to Jan. 1, 1990
    b. Land use / cover prior to tree planting
    c. Current land use / cover at date of inventory
6. Agroforestry site management
    a. Use of fertilizer or herbicide?
        i. Quantity (kg/application)
        ii. Frequency (#/yr)
    b. Weeding
        i. Area (square meters)
        ii. Frequency (#/yr)
    c. Thinning
        i. Number of trees
        ii. Age of trees
    d. Pruning
        i. Amount of biomass (kg)
        ii. Frequency (#/yr)
    e. Harvesting
        i. Whole tree for timber / construction
            1. Number of trees
            2. Age
            3. size (biomass or volume)
                a. DBH
                b. Height
        ii. Fruit, nuts, other NTFP
            1. Amount of biomass (kg)
            2. Frequency (#/yr)
        iii. Fuel wood
            1. Amount of biomass (kg)
            2. Frequency (#/yr)
        iv. Re-planting tree sites
            1. From mortality
            2. From harvesting
            3. Number of trees
            4. Date of re-planting
            5. Species
    f. Certification
        i. Yes/no
        ii. If yes: what agency/organization (FSC, SFI, other)
    g. Does a management plan exist for the agroforestry area?
        i. Yes/No
    h. Is an Environmental Impact Assessment required by Law for a carbon offset project that this site would be a part of?
        i. Yes/No
        ii. If yes, who is the responsible entity for the EIA
    i. Do CO_2 rights/laws exist in the country where this site is located?
        i. Yes/No

Data Management and Reporting

Web-enabled, GIS Project Management Application

The project management application includes Internet-based GIS, relational database, on-line forms, and carbon accounting models. This software is developed by Carbon2Markets at Michigan State University, Department of Forestry. The URL for this system is: www.carbon2markets.org.

All field level data, including GPS/GIS site polygons and permanent plot corner point data are stored and managed via the Carbon2Markets application. The application integrates Google Maps, Carbon2Markets archive of high resolution satellite data (IKONOS, QuickBird, GeoEye) with field GPS/GIS data and field measurements stored in a relational database. Through "Forms" software, carbon owners and carbon project managers can update annual field measurements and access reporting functions from the plot level inventory tree data, to the site level estimates of carbon stock, to the project level aggregate of carbon value over the next 20 – 50 years. Annual acquisitions of high resolution satellite data are used to ensure on-going project monitoring. The application serves as a reporting and verification tool to assure carbon buyers these assets are *real*, *verifiable* and *permanent*. The Carbon2Markets application is an integral part of the measurement, monitoring, verification, and reporting for all project activities.

Database Design

A relational database is used for storing field level measurements and information. The Project-Site ID Numbers are the "key" variable linking Tree level, Plot level, Site level and Project level data and information.

1. Tree Level Data
    a. Project-Site ID
    b. Plot Number
    c. Tree number
    d. Project-Site-Plot-Tree ID
    e. DBH or Circumference (cm)
        i. If Circumference, then DBH = Circumference / π
    f. Height (m)
    g. Above-ground tree carbon – tCO_2e
    h. Below-ground root carbon – tCO_2e
    i. Total tree carbon – tCO_2e

2. Plot Level
    a. Project-Site ID
    b. Project-Site-Plot ID
    c. Date of Baseline Inventory
    d. Plot Size (m)
    e. Plot Area (m^2)
    f. Plot center or corner point geographic latitude location
    g. Plot center or corner point geographic longitude location
    h. Total Carbon at Plot – tCO_2e

i. Estimated Total Carbon per 0.05 ha (500m^2) – tCO_2e
j. Number of Trees in Sample Plot

3. Site Level
    a. Project-Site ID
    b. Land Owner Name
    c. Stratification
    d. Tree Species
    e. Other Vegetation
    f. Year Planted
    g. Area (ha)
    h. Land Use and Land Cover History
    i. Management
    j. Number of Sample Plots
    k. Total Number of Trees - all plots
    l. Total Plot Area - all plots (ha)
    m. Average Stocking (trees/ha)
    n. Average Total tCO_2e /sample plot
    o. Average Total tCO_2e /ha
    p. Total tCO_2e Site - Baseline Carbon Stock

4. Project Level
    a. Project ID
    b. Total Number of Sites
    c. Total Area
    d. Total Number of Sample Plots
    e. Total Number of Trees Sampled
    f. Total Project Baseline Carbon Stock - tCO_2e
    g. Average Annual Increment
    h. Total Annual tCO_2e Sequestered (*ex ante*)

<u>GIS/KML-KMZ files</u>

The site area geographic polygon and plot geographic corner point or plot center point data are stored in a GIS. From the GIS data KML/KMZ files are generated and used in the carbon2markets project management application on-line at www.carbon2markets.org.

The GIS/KML-KMZ files contain attribute variables that link them to the relational data base. They use the key variables:

1. Site area polygons: Project-Site ID
2. Plot center or corner points: Project-Site-Plot ID

QA/QC Audit Checks

The Audit checks of the field measurements consist of the following:

Hot Checks: auditors will observe field crew members during data collection on a field plot and permit the correction of errors in techniques.

Cold Checks: Field crews are not present during an audit check on a field plot.

Blind Checks: the complete re-measurement of a plot by the auditors. Measurement variance will be calculated through blind checks. At the end of the fieldwork 10-20% of the plots will be checked independently.

Plot Inventory And Land Use/Cover History Checks: Tree level inventory field measurement data are checked for errors using scatter plots (DBH/Height) and by constraining allowable values. Outliers are flagged and if possible re-checked in the field. If field checking is not possible, outliers are omitted from use in calculating carbon stock at the plot and site level to maintain an accurate and conservative estimate. Site area polygons and plot centers or corner points are checked against current high resolution satellite data for positional accuracy. Land use and land cover history data is verified using historical Landsat satellite data.

Appendix 1: Definitions

Area Hierarchy:

Project: A project is comprised of sites that are the basic unit area for agroforestry systems. Projects are most often a "bundle" or aggregation of multiple sites. The project ID is alphanumeric.

Site: A site is the basic unit for the agroforestry system. Sites are areas identified by ownership entities. A site may include multiple areas owned by a single person, household or entity, but most often they are single areas owned by a single person, household or entity. The site ID is numeric. The geographic boundary of every site is delineated.

Plot: A fixed-area (500 m^2), stratified, random and permanent sample plot in which all trees >2 cm DBH are measured (species, age, DBH, total height). The geographic location of one plot corner point or the plot center for every plot is logged.

Abbreviation Terms:

DBH: Diameter at Breast Height; Standard method of expressing the diameter of the trunk or bole of a standing tree. The diameter is measured at 1.3 meters above ground. A variable used in allometric equations for calculating biomass.

GPS receiver: Global Positioning System receiver; receivers use the U.S. space-based global navigation satellite system to log geographic location of points, line and polygons anywhere on or near the Earth.

GIS: Geographic Information Systems: software technology that captures, stores, analyzes, manages, and presents data that is linked to location.

KML/KMZ: Keyhole Markup Language; an XML-based language schema for expressing geographic annotation and visualization on existing or future Web-based, two-dimensional maps and three-dimensional Earth browsers. KML was developed for use with Google Earth. KMZ are zipped KML files.

NTFP: Non-Timber Forest Products; any commodity obtained from forests or agroforestry systems that do not necessitate harvesting trees. NTFPs include game animals, fur-bearers, nuts and seeds, berries, mushrooms, oils, foliage, medicinal plants, peat, fuel wood, forage.

Measurement units

cm: centimeters

ha: hectares

m or m^2: meter or square meter

tCO_2e: metric tons of carbon dioxide equivalents

Funding sources outside the APN

The following organizations provided in-kind support of this project (approximate in-kind amount):

- Faculty of Forestry, National University of Laos (USD200.00)
- Mahasarakham University, Thailand (USD200.00)
- Mahidol University, Thailand (USD200.00)
- Kasetsart University, Thailand (USD200.00)
- Department of Science, Technology and Environment, Ministry of Agriculture and Rural Development, Vietnam (USD200.00)
- Vietnam Forestry University (USD200.00)
- Department of Forestry Vietnam (USD100.00)

The following organizations provided co-funding in support of this project (amount):

- National Research Council of Thailand (USD3000.00)
- Department of Forestry, Michigan State University (USD15,000.00)

Glossary of Terms

CCX	Chicago Climate Exchange
CDM A/R	Clean Development Mechanism Afforestation/Reforestation
CFI	Carbon Financial Instrument. A CCX traded entity or contract of 100 metric tons of CO2 equivalent
DBH	Diameter at Breast Height. A biometric measurement often used as the independent variable in alometric models estimating biomass
GVF	Gradient Vector Field
MRV	Monitoring, Reporting and Verification
MTF	Model Training Forest. A Research station of the Faculty of Forestry, National University of Laos
tCO_2e	tons of carbon dioxide equivalents, the unit of measure for trading greenhouse gas emission reductions and offsets
UNFCCC	United Nations Framework Convention on Climate Change