FOREST DEGRADATION IN NORTHERN LAO PDR:

AN ASSESSMENT IN MONITORING OPTIONS AND

CAPACITY BUILDING NEEDS IN HOUAPHANH PROVINCE

James Halperin and Leif Mortenson
United States Forest Service

Cover photo: Village protection forest of Namat Village, Viengxay District, Houaphanh Province, February 2012

Preamble

The Lowering Emissions in Asia's Forests (LEAF) Program, a five-year cooperative agreement, is funded by the United States Agency for International Development's (USAID) Regional Development Mission for Asia (RDMA). LEAF is being implemented by Winrock International (Winrock), in partnership with SNV – Netherlands Development Organization, Climate Focus and The Center for People and Forests (RECOFTC). The LEAF program began in January 2011 and will continue until January 2016.

The US Forest Service International Programs (USFS/IP) collaborates with governmental and non-governmental partners to share best practices and act as an advocate for US interests abroad. The USFS/IP draws on the expertise of the entire agency– National Forest Systems, Research and Development and State and Private Forestry – promoting sustainable forest management overseas and bringing important technologies and innovations back to the United States.

The USFS/IP was requested by LEAF and USAID/RDMA to lead in the development of options for identifying and developing forest monitoring methodologies that can estimate greenhouse gas emissions from forest degradation. The key objectives and outcomes of the LEAF/USFS partnership include:

- Assessing forest degradation drivers and monitoring options at the sub-national level in Lao PDR, Vietnam, and Cambodia. The short, one-month field assessments were completed in the first half of 2012;
- Convening a regional forest monitoring experts' workshop to discuss lessons learned from the sub-national assessments and operational aspects of various forest degradation monitoring approaches, highlighting potentially successful approaches given existing drivers. This workshop was held in Bangkok in November 2012; and
- Communicating results of these activities and regional lessons learned to develop forest degradation monitoring demonstration programs and strengthen capacity in partner countries and regional institutions. This report contributes to this objective.

All three country reports have received extensive reviews from a range of technical experts associated with the LEAF project (including Winrock International experts), USFS and subsidiary projects such as SilvaCarbon, USAID country missions (except in Lao PDR) and relevant USAID bilateral projects such as the Vietnam Forests and Deltas project. However any inadvertent errors or omissions remain the responsibility of the authors and do not reflect the views or comments of the reviewers.

While every effort was made to collaborate with Government counterparts in the design, implementation and reporting of this work, this report does not constitute endorsement or a reflection of the host government's perceptions or opinions on the technically and politically difficult task of monitoring forest degradation. The country reports were produced as part of LEAF's early in-country scoping efforts to help design LEAF's field interventions as well as collectively contributing to the expanding regional knowledge base on forest degradation monitoring options.

Contents

Acronyms

ALOS	Advanced Land Observing Satellite
BA	Basal area
CLASLite	Carnegie Landsat Analysis System
CO2	Carbon dioxide
DAFO	District Agriculture and Forestry Office
DOF	Department of Forestry
FCPF-RPP	Forest Carbon Partnership Fund – Readiness Preparation Proposal
FIPD	Forest Inventory and Planning Department
GOFC-GOLD	Global Observation of Forest Cover and Land Use Dynamics
JICA	Japan International Cooperation Agency
IPCC	Intergovernmental Panel on Climate Change
IREDD	Impacts of reducing emissions from deforestation and forest degradation and enhancement of forest carbon stocks / EU funded research consortium
Lao PDR	Lao People's Democratic Republic
LEAF	Lowering Emissions in Asia's Forests
LiDAR	Light Detection and Ranging
MAF	Ministry of Agriculture and Forests
MRV	Monitoring, Reporting and Verification
NAFRI	National Agriculture and Forestry Research Institute
NTFP	Non-Timber Forest Product
PAFO	Provincial Agriculture and Forestry Office
PFM	Participatory Forest Monitoring
PLUP	Participatory Land Use Planning
PSP	Permanent Sample Plot
RECOFTC	Center for People and Forests
REDD+	Reducing Emissions from Deforestation and Forest Degradation, and conservation of sustainable management of forests and enhancement of carbon stocks
SNV	Dutch Development Organization
SRTM	Shuttle Radar Topography Mission
SUFORD	Sustainable Forestry for Rural Development Project
UNFCCC	United Nations Framework Convention on Climate Change
UNREDD	United Nations collaboration initiative on REDD+
USAID/RDMA	United States Agency for International Development / Regional Development Mission for Asia
USFS	United States Forest Service
WI ECO	Winrock International Ecosystem Services Unit

Executive Summary

Globally, there are very few examples of operational monitoring systems designed to detect forest degradation. This is largely because the technical issues involved in the design and setup of such systems need extensive input from a wide variety of specialists and policy makers. These inputs need to include establishing clear monitoring objectives, a baseline from which to assess change and plans for data collection, analysis, and reporting. In tropical countries, the research and development needed as inputs into the technical design is lacking, as are consistent definitions on which to base monitoring protocols.

The United States Agency for International Development/Regional Development Mission for Asia's program called Lowering Emissions in Asia's Forests (LEAF) is addressing these issues by requesting the United States Forest Service to design and implement an options assessment that may be used to guide development of monitoring strategies with its country partners in Southeast Asia. USFS carried out 3, one month long assessments in Lao PDR, Vietnam, and Cambodia in the first half of 2012. The scale and intensity of the direct and indirect drivers of forest degradation are similar in some cases however not in all. However, regional experience and knowledge of forest degradation drivers can lead to further clarity on monitoring options as a larger body of information is established. This assessment is one step in identifying regional characteristics of forest degradation drivers, capacities to monitor degradation, and the similarities and differences of potential monitoring approaches.

This document presents results from our assessment in Lao PDR, conducted in February 2012. We focused on the two LEAF demonstration districts in Houaphanh Province of northern Lao PDR – Xamtai District and Viengxay District. This is a mountainous region, characterized by steep slopes and narrow valleys. Traditional land use constitutes shifting agriculture on the hillsides and permanent rice paddy agriculture in the valley bottoms. There is a significant land base of forest classified as Production Forest Area, National Protection Area, and Watershed Protection Area in both districts. Population density is low, averaging only about 5 people per hectare in 2010 with a population growth of approximately 2.5%.

In the course of our field assessment in Houaphanh Province and a thorough literature review, drivers identified in the Government of Lao PDR national-level Readiness Preparation Proposal (RPP) to the Forest Carbon Partnership Facility were assessed as to their contribution to forest degradation. The major drivers identified in the RPP were unsustainable wood extraction and shifting cultivation. This assessment corroborates those findings. Unsustainable wood extraction occurs in land cover types that have not been previously converted to other land uses, which we define as a 'forest landscape'. This extraction is likely driven by demand for timber in export markets. Shifting agriculture is a driver of forest degradation in the sense that it does not lead to a decline in net forest area, but in net biomass across a mosaic landscape because the assumption is that the change to an agricultural (non-forest) land use is temporary. Small scale farmers are reducing fallow lengths to plant maize for export markets, creating an increasingly complex landscape of agriculture, fallow, and forest regeneration.

There are many ways in which to approach the design of options for how to monitor the impacts of these drivers of forest degradation. This assessment developed a simple conceptual framework to consider the monitoring options for degradation in Northern Lao PDR. The basis of monitoring options relies on a 'triad' of approaches: ground-based field measurements, remote sensing, and modeling. The links between these approaches is shown in Figure 1.

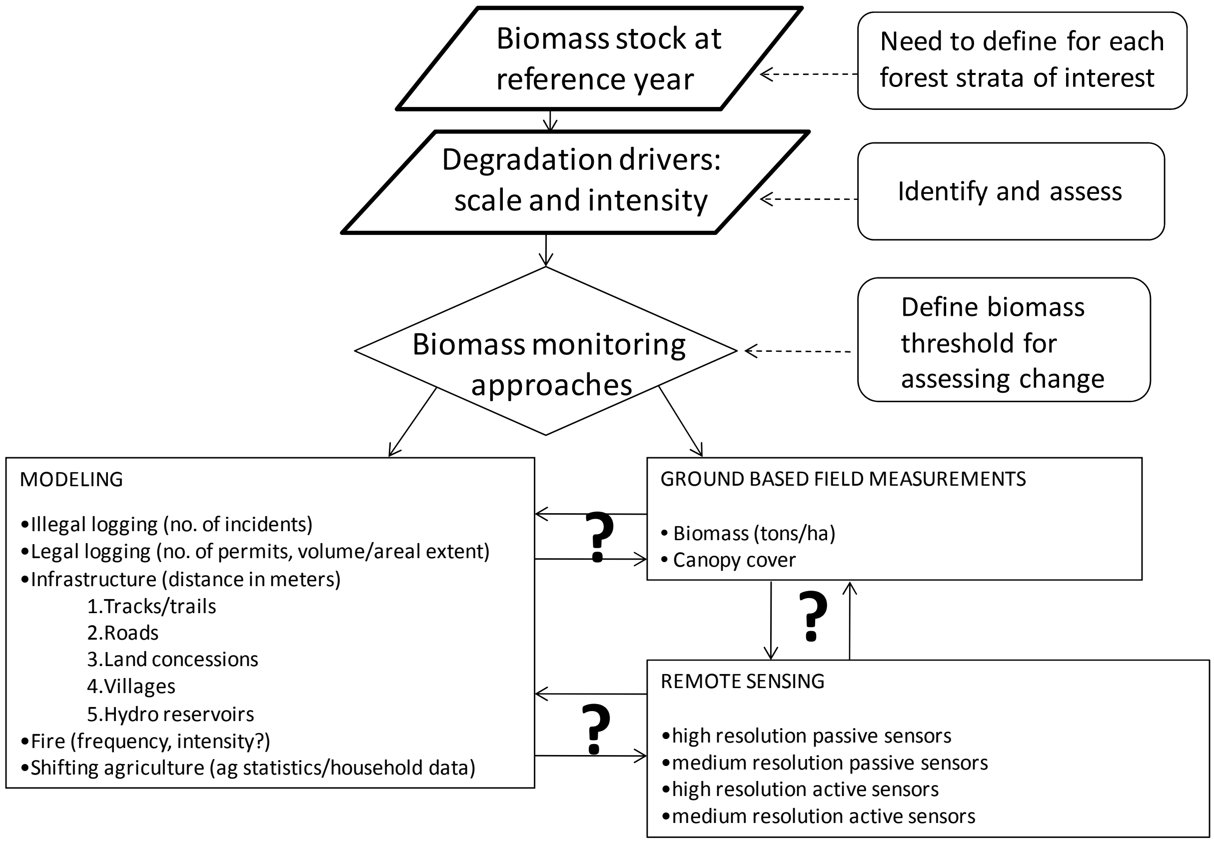

Figure 1. A conceptual framework for assessing options to monitor forest degradation.

Within each branch of the 'triad', there are many options which could be employed to monitor changes in biomass needed to assess forest degradation. The links between the 'triad' all have question marks. This is because research and development of these links could be considered to be ongoing in many instances. Our assessment attempts to clarify these links and make recommendations on methods to monitor forest degradation that draw on the strengths of each.

This assessment analyzed case studies and results of research to find relevant, and feasible, examples that could practically be considered for use by LEAF and their counterparts in its demonstration areas. Eight different monitoring approaches were ranked against qualitative indicators relating to their potential success for implementation in the local context in northern Lao PDR. Overall, approaches that address sustainability and include modeling rank the highest. Integrating all three approaches of the 'triad' makes use of all available data to develop a monitoring system. This is more robust than either ground based field measurements or remote sensing considered individually.

Summary of monitoring recommendations

Monitoring of forest degradation according to the set objectives will need to be developed in an iterative fashion over time and in consultation with relevant stakeholders. The recommendations here are meant to be used as a starting point from which refined protocols and methods can be developed according to the local conditions. Nonetheless, a monitoring objective statement is critical in prioritizing potentially successful monitoring methodologies. We suggest that a LEAF forest degradation monitoring objective for northern Lao PDR could be:

- to quantitatively estimate change in at least Y% above ground forest biomass within 'forest remaining forest' of LEAF project areas beginning from a reference year and monitored at least one time before the end of the LEAF project. Above ground biomass should be estimated at +/- 20% with a 95% confidence interval.

Y is defined as a minimum detectable limit of change that will need to be established during the initial setup of a monitoring program.

We recommend a 2 phased approach (Figure 2). A two phased approach will result in a spatial data product from the first phase that will be useful for a wide variety of purposes, such as land use planning and monitoring deforestation. Phase two will focus specifically on forest degradation and estimation of change in biomass, and the resulting CO2 emissions, from forest degradation.

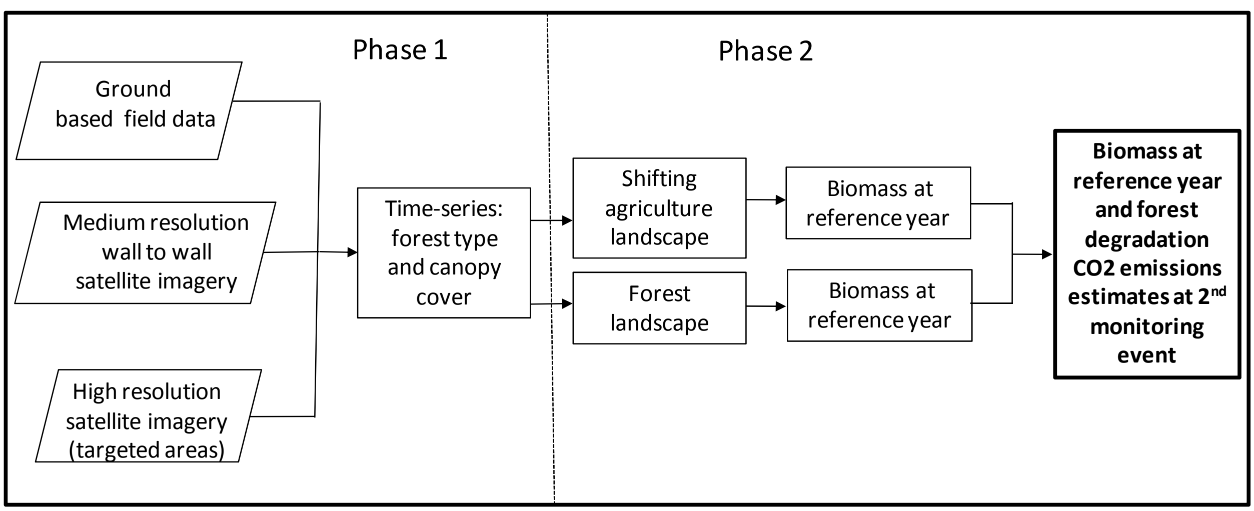

Figure 2. Two phased approach for monitoring forest degradation in Northern Lao PDR.

Phase 1

1. Remote sensing: wall to wall medium resolution time series to assess forest cover change at five year intervals starting in 1990. Assess accuracy of map products at years 2000 and 2005 with a sample of high resolution imagery. Assess accuracy of map product at the current year with network of ground based field measurements from Permanent Sample Plots.

2. Permanent Sample Plots: establish a systematic grid of Permanent Sample Plots with one plot per 5,000 ha in the LEAF focal districts. Try to establish PSP's first within the LEAF focal village clusters and focus on sampling PSP's in those areas first. Visit each PSP twice within the lifetime of the LEAF project.

3. Remote sensing: use the most current year forest cover product to develop a forest type and canopy cover spatial dataset. Focus dataset creation on the areas covered by the network of installed PSP's first, then extrapolate to the focus districts or province, if possible.

Phase 2

1. Assess areas dominated by shifting agriculture and forest areas with no shifting agriculture as two different strata. The forest landscape should have with no discernable shifting agriculture over the past 20 years. Suggested minimum area for a forest landscape is 1,000 ha, however this assumption should be tested based on an analysis of forest patches and local expert knowledge.

2. Shifting agriculture landscape strata: use a combination of a landscape mosaics approach combined with a chronosequence model of biomass change. Landscape mosaics define a range of land use classes within a shifting agriculture landscape where classes are defined by length of fallow period. A chronosequence model establishes biomass estimates for each fallow period class. Refine the chronosequence model with ground based field measurements in the LEAF focus village clusters first.

3. Forest landscape strata: assess biomass and degradation drivers within buffer zones around forest patch edges and possibly within buffer zones around trails within forest patches. Minimum forest patch size should start at 1,000 ha, but refine this based on patch analysis and local expert knowledge. Develop initial buffer widths using expert local knowledge and existing literature. Estimate biomass within buffer zones using either Permanent Sample Plots or Temporary Sample Plots, based on available resources and capacity. Compare biomass estimates within buffer zones with biomass estimates from PSP's outside buffer zones.

Overall

1. Ground based field measurements: work with local district offices and local people using Participatory Forest Monitoring as a conceptual basis. Use data collection and analysis protocols from the Winrock International's "Standard Operating Procedures for Terrestrial Carbon Measurement".

2. Definition of forest: use the Government of Laos definition where: minimum mapping unit is 0.5 ha, minimum canopy cover is 20%, and minimum height is 5 m.

3. Plan for use of Monte Carlo uncertainty assessment at the beginning of designing specific activities.

4. Focus monitoring estimations on above ground biomass, and use standard root-to-shoot ratios for estimating below ground biomass. Only include dead wood, litter, and/or soil according to funding, time, and priorities.

Enhancement of sequestration, reforestation/afforestation, and sustainable management of forests are also important objectives of REDD+. Achieving clarity on the net balance of forest carbon dynamics, and the net CO2e emissions to the atmosphere, is the ultimate goal of a REDD+ forest monitoring program. However, this assessment did not have the time and resources to investigate options for monitoring GHG removals and net changes in forest biomass.

Implementation of these monitoring recommendations will need a program of capacity building and awareness raising, planned in conjunction with other ongoing LEAF activities. For example, Participatory Land Use Planning approaches can be employed with Participatory Forest Monitoring to gather and analyze data that is both locally and regionally relevant. It is recognized that these recommendations will need to be demonstrated in a 'proof of concept' approach. Methods recommended here will need to be further refined and adapted as conditions, capacities, and priorities change due to new, or previously unknown, circumstances. As such, this report should be considered a 'living document' that adapts to new information as it becomes available.

Understanding the intricacies of forest degradation monitoring for the purpose of reducing emissions and improving land management is challenging. Forest types, environmental characteristics, drivers dependent on market demands and social conditions, technical monitoring capabilities and resources all interplay in a complex arena, further complicated by no clear basic definitions. It is hoped that with this assessment, the LEAF program will be able to move forward and take steps in order to meet its goals and help partners improve their capacity to monitor their natural resources.

1. Introduction

Historical changes in forest carbon stocks can be detected through monitoring of deforestation, forest degradation, and/or reforestation. Techniques for monitoring deforestation and resultant changes to forest carbon stocks are widespread and well-published. However, techniques for monitoring forest degradation are relatively untested in developing countries despite their inclusion in current UNFCCC REDD+ negotiations. The lack of a definition of forest degradation, and the broad variety of forest management objectives and expectations of what forests should provide, further complicate forest degradation monitoring. However, the need is indeed great as the Government of Lao PDR predicts that as much as 50% of CO2 emissions from Agriculture, Forestry and Other Land Uses (AFOLU) result from forest degradation (DOF 2010).

The Lowering Emissions in Asia's Forests (LEAF) program of US Agency for International Development/Regional Development Mission for Asia (USAID/RDMA) is being managed by Winrock International in collaboration with Climate Focus and SNV, targeting 6 countries in the Asia-Pacific region (Cambodia, Laos, Thailand, Vietnam, Malaysia, and Papua New Guinea). Two of LEAF's main objectives include building institutional technical capacity for monitoring changes in forest carbon stocks and demonstrating innovation in sustainable land management.

In LEAF countries across the Asia region, many recent assessments for developing REDD+ capacity have noted the need for addressing issues surrounding forest degradation monitoring (Romijin et al 2012, RECOFTC 2012, UNREDD 2012). For example, the 2010 USAID/RDMA Asia Regional REDD Program Planning Assessment Report identified a strong need for increased human resource technical capacity (Winrock 2010). Accurate information on land use trends, forest carbon dynamics, and addressing drivers of forest degradation at local levels is needed for improving land management and limiting future degradation. Deforestation is often preceded by forest degradation (Asner 2006, DeFries 2007), and policies to reduce deforestation may lead to increased forest degradation as timber supplies from land clearing are reduced.

Assessing trends through forest cover mapping in Lao PDR has occurred many times since 1970 (DOF 2010). Mapping approaches have mostly been disconnected, using different data sources, different forest classifications and definitions, and different mapping methodologies. Estimating forest cover change is a challenging situation in this context, especially given persistent haze and cloud cover. The JICA Forest Information Management project with the Forest Inventory and Planning Division (FIPD) within the Department of Forestry (DOF) is currently attempting to create consistent historical and current forest cover maps, though results are still forthcoming. The Sustainable Forestry and Rural Development Project (SUFORD) and DOF carried out forest cover mapping in 2010 using 10 m ALOS satellite data across the entire country (SUFORD 2010). Change assessment results were inconclusive due to inaccuracies and inconsistent definitions of past mapping efforts.

According to land cover statistics reported by the Government of Lao PDR in FAO (2010), Lao PDR had an average deforestation rate of -0.48% / year between 1990 and 2010. DOF (2010) reports an average deforestation rate from 1982 -2002 of -0.8%. Countries in Southeast Asia that are considered net deforesters average approximately -0.77% (FAO 2010). Lao PDR has gone from 75% forest cover in 1990 to 68% in 2010 (FAO 2010), indicating that the country still has a high percentage of forest cover. In the context of a forest transition matrix, Lao PDR can be considered to have high forest cover and a low deforestation rate (Murdiyarso 2008). Countries in this category have the most to gain in a REDD+

mechanism by accounting for forest degradation as the majority of GHG emissions from the forest sector originate from unsustainable management of forests.

This report describes results of an assessment to increase the knowledge base on forest degradation, consistent with identified needs in the FCPF-RPP. This assessment is consistent with similar work done at sub-national LEAF demonstration sites in Cambodia and Viet Nam. Specifically, this assessment aims to:

1. Assess drivers of forest degradation at a sub-national level in Lao PDR; and,
2. Develop and evaluate options for monitoring of forest degradation, with considerations for cost-effectiveness and feasibility in relation to the IPCC principles of consistency, comparable, complete, accurate, and transparent.

To assess options for developing a monitoring framework, it is first necessary to understand the range of information needs that are required. We designed a methodological framework as a conceptual roadmap to clearly identify information needs and how monitoring options align to fulfill these needs (Figure 1). Development of the forest biomass baseline will be a required first step in monitoring of change. The baseline will need to reflect the varying strata of interest. Strata will reflect existing forest types and condition. The level of statistical precision required for biomass baseline estimation depends on several factors, including complexity of strata, ability to carry out sampling in each strata, and stakeholder needs. This assessment did not consider options for development of a historical baseline of forest degradation. Data and information needed for a historical baseline are difficult, and sometimes impossible, to acquire. We focus only on options to monitor forest degradation into the future.

The second step in the framework is to identify and assess the scale and intensity of human activities leading to degradation of forest biomass within the land use category ‘forest remaining forest’. Intensity of changes can be subtle or with great impact, scale of change can be local or widespread. Monitoring options will greatly depend on the drivers and their scale and intensity as technical methods vary in their precision to estimate change. Section 4 of this report documents observations and data on forest degradation drivers from a local level in the LEAF demonstration districts.

Defining the threshold of change in biomass is a critical step. How much change is acceptable? The answer to this question depends on national and sub-national circumstances and country led decision making processes. If acceptable use (i.e., extraction) of timber resources (i.e., biomass) is less than the rate at which forest re-growth occurs in the particular forest type where the extraction occurred, then the use is generally considered sustainable. However, growth and yield information is generally lacking from tropical countries.

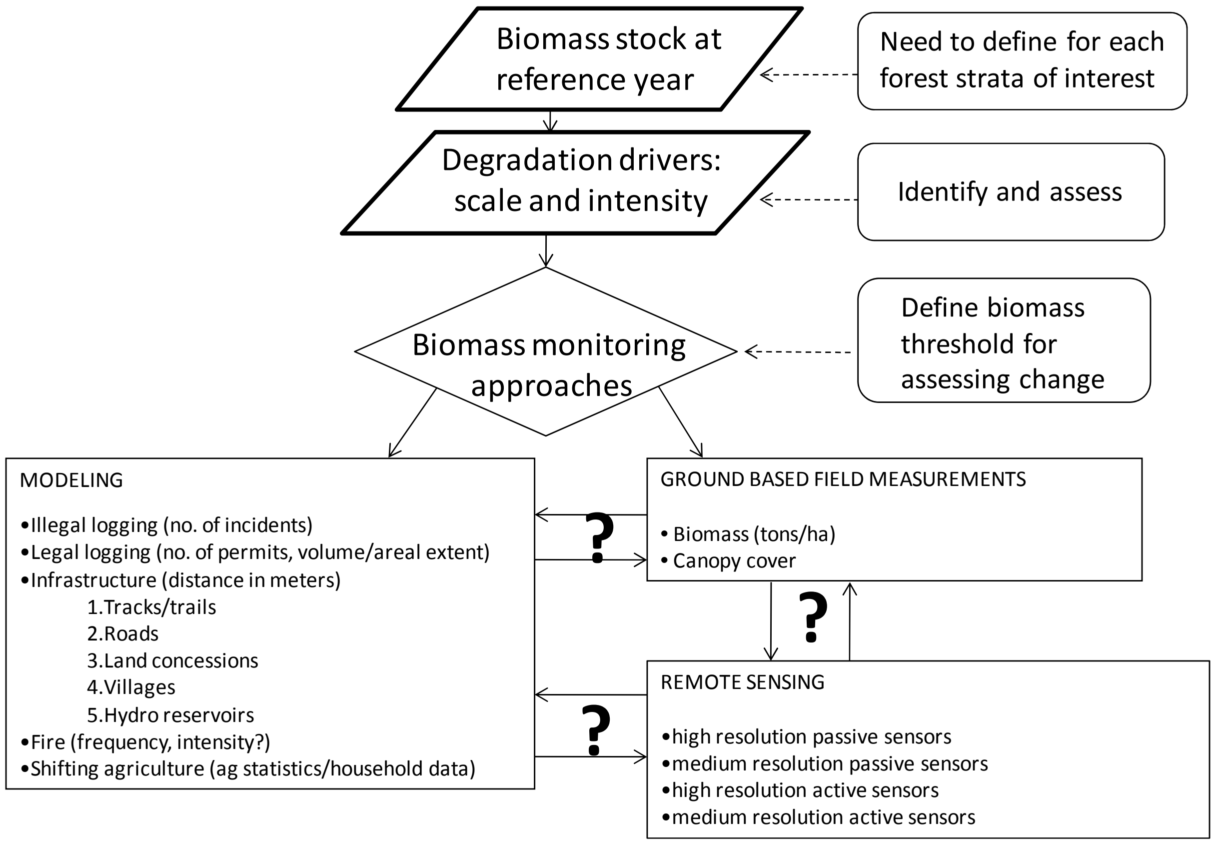

Figure 1. A conceptual framework to assess approaches for monitoring forest degradation.

Assessment of the technical and institutional feasibilities is crucial to the success of change detection and sustainability of initiatives. To assess the multiple criteria needed for identifying options with potential success, section 5 includes a matrix of monitoring options. Monitoring options are derived from a thorough design considerations section that is included in the annex. Options are ranked according to an ordinal scale of indicators across a range of criteria designed to address the suite of issues surrounding monitoring protocol design. Section 5 then suggests options with the highest level of potential success. Capacity building and strengthening recommendations are addressed in section 6. Section 7 provides suggestions on next steps to move forward with the recommendations from the previous sections.

2. Definitions and monitoring objective

a. Attempts to define forest degradation in Lao PDR

It is generally accepted that forest degradation results in a reduction of forest and ecosystem services which includes both globally valued carbon storage, regionally important watershed services, and locally valued goods and services such as Non-Timber Forest Products (NTFP's), fuel wood, and timber. In addition, areas with high levels of forest degradation are also often at high risk of becoming deforested in the future. Several meta-analyses comparing forest degradation definitions have been completed (IPCC 2003, Cadman 2008, Lund 2009, FAO 2011). In the context of a REDD+ mechanism, a definition of forest degradation implicitly needs to include indicators of CO_2 emissions, or biomass lost as a committed emission to the atmosphere.

In the process of determining key reporting categories for UNFCCC National Communications, IPCC (2006a) recommends that a sub-category should be significant if emissions/removals within the sub-category are more than 25-30% of the total for that specific category. In the Lao RPP submitted to the FCPF, annual CO_2 emissions from forest degradation were projected to be almost 50% of the total annual emissions between 2011 – 2015 (DOF 2010).

To define forest degradation, it is first necessary to define forest. Lao PDR has adopted a structural definition of forest whereby the minimum area is 0.5 ha with at least 20% canopy cover and at least 5 m height (DOF 2010).

According to the Ministry of Agriculture and Forestry (2007):

> Article 3.8: "Degraded forest is forest areas that have been heavily damaged such as land without forest or barren forestland, which are allocated for tree planting, permanent agro-silvo-pastoral production, or for other purposes in accordance with the socio-economic development plans."
> Article 3.11: "Degraded Forestland is forestland areas where forest has been heavily and continually damaged causing the loss of balance in organic matters, which prevents natural regeneration to become rich forest again."
> Article 3.12: "Barren Forestland is forestland areas without trees caused by natural or human destruction."

These qualitative definitions are challenging to operationalize in a monitoring context, as the definitions themselves do not lend to identifying monitoring indicators. A map analysis effort by MAF used crown density changes (low: 20-39%; medium: 40-70%; and well-stocked: >70%) as an indicator of forest degradation for the period 1992 - 2002, showing well-stocked forest area decreased by 21% (Winrock 2010). However, these two datasets were derived using different methods and therefore caution needs to be used in the interpretation of the results (Winrock 2010).

Project level definitions of degraded forest in Lao PDR have attempted to apply numerical indicators. As reported in Barney (2011), the Stora-Enso plantation project in southern Lao PDR uses a benchmark of $30m^3$/ha of timber or less to indicate degraded forest (with a minimum dbh of 15 cm). Oji Paper Plantations in Lao PDR established a benchmark of $20m^3$/ha of timber or less, but the extent of crown cover and tree height is also taken into consideration. Thresholds such as these do not take into consideration the natural stocking, forest types, or management history. For comparative purposes, the overall mean stocking across all forest types is 91 m^3/ha (DOF 2010).

b. Monitoring objective statement

In the development of any monitoring program, there are certain basic fundamentals that need to be addressed in order to be able to assess change. These include general factors such as: review of existing literature, objective setting, monitoring methodology design, pilot implementation, analysis, and feedback (Elzinga, no date). The framework for specific monitoring objectives needs to be inter-linked with management and project goals for long term success. REDD+ initiatives seek to improve land management thereby reducing CO_2 emissions. Design of specific monitoring systems to assess forest degradation as a component of REDD+ have largely been ignored. However, IPCC (2003) has suggested that forest degradation as a process could be defined as a:

> ***direct human-induced long-term loss (persisting for X years or more) of at least Y% of forest carbon stocks (and forest values) since time T and not qualifying as deforestation.***

It is very difficult to substitute the X and the Y in the statement above for several reasons:

- activities resulting in forest degradation have different intensities, therefore different X years of persistence
- activities implemented in different forest types have varying impacts on Y carbon stocks, relevant to the natural stocking, or forest carbon carrying capacity
- no country has tested the above definition and no country is making any efforts within UNFCCC to establish a framework for defining the X and Y

For this assessment, it will suffice to remove the X from the statement above so that forest degradation could be more simply defined as:

> ***direct human-induced loss of Y% of forest carbon stocks (and forest values) since time T and not qualifying as deforestation.***

The monitoring objective then becomes simplified. In this assessment, we attempt to identify possible threshold values for Y by conducting rapid forest inventories, comparing disturbed and undisturbed forests.

IPCC (2006c) suggests that it is good practice to estimate change in biomass from five carbon pools: above ground biomass, below ground biomass, dead wood, litter, and soil organic matter. Cost, appropriate methodologies, and capacities limit what is achievable in monitoring changes across all five carbon pools. These challenges are recognized by IPCC and further illustrated by GOFC GOLD (2011). Both of these expert panels suggest ignoring certain carbon pools leads to conservative estimates when those carbon pools have high levels of uncertainty. We recommend focusing all LEAF forest degradation monitoring work on above ground biomass, and using standard root-to-shoot ratios for estimating below ground biomass.

A possible objective for monitoring forest degradation at sub-national sites could then be stated as:

- **to quantitatively estimate change in Y% above ground forest biomass within 'forest remaining forest' of LEAF project areas beginning from a reference year and monitored at least one time before the end of the LEAF project.**

Y is defined as a minimum detectable limit of change that will need to be established during the initial setup of a monitoring program.

Statistical precision will be limited by many factors, including variability of above ground biomass within different forest types in different site conditions, forest management history, and the scale and intensity of forest degradation drivers. It will be important to strive for statistical precision as recommended by IPCC, however given these factors, it is necessary to set achievable statistical precision targets.

We recommend estimating above ground biomass per strata at +/- 20% with a 95% confidence interval.

Enhancement of sequestration, reforestation/afforestation, and sustainable management of forests are also objectives of REDD+. Achieving clarity on the net balance of forest carbon dynamics, and the net CO2e emissions to the atmosphere, is the ultimate goal of a REDD+ forest monitoring program. However, this assessment did not have the time and resources to investigate options for monitoring GHG removals and net changes in forest biomass.

3. Rapid Assessment Results in LEAF Demonstration Districts

a. Brief overview of the districts

The LEAF program is working in two districts in the northern province of Houaphanh, Xamtai and Viengxay Districts (Figure 2). The capital of Houaphanh, Xamnuea, is at 900 m elevation. Elevation is quite high across the province, with more than 50% occurring above 1000 m elevation according to SRTM 90 data (Table 1).

Table 1. Elevation classes in Houaphanh Province, northern Lao PDR from SRTM 90 DEM data.

Elevation class	Hectares	Percent total
150 - 499	103,433	6%
500 - 999	710,345	41%
1000 - 1499	829,654	48%
1500 - 2250	86,202	5%

Slopes across Houahpanh are steep. According to SRTM 90 data, more than half of the area in the province is greater than 30% slope (Table 2).

Table 2. Percent slope classes in Houaphanh Province, northern Lao PDR.

Percent Slope class	Hectares	Percent total
0 – 19	393,451	23
20 – 29	388,901	22
30 – 39	384,427	22
40 – 59	449,696	26
> 60	113,177	7

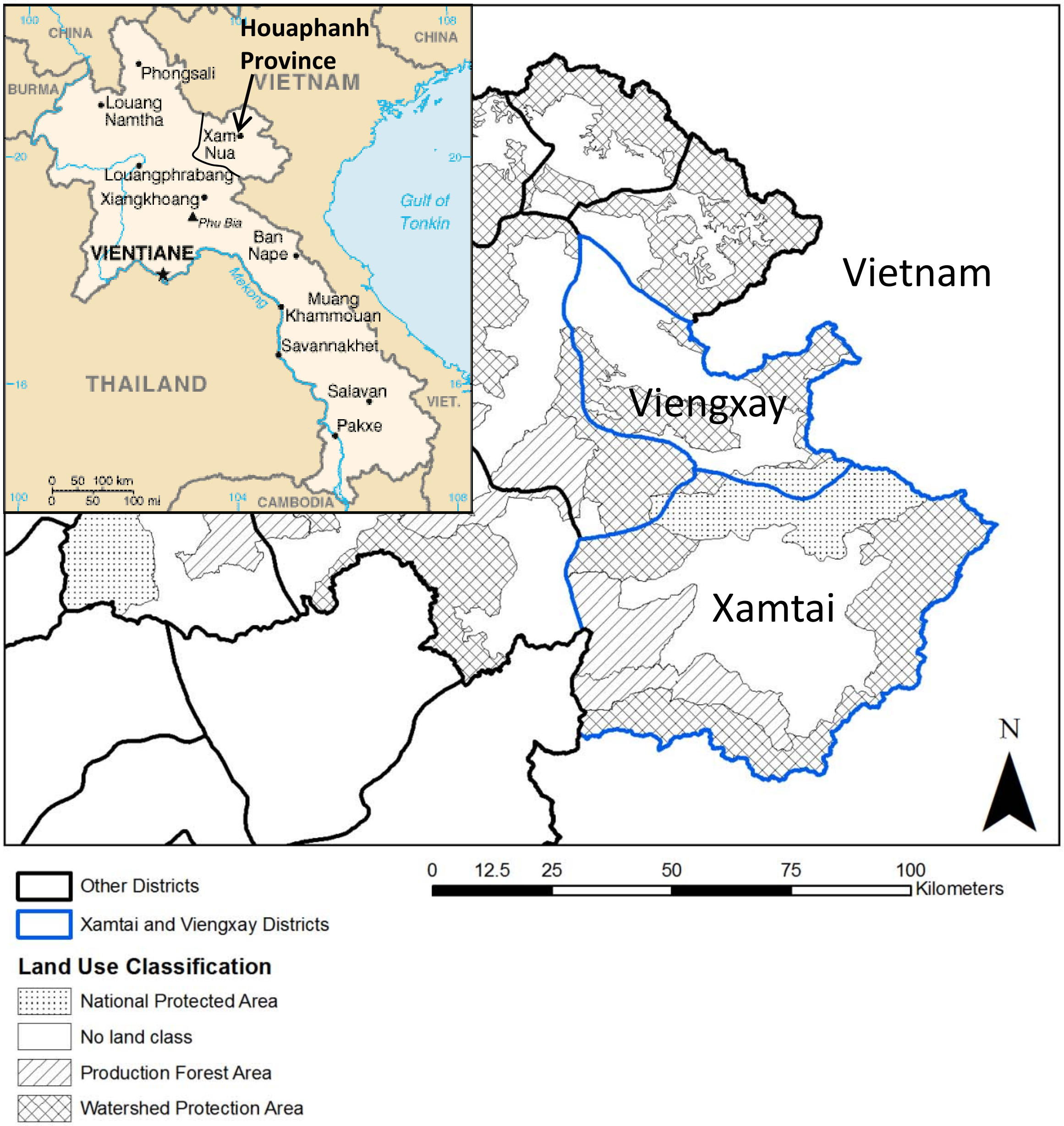

Figure 2. Location of Xamtai and Viengxay Districts, Houaphanh Province in northern Lao PDR.

Unofficial data of the national level land use classes indicate that land area is evenly split between National Protected Area, Watershed Protection Forest, and Unclassified land used for agriculture (Table 3). The area of Production Forest is less than half of any other land use class.

Table 3. Unofficial statistics of land use classification status of Houaphanh Province.

Land Use Classification	Hectares
National Protection Area	427,623
Production Forest	170,160
Watershed	556,231
Unclassified	582,293
Total	1,736,307

Xamtai District is 388,550 ha and Viengxay District is 152,315 ha. The LEAF program focuses efforts in four village clusters within each district. Spatial data do not exist for village or village cluster boundaries so the hectares of the focus areas are not known at this time.

b. Drivers of forest degradation in LEAF Pilot Districts

General Assessment

The Lao PDR FCPF RPP identifies 9 direct drivers of deforestation and forest degradation (DOF 2010). The two major drivers of degradation described are unsustainable logging and shifting cultivation. Unsustainable logging is subdivided into two categories: logging to supply market demand, and logging for domestic consumption. Shifting cultivation is also subdivided into two categories: pioneer shifting cultivation and rotational shifting cultivation. The latter contributes to forest degradation through a reduction in the fallow cycle across landscapes. This is not considered deforestation as overall forest area does not decline, but the average biomass per unit area does.

The Lao PDR FCPF RPP describes 8 indirect drivers behind unsustainable logging and 9 indirect drivers behind shifting cultivation. For this assessment, we focus a short description on each indirect and direct driver relevant to the context in Houaphanh. We considered other direct drivers, and this can be found in Annex 4, along with a complete list of the indirect drivers from the FCPF RPP.

Indirect driver: demand for timber

As reported in the Lao PDR FCPF R-PP, occurrence of unsustainable logging is driven by high profits due to the demand for timber on the international market, presence of high value timber species, and weak law enforcement (DOF 2010). Until 2009, there was a system of quota logging in Houaphanh whereby the central government issued an annual allowable cut to certain Production Forest Areas (Phommalath 2011). This system was discontinued in 2010, at which time a non-quota logging system was established. Non-quota logging allows harvesting activities for three purposes: 1) public infrastructure development (schools, government offices), 2) economic development (i.e., hydropower, mining, etc), and 3) local livelihoods (village housing). It is unclear if a management plan or environmental impact statement is needed in order to conduct non-quota logging, or how these documents would be monitored in this context. In the absence of a management plan, timber harvesting activities are generally determined to be unsustainable.

Direct driver: unsustainable timber extraction

Two log yards were visited in Houaphan Province (Figure 3), one in Xamtai District and one in Xamnuea District only 5 km from Xamnuea town, the provincial capital. It was estimated that the log yard in Xamtai had several hundred cubic meters of logs scattered about, all $\geq$ 50 cm. About a third of the logs present behind a fence appeared to be fresh cut. The Xamnuea log yard, however, was full of fresh cut logs. The local, commercial name given was “long leng”. This is likely *Cunninghamia lanceolata*, and is also called Chinese fir. The wood from this tree is highly sought after for material to make coffins (Foppes personal communication). Of the three purposes to engage in non-quota logging, it is possible that these log yards do not provide material for local livelihoods nor for public infrastructure. We were not able to visit any active sites under infrastructure development to assess if these logs were coming from land clearing for these purposes. However, it is clear that the Houaphanh Provincial and District Agriculture and Forestry Offices do not have enough resources in order to monitor harvesting activities in the province.

Figure 3. From top left, clockwise: freshly cut tree already cut into boards at the stump in Laeng Namm Watershed Protection Area; log yard near Xamtai town; long leng logs at the Xamnuea log yard; squared timbers, or cants, from long leng at the Xamnuea log yard.

Indirect driver: regional demand for maize

Agricultural land use in northern Lao PDR has been dominated by shifting agriculture for generations (Roder 2001). This system of agriculture, sometimes referred to as swidden, is practiced on a rotational basis whereby upland rice is planted on a plot for 1-3 years then abandoned to fallow for 10 years or more. Rice is the basic food staple for people in the region and at a minimum, 1 household requires 1.5 tons of rice production for consumption. Rice is most productive on flat, irrigated land however due to the topographic conditions in Houaphanh there is very little optimal rice growing land. Maximum hillside rice production is 2 t/ha, while the average is between 0.7 t/ha and 1.2 t/ha (Foppes, personal communication).

The production of maize in Houaphanh as a cash crop for export to Vietnam has risen sharply in the last 5-10 years (Viau 2009). In Xiengkhor District of Houaphan, a recent study in 5 villages found that upland areas being cultivated were predominantly planted in maize (416 ha), almost 2.5 times more than the upland rice being cultivated (Keophosay 2011). This has caused a reduction of fallow periods, and an increase in forest land considered to be temporarily unstocked. Cultivation of maize as a cash crop is also cited as an indirect driver in the FCPF RPP (DOF 2010).

Direct driver: declining rotations of shifting cultivation

This assessment was not able to quantify land use/land cover to estimate a time series of change. Ideally, with proper land use/land cover change maps and socio-economic data, causal relationships could be developed that relate this change to policy and/or economic conditions. However, evidence is emerging that rural farmers are shortening the fallow cycle in order to grow maize in the uplands along with traditional rice cultivation (Viau 2009, Keophosay 2011, Castella personal communication). We observed upland agriculture in many different forms (Figure 4). Shifting cultivation is included as a driver of degradation because it results in a temporary reduction of biomass, followed by fallow periods of forest regeneration (DOF 2010).

Figure 4. From top left, clockwise: recent burning on upland agriculture, adjacent to secondary forest in Viengxay District; secondary forest dominated by bamboo in Viengxay District; a swath of recent clearing

with fallow above and below, in Xamtai District; fallow dominated by banana adjacent to secondary forest in Viengxay District.

c. Current forest conditions

The goal of this data collection was to quickly assess forest condition and relate this condition to observed current disturbances or inferred past disturbances. Our objective was to develop a rough estimate of the difference in forest structure between degraded and non-degraded forest conditions. This difference could be used as a threshold for the Y in the monitoring objective statement in Section 3 and allow for a rough assessment of future forest monitoring techniques that may be relevant to the past and/or ongoing forest degradation drivers.

We were not able to sufficiently sample the two forest types to be able to make a statement about the relative difference in forest structure between degraded and non-degraded forest. Time, cost, and coordination with local authorities and organizations were all factors in determining how much data could be collected and where. However, we were able to sample a limited area. When comparing our volume and density estimates with those published in the FAO FRA (2005) and in the NFI (Vesa 2009), the differences are minimal. A full report of our results can be found in the Annex. Possibly more importantly, our field visits allowed us to have a deeper understanding of forest degradation drivers and the context in which these drivers occur.

4. Degradation monitoring

a. Monitoring options

The need to assess multiple criteria across monitoring metrics is a challenging task. Multiple actors, levels of capacity, approaches, systems, data, research, feasibility, and required precision all play a role in the potential success of any monitoring system. In order to facilitate this assessment, a simple ranking system of methods was developed for quantifying potential success based on information presented in this report (Table 4). Definitions of all criteria are below the table. The methods are derived from a thorough design considerations assessment and are described in the annex.

There is a direct trade off in Existing capacity versus Sustainability in comparing External and Collaborative PFM ground based field measurements. While External sampling approaches may be easier to implement, the long term sustainability of this approach needs to be questioned. Likewise, the Existing capacity for implementing Collaborative PFM would need careful consideration in the development of monitoring procedures in order to ensure Sustainability.

Landscapes dominated by widespread disturbance such as shifting cultivation can be more effectively monitored through remote sensing and/or a combination of remote sensing with field based models to estimate biomass across wide areas. Modeling approaches to monitor change in biomass (i.e., gain-loss in IPCC terms) in forested landscapes impacted by timber harvesting have not yet reached operational status.

The most promising include those generated locally and/or with a landscape perspective. Using the PLUP process to engage communities in monitoring of the changing dynamics of shifting cultivation could align well with existing government processes of collecting land use statistics. However, this process is currently non-standardized with no error checking and produces unreliable data. However, it is a system embedded in current structures and could be one way to track land use in collaboration with participatory processes. The Hett/Kiyono approach (see Annex for description) shows promise and is more easily verifiable than a pure PLUP approach. There is likely 1-2 staff at the provincial level with basic training in remote sensing data analysis.

Table 4. Ranking of approaches that are relevant to conditions in Houaphanh Province.

	Method and metric	**Technical difficulty**	**Existing capacity**	**Sustain - ability**	**Existing research**	**Use in historical analysis**	**Use in MRV**	**Total**
Ground based field measure-ments	External* ; t C/ha	3	3	1	2	0	2	11
	Collaborative PFM*; t C/ha	2	1	3	2	0	2	10
Remote sensing + field measure-ments	CLASLite + LiDAR ; ha + t C/ha	1	0	1	1	0	3	7
Modeling	buffer on trails / roads; meters	2	1	2	1	0	1	7
	PLUP, combining agricultural statistics; ha + t C/ha	3	3	3	2	0	1	12
Remote sensing	high-res RS, pixel based; ha	1	1	2	1	1	2	8
	national land cover maps; ha	1	1	1	1	2	3	9
Remote sensing + modeling	Hett and Kiyono approach; ha + t C/ha	2	1	2	1	2	3	11

Technical difficulty: 0 – impossible, 1 – high, 2 – medium, 3 – low

Existing capacity (human resources and institutional capacity at sub-national levels): 0 – none, 1 – low, 2 – medium, 3 – high

Sustainability (ownership by stakeholders, financing commitments): 0 – not sustainable, 1 – low, 2 – medium, 3 - high

Existing research: 0 - no data or previous research; 1 - one to two initiatives to pilot a similar approach in Laos and/or another Mekong country; 2 - more than three initiatives in the Mekong region AND at least one similar

initative in the province; 3 - two or more similar initiatives in the province
Possible to use for historical (possibility to use for generation of historical reference emission levels): 0 - not possible to develop; 1 - at least one historical reference point OR at least two historical reference points where uncertainty is unknown; 2 - at least 2 historical reference points where uncertainty has been assessed
Use in MRV system (potential to be incorporated into MRV systems that will achieve statistical precision requirements): 0 – not possible, 1 – low, 2 – medium, 3 – high
External: data collection led by outsiders, analysis, and use of findings done without involving stakeholders (other than delivery of a report)
Collaborative PFM: a step-wise approach to data collection, analysis, and use of findings that involves capacity building and awareness raising of local stakeholders

Several challenges exist across all approaches listed in Table 11 above. One major challenge will be in mentoring partners over a medium to long term in proper data management. Metadata is very uncommon and historical data is difficult to access or non-existent. Another challenge will be to instill a common vision for information needs and mainstream the idea of how data can be used for information to improve land management conditions. This applies to any scenario, including REDD+, community forest management, and/or conservation in National Protected Areas. Lastly, sustainable financing poses questions into the long term commitment to engage in monitoring by local stakeholders. However, it is beyond the scope of this assessment to deeply engage in these issues. This assessment is focused on a 3-4 year timeframe of intervention for LEAF.

b. Monitoring recommendations

Monitoring of forest degradation according to the set objectives will need to be developed in an iterative fashion over time and in consultation with relevant stakeholders. The recommendations here are meant to be used as a starting point from which refined protocols and methods can be developed according to the local conditions. The precise methods and steps should ideally come from full realization and awareness on the part of these stakeholders.

We recommend a 2 phased approach (Figure 5). A two phased approach will result in a spatial data product from the first phase that will be useful for a wide variety of purposes, such as land use planning and monitoring deforestation. Phase two will focus specifically on forest degradation and estimation of change in biomass, and the resulting CO_2 emissions, from forest degradation. We describe the phases in detail, below.

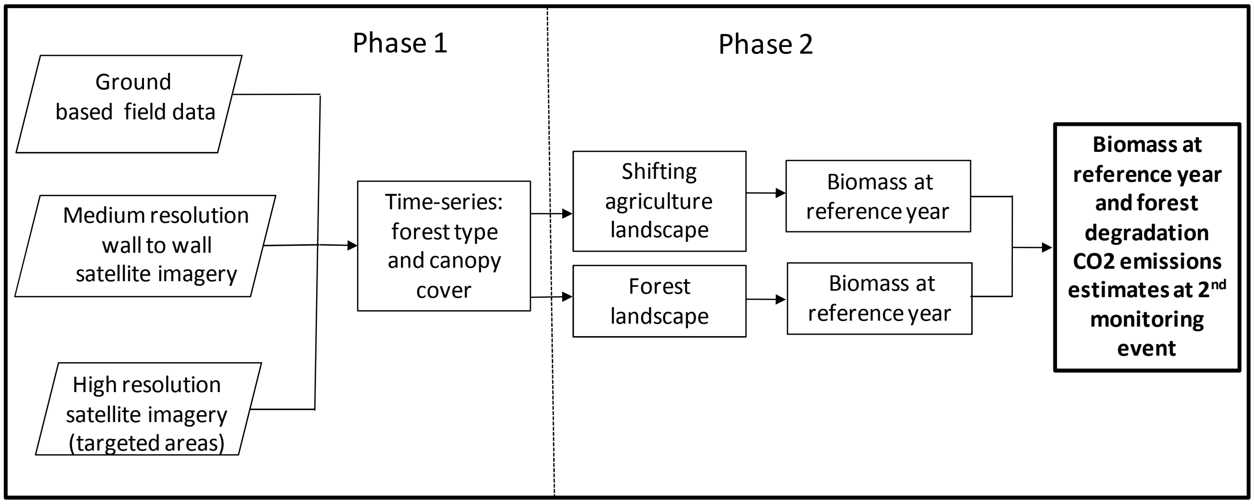

Figure 5. Two phased approach for monitoring forest degradation in Northern Lao PDR.

<u>Phase 1</u>

Phase 1 should target creation of a time series of forest cover change based on a combination of three data sources. Wall to wall medium resolution satellite imagery can provide the basis for land cover mapping. Historical ground truthing data for the time series could be acquired from a systematic sample of high resolution imagery across the study area. Current ground truthing data can be acquired from a systematic sample of ground based field measurements. Ideally this ground based sample will also coincide with the spatial locations of the historical high resolution imagery. The current LEAF program of work to map forest cover change will likely be sufficient to meet the target of a forest cover change time series if sufficient ground truthing can take place. This time series is not intended to establish a baseline of change within 'forest remaining forest' to estimate forest degradation for an REL. Rather, the time series will be used in Phase 2 for refined stratification approaches.

To set a biomass reference, the systematic grid of ground based field measurements can be used as Permanent Sample Plots (PSP). This network of PSP's will help to refine the most current year of land cover data in creating a forest type and canopy cover map. Sample size can be initially determined using a the Winrock International Terrestrial Carbon Stock Calculator Tool[1]. If the full data set is not available for this calculation we recommend 1 PSP per 5,000 ha across the two LEAF focus districts[2]. The combined area of these districts is 540,865 ha. This equates to 108 PSP's. In all likelihood, there will be plots that are not accessible and finances may not be sufficient. We recommend first sampling PSP's located within the LEAF focus village cluster boundaries. Spatial data for these boundaries is not currently available. However, LEAF project staff can work with local partners to determine which PSP's are most likely to be in the focus village clusters.

We recommend that PSP's be installed according to the Winrock International "Standard Operating Procedures for Terrestrial Carbon Measurement". Plot size and diameter limits can also be informed from the lessons learned from IREDD pilots in northern Lao PDR. Specific plot design parameters will need to be established with further technical assistance. At a minimum, however, plot data variables will

[1] http://www.winrock.org/resources/terrestrial-carbon-stock-calculator-tool

[2] The work of IREDD in Northern Lao PDR can help to further quantify sample size through their work on determining a specific Coefficient of Variation for use in standardized sample size equations.

need to include: tree dbh, tree height, species identification at least to the genus level, and plot canopy cover. Ideally, PSP's will be re-measured at the establishment of the biomass reference year and before the end of the LEAF project.

A forest type and canopy cover map will need to be created only for the most current year of satellite image analysis. This map will establish a reference year from which to monitor future change in canopy cover, especially in 'forest remaining forest'. Forest type classification should follow the same typology as that used by the Government of Laos.

Phase 2

This first step of phase 2 is refined stratification. At a province level, we recommend separation of the landscape into 2 strata: landscapes dominated by shifting agriculture and landscapes dominated by forest without shifting agriculture. These two strata each represent components of the overall landscape dominated by different forest degradation processes, or activities. Both strata can be developed from the Phase 1 time series, forest type, and canopy cover spatial data. In assessing the distribution of these strata, it may be possible that this analysis will determine that there is no forest area large enough to constitute a forest landscape (see Box 1 for suggested minimum parameters). In this case, phase 2 methods for shifting agriculture landscape can be applied across the entire focus area.

Box 1. Definition of 'forest remaining forest'

IPCC (2006c) suggests that all forest land within a country be stratified according to its management status of "managed" or "unmanaged" and that only "managed" forests should be subject to GHG inventory and reporting. In the context of northern Lao PDR, we consider all forest land to be "managed" as local people have used the forests for generations.

Time: IPCC (2006c) suggests that "managed" forests should be inventoried only if it is known that the "managed" forest area has been maintained in consistent forest cover for a 20 year period prior to the inventory date. We recommend that Phase 2 forest landscape methods be applied only when the time series data proves that shifting agriculture has not been present in a given area for a 20 year period prior to the current monitoring year.

Area: IPCC (2006c) does not provide guidance on minimum area to be considered as 'forest remaining forest' at a landscape level and only suggests Minimum Mapping Unit of between 0.1 and 1 ha. The MMU of Lao PDR is 0.5 ha. This is problematic to implement in analysis of complex landscapes such as Houaphanh, as we want to identify large blocks of forest that have not been subject to non-forest uses for a 20 year period. Forest that is "intact" provides a similar conceptual framework for 'forest remaining forest'. GOFC-GOLD (2011) suggests the following parameters for delineation of "intact" forest:

- Situated within the forest land according to current UNFCCC definitions and with a 1 km buffer zone inside the forest area;
- Larger than 1,000 hectares and with a smallest width of 1 kilometers;
- Containing a contiguous mosaic of natural ecosystems;
- Not fragmented by infrastructure (road, navigable river, pipeline, etc.);
- Without signs of significant human transformation;
- Without burnt lands and young tree sites adjacent to infrastructure objects.

We recommend that these parameters be applied initially to test if they are relevant to defining a forest landscape in Houaphanh. Parameters may be modified to suit the local conditions and context.

Shifting agriculture landscape

A gain-loss model of biomass change is best suited to assessing forest degradation in areas dominated by shifting agriculture (Figure 6). Gain-loss models are developed from activity data and emission factors. Activity data estimates land use/land cover change between time periods. Emission factors estimate the change in biomass associated with the change in specific land use/land cover categories. We recommend use of established models for each of these components, backed up by collection of ground based field data to validate and improve the models.

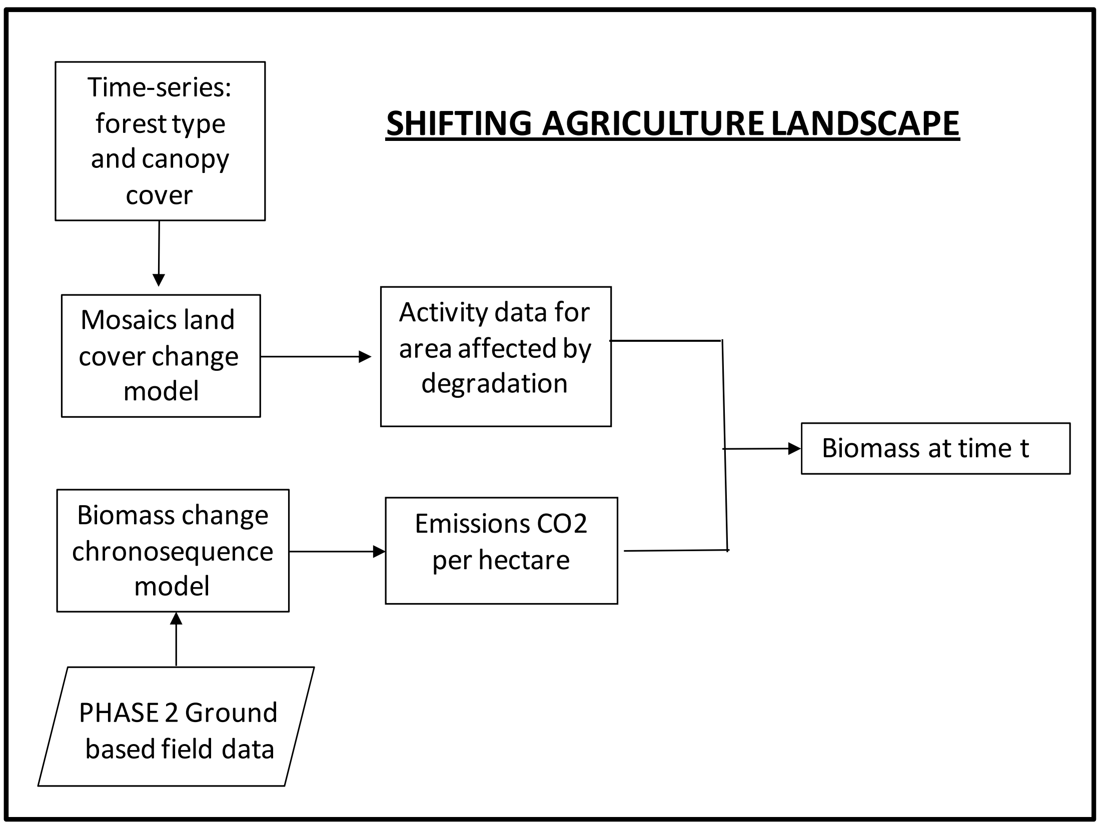

Figure 6. Forest degradation monitoring approach for areas dominated by shifting agriculture in Northern Lao PDR.

Mosaics land cover change model

The approach set out by Hett (2011, and described in the annex) in using land use/land cover change matrices developed by using moving window spatial analysis is an efficient method to use in assessing complex landscapes dominated by shifting agriculture. It lends well towards use in MRV systems for REDD+ and has applicability for use in PLUP. This method could also be used with historical data in the current LEAF forest cover change assessment. The main strength of this method is best taken advantage of by using the current LEAF forest cover change assessment. The land cover classification being used by FIPD and the LEAF forest cover change assessment provides an initial starting point for further refinement using the classes listed in Figure 7. We recommend that this spatial dataset achieves an overall accuracy of 80%.

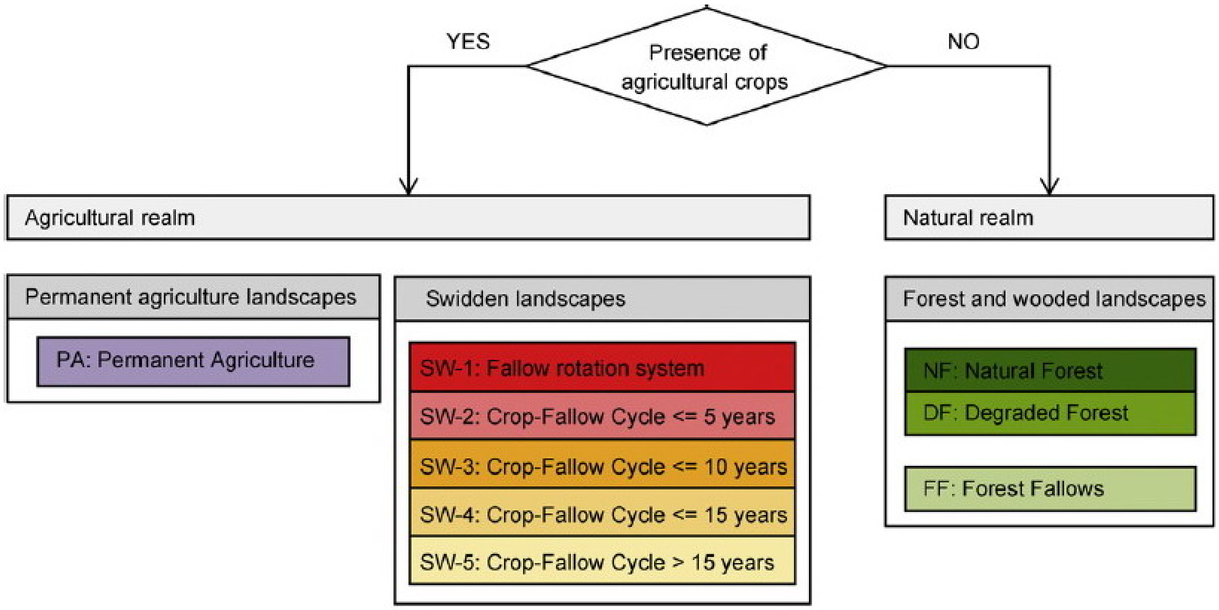

Figure 7. Land use/land cover classes used in a landscape mosaics assessment in Luang Prabang Province, northern Lao PDR (taken from Hett 2011).

This method should be completed at least twice time in the life of the LEAF project, preferably three times so that a land use change matrix can be constructed, as in Figure 8 below. Similar matrices are recommended for use in GOFC-GOLD (2011). The focus of this matrix will be on landscape changes from long term crop fallow cycles (i.e., SW-5, SW-4) into short term crop fallow cycle, and from Degraded Forest and Forest Fallows into Swidden Landscapes.

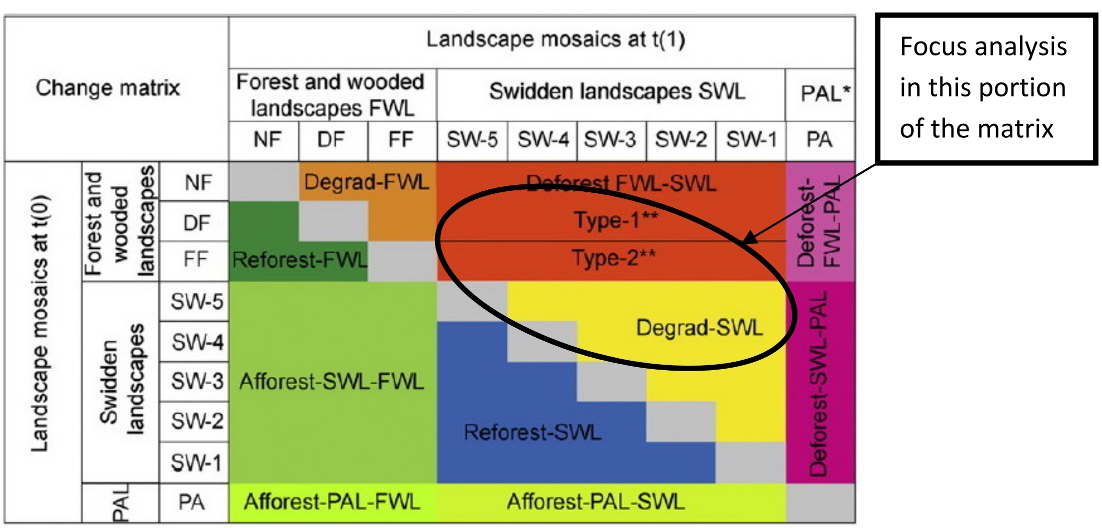

Figure 8. Land use change matrix to assess land cover dynamics in a mosaics approach (taken from Hett 2011). Land cover classes are described in Figure 8. Type 1 is forest loss from pioneering shifting cultivation. Type 2 is forest loss from re-use of areas formerly under agriculture.

Biomass change chronosequence model

To develop an emission factor representing change in biomass per unit area for shifting agriculture, a chronosequence of biomass change is needed. This chronosequence is a model of biomass dynamics that relates to the different stages, or land use classes, of shifting agriculture as outlined in Figure 8. A chronosequence model of change was developed by Kiyono (2007) and tested by Inoue (2009). These methods are further described in the annex. The models can be applied by populating the attribute tables of the land use/land cover spatial datasets.

Phase 2 ground based field data will constitute ground truthing of the chronosequence model. This will be important to verify that the parameters in Kiyono (2007) apply to the Houaphanh context. To maintain consistency with the Kiyono model, we recommend gathering data to assess basal area and average stand height. Ideally, each LEAF village cluster would collect 5 – 10 plots per land cover/land use class (FF, SW5, SW4, SW3). However, there are 4 LEAF village clusters in each district. If all 8 clusters collected 10 plots in 4 different fallow lengths, this would mean 320 plots. It is recommended that at least one cluster per district collect 10 plots per class (80 plots), or two clusters per district collect 5 plots per class (80 plots). Data analysis can be conducted by LEAF technical assistance service providers, in collaboration with LEAF staff and partners.

Forest landscape

In tropical regions, subtle changes to forest structure are very challenging to detect using remote sensing techniques. Even detecting large changes to forest structure in 'forest remaining forest' can be difficult when persistent cloud cover and haze are present. To attempt to overcome these issues, we recommend using a spatial modeling approach to identify forest areas at risk of degradation, then sample these areas using ground based field data to assess biomass change (Figure 9). This is similar to a gain-loss method only the gain is not estimated. The Phase 2 ground based field measurements will be collected at each monitoring time period to estimate the change in biomass.

Using the forest type and canopy cover data from Phase 1, we recommend creating buffer zones around the forest landscape edges (see Box 1 above for suggested minimum parameters) and trails within the forest landscape (to the extent possible). Degradation driver occurrence information can be used to derive initial estimates of buffer zone width. This information on degradation driver occurrence can be gathered through PLUP processes. Buffer zone width will need to be tested in order to adequately capture the potential extent of forest degradation activities. Evidence from other research and projects in other tropical areas suggests that a 500 m buffer should be sufficient (Brown personal communication). It may be that unmanaged extraction could be more frequent outside buffer zones within the forest landscape; however the intensity of extraction is likely higher within buffer zones.

Buffer zones will provide the sampling frame for phase 2 ground based field data. It may be that several classes of forest type and canopy cover will be within the buffer zones. We recommend focusing sampling efforts in buffer zone areas that already exhibit signs of degradation (i.e., average canopy cover less than 70% over 50 ha; a 50 ha area is 1,000 m long if a 500 m buffer width is used).

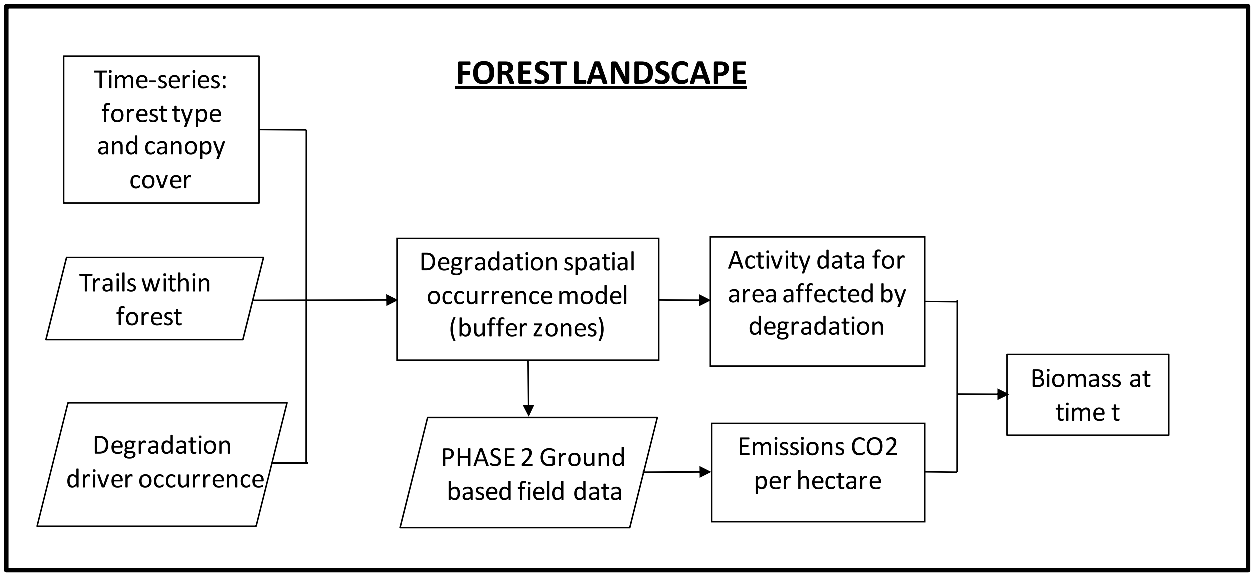

Figure 9. Forest degradation monitoring approach for forest landscapes in Northern Lao PDR.

Option #1
Permanent Sample Plots

If PSP's from Phase 1 happen to fall within forest landscape buffer zones, these plots should have high priority for re-measurement before the end of the LEAF program. Plot sampling design will need to be established with technical assistance after the forest landscape buffer zone stratification has been established. Plot establishment can follow methodology from Phase 1 using the Winrock International "Standard Operating Procedures for Terrestrial Carbon Measurement". Plot size and diameter limits can also be informed from the lessons learned from IREDD pilots in northern Lao PDR.

Option #2
Temporary Sample Plots

Temporary Sample Plots can be established using more rapid techniques and do not need to be monumented for re-measurement. Sampling can occur using the Bitterlich method with an angle gauge, cruiser's crutch, or other simple tools for determining tally and measure trees. The method employed should be consistent with protocol to facilitate analysis using Biomass to Basal Area Ratio (BBAR) techniques. There will need to be careful attention to slope corrections and limiting distances that depend on specific Basal Area Factors used. As with PSP's, plot sampling design for Temporary Sample Plots will need to be established with technical assistance after the forest landscape buffer zone stratification has been established.

c. Uncertainty

Tracking the uncertainty through a series of forest monitoring techniques is a challenging undertaking. Errors are classified into two categories: sampling errors and non-sampling errors. Sampling errors arise because any methodology to estimate a true value will never be completely precise. These types of errors are due to sample design and sample size. Non-sampling errors are due to a variety of issues, such as: application of classification schemes, measurements, data entry, data analysis, application of models, and others. Each of the monitoring methodology recommendations in the sections above can have both sampling and non-sampling errors.

Several methods exist to assess errors from multiple sources in a modeling framework. One increasingly common approach is the use of Monte Carlo simulations. A Monte Carlo approach to assessing uncertainty does not rely on use of linear models and is flexible in its application. Assumptions of data normality are not required for error estimation and Monte Carlo can assess uncertainty across multiple modeling approaches. We recommend that a Monte Carlo approach be considered in application of the recommended monitoring methodologies. We recognize that the technical and statistical tools needed to implement a Monte Carlo approach will be beyond the technical capacity of most of LEAF's partners at provincial and district level. However, LEAF and its technical service providers would be well placed to make an effort at including this approach in overall sample design and reporting.

d. Summary of monitoring recommendations

Phase 1

1. Remote sensing: wall to wall medium resolution time series to assess forest cover change at five year intervals starting in 1990. Assess accuracy of map products at years 2000 and 2005 with a sample of high resolution imagery.

2. Permanent Sample Plots: establish a systematic grid of Permanent Sample Plots with one plot per 5,000 ha in the LEAF focal districts. Try to establish PSP's first within the LEAF focal village clusters and focus on sampling PSP's in those areas first. Visit each PSP twice within the lifetime of the LEAF project.

3. Remote sensing: use the most current year forest cover product to develop a forest type and canopy cover spatial dataset. Focus dataset creation on the areas covered by the network of installed PSP's first, then extrapolate to the focus districts or province, if possible.

Phase 2

1. Assess areas dominated by shifting agriculture and forest areas with no shifting agriculture as two different strata. The forest landscape should have with no discernable shifting agriculture over the past 20 years. Suggested minimum area for a forest landscape is 1,000 ha, however this assumption should be tested based on an analysis of forest patches and local expert knowledge.

2. Shifting agriculture landscape strata: use a combination of a landscape mosaics approach combined with a chronosequence model of biomass change. Landscape mosaics define a range of land use classes within a shifting agriculture landscape where classes are defined by length of fallow period. A chronosequence model establishes biomass estimates for each fallow period class. Refine the chronosequence model with ground based field measurements in the LEAF focus village clusters first.

3. Forest landscape strata: assess biomass and degradation drivers within buffer zones around forest patch edges and possibly within buffer zones around trails within forest patches. Minimum forest patch size should start at 1,000 ha, but refine this based on patch analysis and local expert knowledge. Develop initial buffer widths using expert local knowledge and existing literature. Estimate biomass

within buffer zones using either Permanent Sample Plots or Temporary Sample Plots, based on available resources and capacity. Compare biomass estimates within buffer zones with biomass estimates from PSP's outside buffer zones.

Overall

1. Ground based field measurements: work with local district offices and local people using Participatory Forest Monitoring as a conceptual basis. Use data collection and analysis protocols from the Winrock International's "Standard Operating Procedures for Terrestrial Carbon Measurement".

2. Definition of forest: use the Government of Laos definition where: minimum mapping unit is 0.5 ha, minimum canopy cover is 20%, and minimum height is 5 m.

3. Plan for use of Monte Carlo uncertainty assessment at the beginning of designing specific activities.

5. Capacity Building Recommendations

a. Participatory Forest Monitoring

Collaborative Participatory Forest Monitoring is the preferred alternative for collecting ground based field measurements for Phase 1 and Phase 2. PFM will require close collaboration between LEAF, its sub-national (and national) partners, and its technical service providers. Several, simultaneous activities would be recommended in the design of a PFM approach. There should be:

> Agreement among the LEAF partners of the general approach to adopt and a roadmap for training and implementation. This assessment considers two options.
>
> Awareness raising and development of a sense of ownership among stakeholders. This is critical to the long term success of any monitoring program.

Data Collection

WHO: Initial focus for training should work with Village Foresters, DAFO staff, and Village Cluster Extension Service Centers as mentioned in the PLUP guidelines for Lao PDR. Training and outreach can be conducted by LEAF technical assistance service providers.

HOW: The PLUP process should be leveraged when and where possible. Though implementation is weak, PLUP is commonly known in Lao PDR and the framework is already established. PFM concepts and pilots can be introduced in the context of PLUP exercises.

WHAT: Firmly place emphasis on acquisition of data for analysis of biomass. This means that data collection procedures need to focus first on tree diameters. Data recording quality will be essential. Other essential variables include: coordinates (use of GPS), slope, and local names of tree species. Training on height measurements and canopy cover estimation will be necessary once stakeholder practitioners are comfortable with the process and essential variables. Other variables that would be useful include coarse woody material. However, practitioners would need advanced training and exhibit proficient skill with the basic variables before implementing other data collection procedures.

Data management, analysis, and quality assurance

WHO: Build collaboration with DAFO as a data management and quality assurance provider. Training can be conducted by LEAF technical assistance service providers.

HOW: It will be necessary to identify at least two individuals in each DAFO office with interest and/or enough educational background to understand PFM concepts, data management techniques, and simple tools for data analysis.

WHAT: Build module for Excel to manage and analyze ground based field measurement data from Phase 1 and Phase 2. Use and or refine existing Winrock International data entry and analysis tools to the extent possible. Ensure that error checking SOP for field data is robust.

b. Remote Sensing

Landscape mosaics approach

WHO: Identify 1-2 individuals at PAFO with education and/or training in remote sensing. If no one at PAFO, reach out to NAFRI. Training can be conducted by LEAF technical assistance service providers.

HOW: Begin with the LEAF forest cover change assessment as a ‘proof of concept’.

WHAT: Develop land use change matrix as in Hett (2011). Use historical data from the forest cover change assessment. If this is not practical, then substitute with national data, provincial land use statistics, or theoretical numbers. The idea of using other data sources is to provide a demonstration only. Future assessments can be conducted based on the 2012 data.

Ground truthing landscape mosaics model data

WHO, HOW, WHAT: Incorporate into PFM capacity building.

6. Next Steps

Reference year

Creation of a biomass reference year from which to assess future biomass changes is very important. In the case of both a shifting agriculture landscape and a forest landscape, a reference year of land cover is a key first step.

Output: refine the 2012 LEAF land use cover data to reflect forest type and canopy cover

Time series and Reference Emission Level

It is possible that a time series of land cover change can be used to develop a Reference Emissions Level (REL) for a shifting agriculture landscape. Activity data for this REL could initially be generated through the LEAF forest cover change assessment, based on the landscape mosaics approach with emission factors based on the biomass chronosequence model. Forest landscapes, however, pose more of a challenge. A baseline for changes in biomass due to unmanaged timber extraction will likely have to be calculated in the future, as historical activity data will likely be inconclusive. Emission factors for activities in forest landscapes will need to be generated using Phase 2 methods and data collected in the future.

Output: pilot use of the Landscape Mosaics approach and biomass chronosequence to generate a Reference Emission Level in shifting agriculture landscape

Technical assistance

The committed and coordinated input of technical service providers (WI ECO, USFS, IREDD) to work with LEAF in project design, implementation, and mentoring will be key to success. It will be important for the LEAF project to strategically manage this technical input, as well as identify a few key partners in which to plan and implement this work. Examples of partners could include: skilled technical experts at NAFRI, FIPD; technicians at PAFO and DAFO; decision makers at DOF, PAFO, and DAFO.

Output: training program feasibility report led by a LEAF technical service provider on assessment of stratification, sample size, plot distribution, plot configuration, and data collection methodology for use in PFM.

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9. Annex

Current forest conditions

Objectives

The objective of this data collection is to quickly assess forest condition and relate this condition to observed current disturbances or inferred past disturbances. This will allow for a rough assessment of future forest monitoring techniques that may be relevant to the past and/or ongoing forest degradation drivers in Xamtai and Viengxay Districts of Houaphanh. Time, cost, and coordination with local authorities and organizations were all factors in determining how much data could be collected and where.

Stratification

We intended to stratify the landscape to conduct sampling for determining rough estimates of forest condition per forest type and disturbance level. Reliable maps of land cover or forest type do not exist at a relevant scale in order to guide sampling. In order to stratify the landscape to best meet our objectives without any land cover data, we decided to stratify our field visits by degraded forest and non-degraded forest. By using these two strata, we hoped to assess a relative difference in forest structure between areas that had been disturbed by human use and areas that had not been disturbed by human use. A similar stratification approach was recently used in Madagascar (Eckert 2012). In each district, the assessment team worked with DAFO staff and local people to identify two sites each in degraded and non-degraded forest. Satellite imagery on the Google Earth platform was used as a secondary information source to assess relative land cover and compare with locations identified by DAFO and local people.

It was recognized early on that in asking the opinion of local DAFO and villagers on where non-degraded forest exists would likely introduce bias into the assessment for a couple reasons. Non-degraded forest areas may be far from settlement areas and unknown to local people and/or our explanation (through translators) of non-degraded forest may have created uncertainty. However the absence of data on recent land cover encouraged more discussion among the DAFO staff, consensual recognition of where existing forest occurs, and what its relative condition may be. There was not significant discussion with DAFO on what specific forest type to visit. This is because much time was spent by the LEAF staff in socializing the objectives of the LEAF program, as this was the first field visit by LEAF staff to these areas.

Five forest areas were visited in three districts of Houaphanh Province (Table 5 and Figure 10). The Xiang Luang Village Forest is outside of a LEAF target village cluster, but was chosen for comparison purposes and because of easy access from a main road. The Naman Village Forest appears to be within the large Laeng Namm Watershed Protection Forest. However, this land use classification was developed at the national level probably based on topographical characteristics and without regard to existing land cover. The majority of Laeng Namm did not appear to be forested, at least from the road. The Nam Nga Village Cluster has relatively little forest and is largely an agricultural landscape.

Table 5. Strata and name of forest areas visited in February 2012. Numbers correspond to the locations in the figure below.

	Village Cluster and District	Strata	Area name
1	Long Kem, Xamtai	Intact, non-degraded	Namxam National Protected Area
2	Long Kem, Xamtai	Non-intact, degraded	Namat Village Forest
3	Nam Nga, Viengxay	Intact, non-degraded	Laeng Namm Watershed Protection Forest
4	Nam Nga, Viengxay	Non-intact, degraded	Naman Village Forest
5	Xiang Luang, Viengxay	Intact, non-degraded	Xiang Luang Village Forest

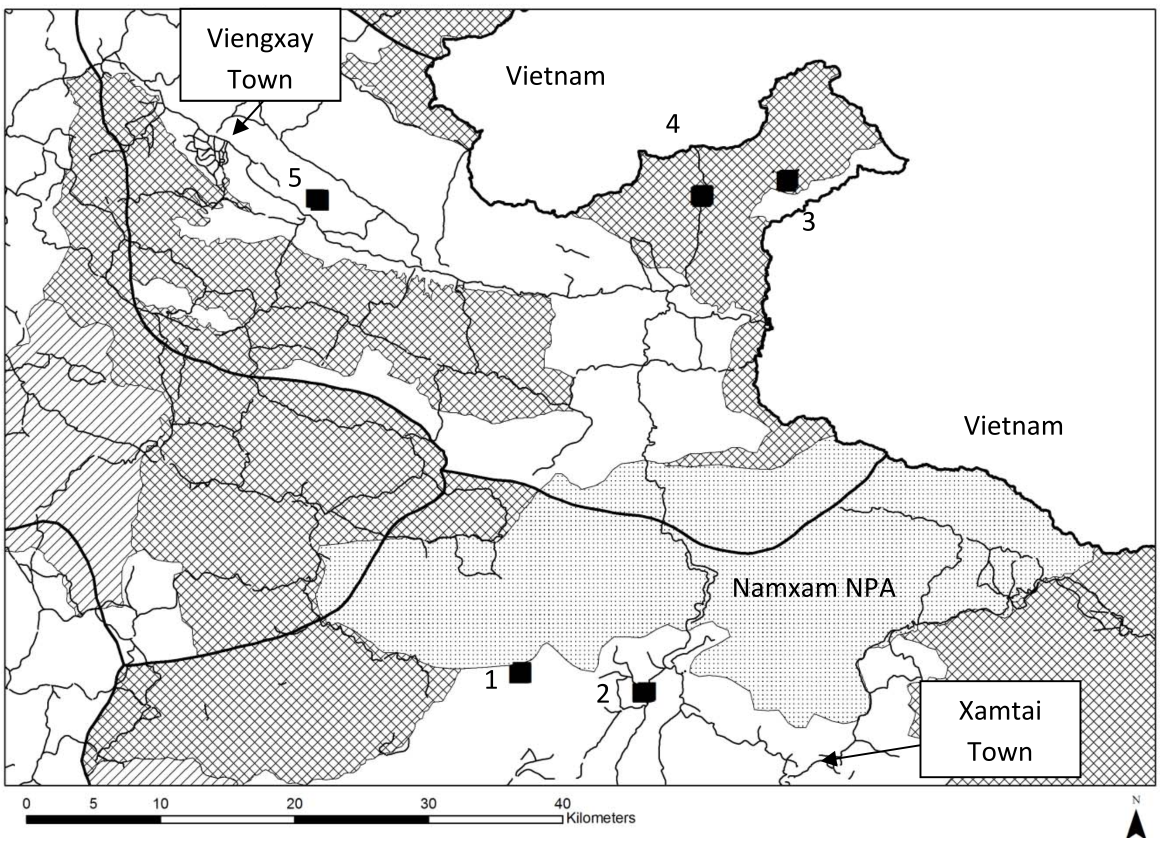

Figure 10. Map of data collection locations in Xamtai and Viengxay Districts, Houaphanh Province, Lao PDR. Numbers correspond to sites of data collection, listed in Table 4.

<u>Methods</u>

In order to facilitate rapid data collection on tree volume and density, we used variable radius point sampling. This has been proven effective in other tropical forests within SE Asia and the Pacific (Kronseder 2012, Bryan 2010). We used a metric BAF 2 prism in all plots to maintain consistency. Ocular estimates of overstory and understory (if applicable) canopy cover, bamboo cover, and stand height were made in a ~10 m radius around each sampling point. We measured the diameter of each sample tree to the nearest 1 cm. We recorded average slope and topographic position, as well as any relevant disturbance factors within sight of the point (i.e., proximity to shifting agriculture, presence of stumps, etc). The first sampling point was placed 50 m from the boundary and inside the strata. Each successive sampling point was established on a transect at 100 m intervals, in a direction away from the strata boundary. We calculated bole volume using an equation developed from the SUFORD project (Pukkala 2005).

Results

Within intact and non-intact strata, two different forest types were sampled - upper evergreen and dry dipterocarp. Descriptions of these forest types are found in FRA (2005):

> *The Dry Dipterocarp Forest occurs in open stands. The tree diameter is comparably small and the height of the stand varies from 8 to 25 m. The crowns do not spread out widely. This type of forest is normally found in places with shallow soil, where the hard pan emerges above the ground, and on latirized soil. On the most poor and shallow soils the trees are crooked and do not exceed 10 m in height.*
>
> *The evergreen forest type is a multi-story forest consisting of more than 80% trees of evergreen species. Most of the trees have long and cylindrical boles, many of them with a big buttress. Usually, the height of the trees of the upper story is more than 30 m. Another typical characteristic of this forest type are climbers and lichen on the tree stems. Bamboo is usually not found except when the canopy has been opened. Evergreen forest located at an altitude above 200 m is classified as Upper Evergreen Forest. Areas below that altitude are classified as Lower Evergreen Forest.*

The evergreen forests at the Namxam National Protection Area and the Laeng Namm Watershed Protection Forest were both characterized by large diameter, tall canopy trees. In the 2005 FAO FRA, the GoL reported an average of 88 m3/ha for 'Natural High Forest' and 51 m3/ha for Dry Dipterocarp Forest. This is consistent with our findings from very limited field data (table 6). Density ranged from 330 trees per hectare in evergreen forest to 630 trees per hectare in dry dipterocarp forest. Unpublished analyses of the 1990's NFI dataset for SUFORD estimate an average of 302 trees per hectare across all forest types except dry dipterocarp, in Houaphanh (Vesa 2009).

Table 6. Forest structure characteristics from a rapid assessment in Houaphanh Province, Lao PDR.

Forest type	Area name / strata	# of plots	Mean overstory height (m)	Mean overstory canopy cover (%)	Mean understory canopy cover (%)	Basal area per hectare (m^2)	Trees per hectare	Bole volume / ha (m3)*
Evergreen	Namxam / intact	5	20	75	99	13.2	330	94
	Laeng Namm / non-intact	6	20	75	NA	13.0	515	87
Dry dipterocarp	Namat	6	7		NA	10.3	492	54
	Naman	8	8	93	NA	4.0	366	18
	Xiang Luang	6	10	73	NA	16.7	630	90

* Bole volume = $0.000115 \times D^{2.436}$, from Pukkala 2005.

There was no evidence of forest degradation drivers in Namxam, however use of the Laeng Namm forest seemed to be high. We encountered several stumps along the 600 m transect, some seemed to be old as canopy closure had already occurred and the stumps were becoming decayed. However, some stumps were newly cut and boards had recently been extracted (the boards were piled on the roadside). There was no evidence of mechanized extraction, only single tree selective harvest targeted at high value species. Extraction seemed to occur by carrying boards along footpaths. In Laeng Namm, we encountered two small (< 0.25 ha) clearings where poppies were being grown. Also in Laeng Namm, we observed several cases of NTFP collection, mainly medium sized (3-5 cm) tree roots cut and piled for gathering.

Degraded versus non-degraded strata classification for dry dipterocarp forest is very difficult. Both Naman and Xiang Luang areas were cultivated in the past (10 and 20 years ago, respectively) and are in a period of forest regeneration. The Namat area has never been cultivated due to the poor, thin soils and steep slopes. All three areas are managed by local authorities as village forests. There is a minor amount of illegal harvesting of fuel wood or construction poles in both Naman and Namat as evidenced by recent stumps in both areas. No recent stumps were observed in Xiang Luang.

Stratification of degraded versus non-degraded dry dipterocarp forest is likely not an issue in Houaphanh. For the SUFORD analysis of NFI data, no results were presented for this forest type in Houaphanh (Vesa 2009). It could be possible that the Xiang Luang area we visited is of the evergreen forest type, but with a different suite of early successional species. Without more time to understand the interplay between site history, forest dynamics, shifting agriculture, and land cover change, it will be challenging to apply this type of classification to the dry dipterocarp forest type.

Forest degradation monitoring design considerations

1. Direct and indirect approaches: Remote sensing

Dozens of options exist for use of remotely sensed data to capture information on change within forests. Costs, data availability, institutional and human resource capacity are all key considerations in monitoring systems design. Temporal aspects of monitoring with remotely sensed data are a key component, allowing for inter-annual change assessment (Lambin 1999). Herold (2011) made a broad assessment at national level scale of opportunities to assess historical degradation (table 7). This assessment did not consider shifting cultivation as a form of forest degradation. A direct approach is considered as potentially useful in monitoring commercial logging. However, as this is based on remotely sensed or ancillary data it does not 'directly' sample change in biomass.

Table 7. Options for estimating activity data for historical degradation on the national level beyond the use of default, Tier 1 data (adapted from Herold 2011).

Activity and driver of forest degradation	Suitable and availabe data sources for activity data (national level)
Extraction of forest products for subsistence and local markets, such as fuelwood and charcoal	- Limited historical data - Information from local scale studies or national proxies (i.e., population growth and wood demand), if available - Only long-term cumulative changes may be observed from historical satellite data
Industrial/commercial extraction of forest products such as selective logging	- Historical satellite data analyzed with concession areas - Direct approach should be explored for recent years (since ~2000, depending on national coverage) - Indirect approach should be explored for historical period (back to 1990)
Other disturbances, such as (uncontrolled) wildfire	- Historical satellite-based fire data records (since 2000) to be analysed with Landsat-type data

An assessment of pilot activities across Asia was conducted by Japanese researchers in order to rank the potential usefulness of remotely sensed data for monitoring variables related to forest degradation process (Table 8). This study used a qualitative ranking to determine relevance of methodologies by degradation driver. According to the knowledge gained through these pilot studies in Asia, very few possibilities exist with current levels of knowledge and research. Further, methodologies that do exist are hampered by cloud cover and steep terrain. The former is a large constraint in Lao PDR where mean annual cloud cover is 65% (Herold 2009) and slopes are very steep. In this assessment, data was collected in areas where slopes ranged from 50 to 84%, and averaged 66%.

Table 8. Options for use of remotely sensed data to characterize variables of interest that relate to forest degradation processes (adapted from Kiyono et al 2011).

		Considerations			Ranking by activity		
Variable of interest	**Data source**	**Costs**	**Large area acquisition**	**Technical difficulties**	**Reducing fallow period**	**Logging**	**Fuelwood collection**
Forest cover classification							
Area	Optical RS data, med to high resolution	Medium	Easy	Not applicable when clouded	Possible	Partially possible	Partially possible
Area	Radar, longer than L-band	Medium	Easy	Not applicable to areas with steep slopes	Possible	Unknown	Unknown
Forest structure classification							
Crown diameter	High resolution aerial photography	High	Medium	Not applicable when clouded; Crown recognition difficult in some forests	Impossible	Partially possible	Impossible
Overstory height	Radar, multi-polarization SAR	Low	Medium	Methods not tested; Applicable to small parts of the globe	Unknown	Unknown	Impossible
Overstory height	LiDAR, airborn	High	Difficult	Nothing in particular	Possible	Possible	Impossible
Overstory height	High resolution aerial photography, stereo mapping	Medium	Easy	Not applicable when clouded; Methods not tested	Unknown	Unknown	Impossible

The US Forest Service Remote Sensing Applications Center reviewed selected remote sensing methodologies to provide a snapshot in time of current applications used to establish a baseline and monitor change in forest attributes for REDD+ (Brewer 2011). A ranking (low, medium, high) was done of 11 methodologies to assess operational readiness. Four of these were considered to be in high stage of operational readiness and all four have the potential for degradation monitoring. Three of these four are in development by Asner's Carnegie Airborne Observatory with a wide array of partners. These approaches have not seen widespread testing in the Asia-Pacific region. Three of the four rely on highly expensive LiDAR data and aerial collection methods. CLASLite, the fourth, relies on analyses at the pixel level to assess very fine differences in spectral responses between similar land cover classes (i.e., logged forest versus secondary forest).

One of the first demonstrations of CLASLite in Asia was used to determine complex land use dynamics at a district scale in Indonesian Borneo (Carlson 2012a). Assessing forest degradation processes requires frequent (1-2 year) use of remote sensing, as forest canopy cover can regenerate quickly in Southeast Asia. This study was able to use CLASLite for population land use matrices over time (including degraded forest) at a district level. However, when the authors attempted to perform a similar assessment across all of Indonesian Borneo, they met with limited success because they were not able to process cloud free imagery at necessary time intervals (Carlson 2012b).

CLASLite used in combination with LiDAR was not assessed in the USFS review; however it has been employed through the Asner Observatory in the Peruvian Amazon with initial success (Asner 2009). In the USFS assessment, only one other approach for degradation monitoring was assessed which could be considered cost-effective – Normalized Difference Fraction Index using free LandSat archived data. The authors considered the operational readiness of this approach to be low.

Sampling with satellite imagery to estimate land cover has been proven as a useful approach at global scales (Ridder 2007). Scaling down this strategy to estimate land cover and land cover changes at sub-national scales with multiple-date high resolution imagery could prove to be a useful concept for assessing forest degradation. Visual interpretation methods would be best applied in this type of estimation. Kiyono et 2011 mentions this as a 'partially possible' technique based on ease of acquisition and medium level costs. Multiple date sampling of images covering the same area could prove most challenging in the context of persistent cloud cover.

2. Direct approach: ground based plot measurements

Options for collecting and analyzing field data are no less than the options for remote sensing. In considering design of monitoring options, capacity and funding are critical components to assess. Danielson (2009) approached design of potential options from the perspective of who is to accomplish the work (Table 9). This is a critical perspective in the design phase in order to assess the potential for who will be involved in which activities, and to what level.

Table 9. Categories of actors involved in forest monitoring (adapted from Danielsen 2009).

Monitoring category	Category definition	Primary data gatherers	Primary data users
1	Externally driven, professionally executed	Professional researchers	Professional researchers
2	Externally driven with local	Professional researchers	Professional researchers

	data collectors	and local people	
3	Collaborative monitoring with external data interpretation	Local people with professional researcher advice	Local people and professional researchers
4	Collaborative monitoring with local data interpretation	Local people with professional researcher advice	Local people
5	Autonomous local monitoring	Local people	Local people

Danielsen et al (2009) determined that the needs to include professional, external expertise in most forms of actor driven monitoring is high (table 10). This directly relates to the transaction cost of training, capacity building, and mentoring over time to ensure that collaborative processes are sufficiently empowered to succeed. Likewise, accuracy and capacity to inform national monitoring systems are determined to be low if autonomous monitoring is implemented without assistance from other actors. In any step-wise or nested approach to monitoring and the broader MRV context, this is a serious consideration. The USFS-International Programs assisted in the design and initial training for Participatory Forest Monitoring in Ghana in 2009-10. Main findings demonstrate that successful approaches must include continued mentoring for local actors in collaborative approaches (Stanturf 2011).

Table 10. Design considerations for field based forest monitoring by category of participants (adapted from Danielsen 2009).

Monitoring category	Cost to local stakeholders	Cost to others	Require-ment for local expertise	Requirement for external expertise	Accuracy and precision	Capacity to inform national monitoring schemes
1	*	***	*	***	***	***
2	**	**	**	***	***	***
3	**	**	**	***	***	***
4	***	* and ***[1]	***	** and ***[2]	**	**
5	***	*	***	*	*	*

* = low; ** = moderate; *** = high

1. Recurrent costs to non-locals is low, set-up and training costs to non-locals is high.

2. Recurrent requirement for non-local expertise is intermediate; requirement for non-local expertise is high during set-up and training phases.

The monitoring objective is to assess any change in biomass over time (given a certain baseline). Sampling design, data collection design, and protocol development are the next steps in determining how information be collected and assessed, after and/or at the same time as determining who. One common method is the implementation of Permanent Sample Plots (PSP). Kiyono et al (2011) notes that PSP's can be used to monitor changes in biomass due to logging, fuel wood collection, and reduction of fallow periods, although the costs are predicted to be high along with the difficulty in acquiring data over large areas. An analysis of forest density in three stands of different density classes was conducted to assess accuracy and efficiency of six different methods in the south-central United States (Sparks

2002). Each stand was less than 1 ha and estimates were compared to stand census data to assess absolute precision for each method. Methods used included: 2 different radii for fixed circular plots, square plot, variable radius point sampling, belt transects, and the point center quarter method. Findings indicate that fixed radius plots and the point center quarter method were most accurate. However, when combining accuracy and efficiency, the variable radius point sampling method was recommended for sampling stands with larger stems.

Various methods were also compared in high elevation forests of Tanzania to assess accuracy and efficiency in estimating levels of disturbance (Holck 2008). Results of data analysis by local actors were compared to results from professionally trained scientists for two of the four methods in the analysis. It was determined that proper training can improve reliability of results, and that simplified methods also play a large part in accurate estimations. The four methods were assessed contextually to provide an overview of the pros and cons of each method (table 11). This indicates that costs can be kept low, yet at the sacrifice of accuracy. The author noted that the Bitterlich angle gauge method was most suitable in this local context in Tanzania.

Table 11. Cost-benefit assessment of forest inventory methods to assess forest structure in Tanzania.

	20 trees method	**Bitterlich angle gauge**	**Disturbance checklist**	**Permanent plots**
Costs (USD/ha/yr)	0.08 - 0.12	0.04	0.08 - 0.12	1.88
Pros	Easy Cost effective Equipment locally available	Easy Cost effective Equipment locally available Provides useful data on a short term scale	Easy Cost effective Equipment locally available Provides useful data on a short term scale	Provides scientifically good data Detects long term changes Can also be used for biodiversity studies
Cons	Less precise More time consuming Needs many samples Not shown capable to describe disturbance	Less precise Requires training Results can be individual	Less precise Requires training Requires at least 3 people Need to develop biomass relationships **	Number of plots needed is high Expert needed for identification Relatively expensive Very time consuming

				Not suitable for short term disturbance monitoring

** Added by Halperin.

3. Indirect: modeling

There is not a large body of literature pertaining to models which apply to forests and forest dynamics in Lao PDR. Likewise, modeling forest degradation in general is not well studied. GOFC-GOLD (2011) provides a brief overview of various models, focusing on models most useful for predicting forest cover change and not specifically on forest degradation. Parameterization of any model with proper data is a key consideration (Rautiainen 2012). The SUFORD project has been able to collect and analyze site specific data for natural forest timber concessions in southern Lao PDR, and has supported analysis of NFI data. However, the NFI data has not been collected/analyzed over multiple dates and represents a scale more coarse than the degradation drivers present in Houaphanh.

Predictive modeling to estimate spatial patterns of deforestation and degradation has been attempted in several tropical countries (Mon 2012, Eckert 2012), and regionally and globally (Zhao 2006, Rautiainen 2012). Input variables of these various studies depend on topographic data, distance to urban and/or rural population centers, population density, roads, trails, forest type, forest condition, and/or logging intensity. All of these approaches rely on a 'triad' of components: forest inventory, remote sensing, and the model itself (Figure 11).

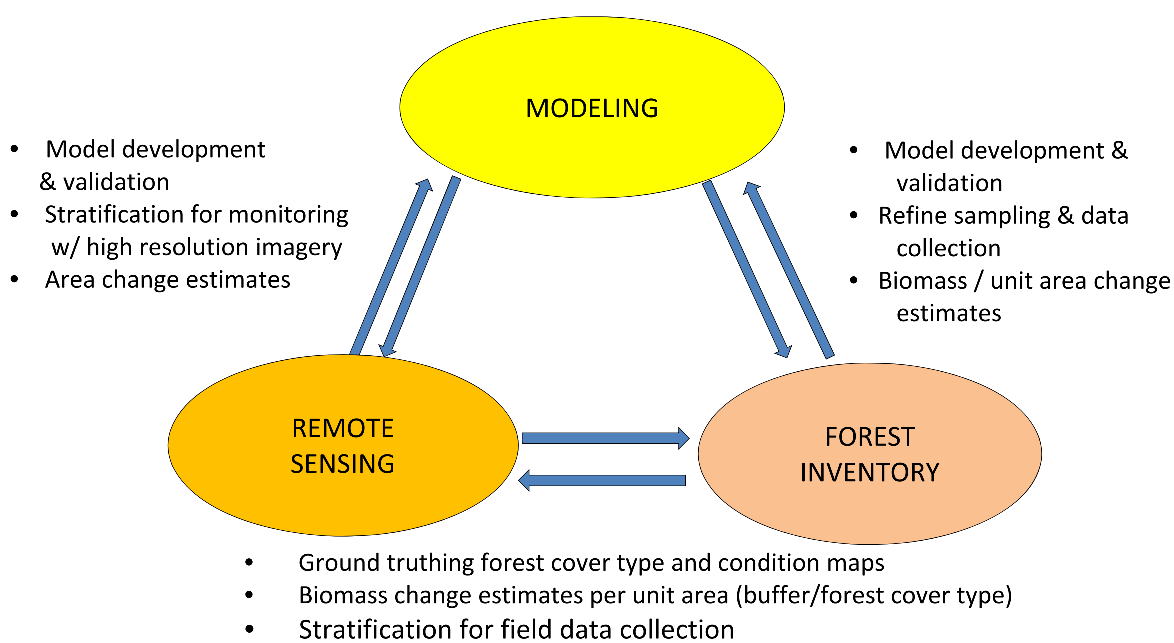

Figure 11. Conceptual arrangement of an approach to model forest degradation, combining field measurements and remote sensing.

Approaches to modeling should be flexible, yet robust enough to meet statistical accuracy targets. Models should also be as simple as possible, minimizing input data to only those variables that are essential to the predicted output.

The concept of using buffer zone analyses to assess extent of degradation within intact forested landscapes has been employed in several tropical countries in the last few years (Margono 2012, Bucki 2012, Potapov 2008). Use of buffer zones in this manner attempts to identify new infrastructure in large, undeveloped forest areas. Intact Forest Landscapes are generally considered to be at least 1,000's of hectares in size with no road network at the time of initial assessment. It is assumed that new roads within Intact Forest Landscapes are constructed for extraction of timber resources and that a given distance buffered around the roads will delineate the extraction zone.

Within Intact Forest Landscapes, Margono (2012) used historical satellite LiDAR data to compare mean canopy height within a road buffer compared to outside a road buffer. Results indicated that the mean canopy height was 10 m greater outside the buffer than inside the buffer. This study did successfully demonstrate biophysical differences in tropical forest structure using a buffer zone approach and is an approach that can be validated with field data. However, drawbacks to this approach include: the satellite LiDAR is no longer operational, repeated extraction over the road network (when the forest no longer becomes intact), extraction that occurs using trails and not roads, and the relationship between mean canopy height and biomass has not been tested.

Shifting agriculture is, and has been, an important part of the landscape in northern Lao PDR for centuries. Cultural practices of swidden systems are embedded in agricultural production (Mertz 2009). Government policies and market demands for cash crops have changed this paradigm into a shift to more permanent upland agriculture (Keophosay 2011, Viau 2009). Traditionally, fallow cycles between planting lasted much longer than the current 1-3 year average for Houaphanh. Shortening fallows will result in the forest never being allowed to grow back for long enough to meet the minimum requirements of the definition of forested land in Lao PDR (0.5 ha, 10% canopy cover, 5 m ht.). A recent study by Sovu (2009) in southern Lao PDR clearly showed an increase in basal area and decrease in stem density with increasing fallow age. There was also a clear relationship between the number of bamboo clumps per hectare and the number of times a plot of land has been cultivated.

The difficulty in assessing forest cover over a dynamic landscape that constantly changes into, and out of, a forested state with small agricultural patches is particularly challenging (Yamamoto 2009). The intersection of the forest definition with the definition of forest degradation is an issue of scale. One approach to address this issue has been successfully tested in northern Lao PDR under conditions very similar to those in Houaphanh Province (Hett 2011). Maps created from remotely sensed imagery were classified into classes of fallow period, degraded forest, and intact forest. Each pixel was then assessed according to neighboring land uses over a 2km moving window to create matrices of land use/land cover change at a district scale. Results show that this method can be employed to assess the dynamics of land use change across a given landscape. Similar methods have also been employed at the national level in Lao PDR (Messerli 2009) and more recently at the sub-national level in the DRC (Bucki 2012).

The above method, however, does not estimate biomass across a given landscape. This is a critical need to frame a landscape mosaics approach in terms of biomass in order to operationalize the monitoring objective of this work. Japanese researchers studied biomass variation according to 6 different fallow lengths (< 1 year to 20 years) in northern Lao PDR (Kiyono 2007). According to their results, Above Ground Biomass was best modeled using basal area.

Biomass = 4.710(BA) + 19.43
($n = 6$, $r^2 = 0.9881$, $p < 0.001$)
BA = sum of basal area for each plot sampled, each plot was 40m x 40m, sum basal area comprised of all living trees and bamboo culms ≥ 4 cm

Further, this study analyzed the relationship between average overstory height and biomass for each plot. The relationship between height and biomass appears strong for young, secondary forests in shifting agriculture systems (Figure 12). While this research was limited to one area in northern Lao PDR, plots were all located relatively close to villages (< 1 hour walking), and the biomass – basal area relationship is based on somewhat limited research (published in Japanese), it does provide for an interesting starting point to assess carbon stocks in complex landscapes dominated by shifting agriculture.

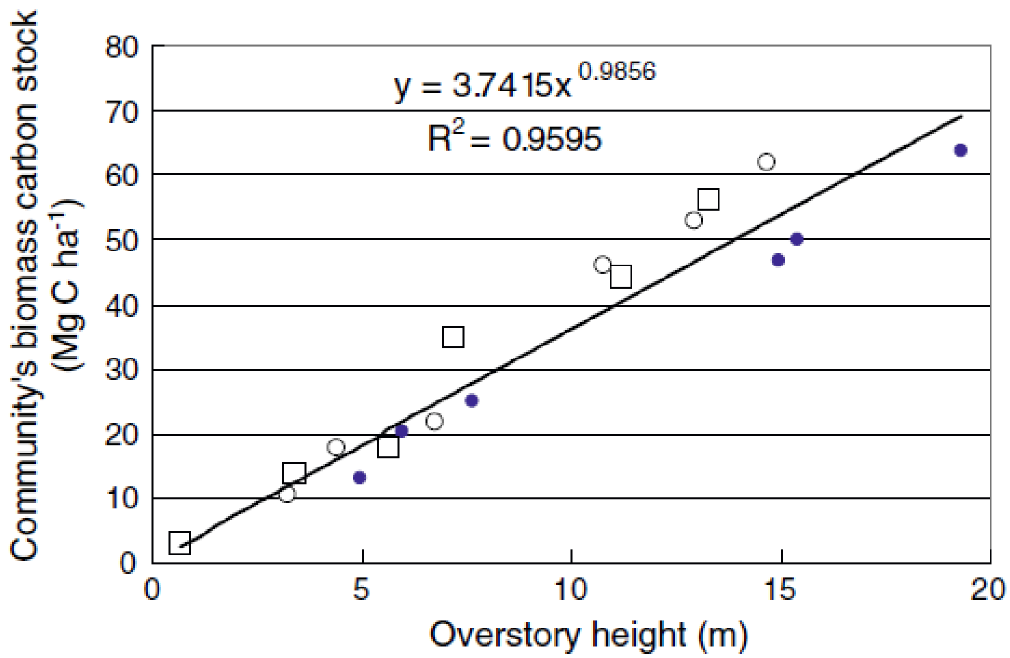

Figure 12. Relationship between overstory height (x) and a community's biomass carbon stock (y) in northern Lao PDR. Biomass data were collected in April 2004 (open square), April 2005 (open circle), and April 2006 (filled circle). (from Kiyono 2007).

Results from this work were also extrapolated to develop a theoretical model of carbon dynamics based on time of cultivation period combined with length of fallow (Inoue 2009, Figure 13). This model is a chronosequence of changes in biomass over time in a shifting agriculture landscape. A similar approach has been recommended for use in an MRV system at the national level in Guyana (Brown pers comm.). Testing the validity of this model would be of interest to determine its usefulness in other provinces and conditions.

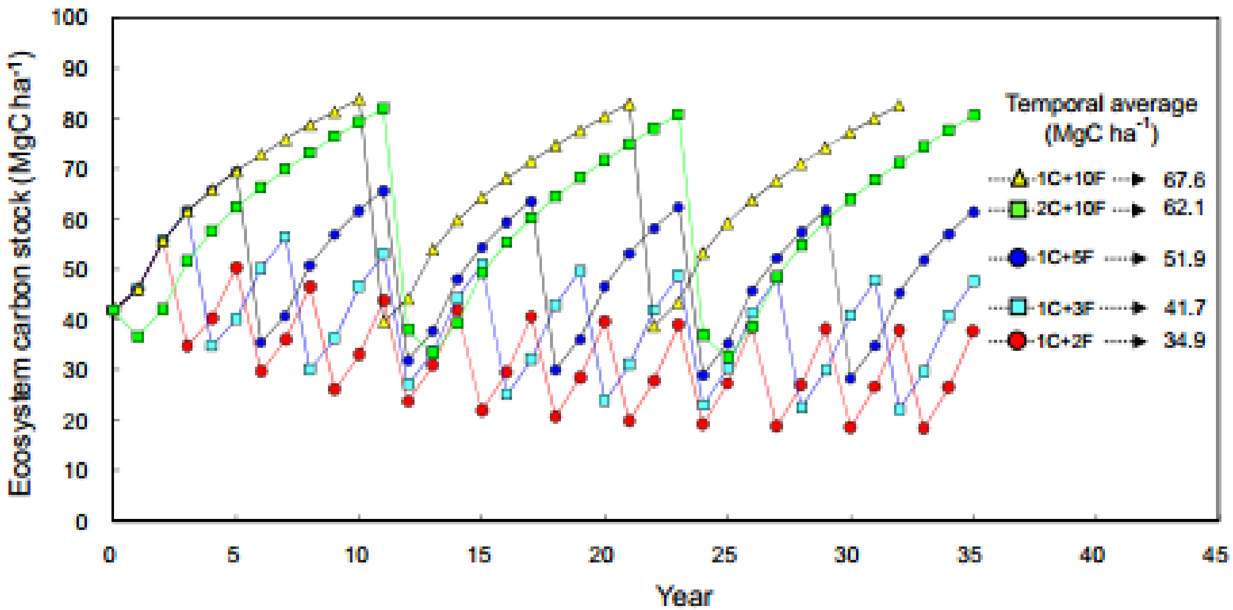

Figure 13. Chrono-sequential changes in ecosystem carbon stock under some typical land-use patterns in Luang Prabang Province as assessed by a coupled model of carbon in soil and fallow vegetation. “C” and “F” denote cropping and fallow, respectively, so that “1C + 10F” means 1 year cropping and 10 year fallow period. The arrow and number attached to each line indicate the temporal average of carbon stock. (From Inoue 2009.)