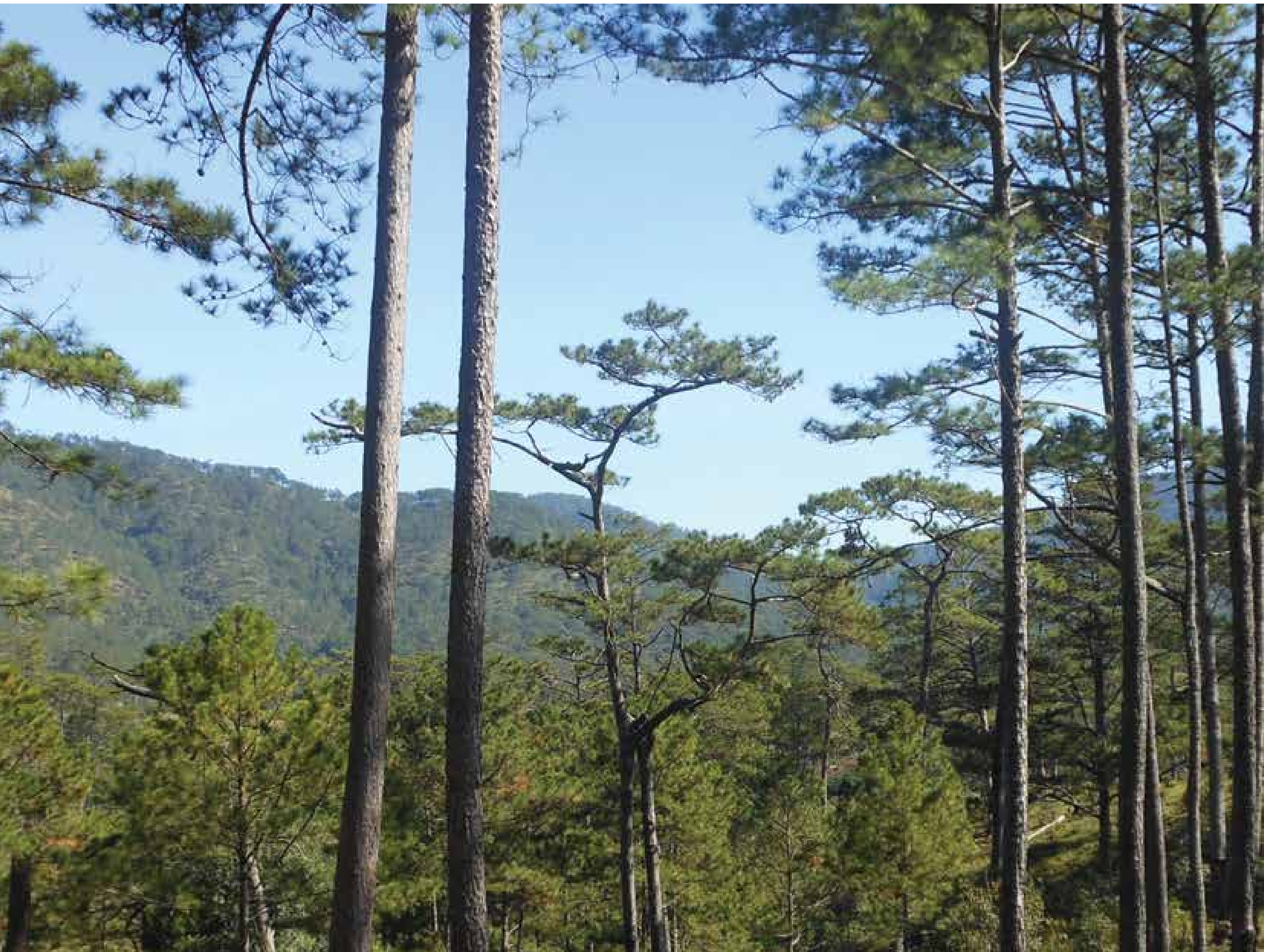

Report

Establishing a Reference Level for REDD+

From 1990 to 2010

Lam Dong province, Viet Nam

Alexandre Grais, Silvia Petrova, Katherine Goslee and Sandra Brown, Winrock International

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This report has been produced by the USAID-funded Lowering Emissions in Asia's Forests (USAID LEAF) program in its support for the development of the Lam Dong Provincial REDD+ Action Plan (PRAP). It is one of five technical reports that have been developed to help the Lam Dong Department of Agriculture and Rural Development (DARD) in defining an appropriate Forest Reference Level for the Province from which its policies and measures introduced to reduce emissions and increase greenhouse gas (GHG) removals from the forestry sector can be measured against. Specifically, this report considers the context in which the provincial Forest Reference Level will be set, consolidates the previous analytical work to present a number of options in setting a Forest Reference Level for the province of Lam Dong and recommends a number of actions that should be taken to reduce uncertainty levels in the setting of the Forest Reference Level for the province of Lam Dong.

Authors

Alexandre Grais, Silvia Petrova, Katherine Goslee and Sandra Brown

The report is available through the USAID LEAF website at:

http://www.leafasia.org/resources_tools

For further details please contact:

Ms Ly Thi Minh Hai

USAID Lowering Emissions in Asia's Forests (LEAF)

Viet Nam USAID LEAF Country Manager, SNV REDD+ Sector Leader

6th floor, Building B, La Thanh Hotel,
218 Doi Can, Ba Dinh, Hanoi, VIET NAM

Telephone: +84 (4) 3846 3791 /108
Email: HLyThiMinh@snvworld.org

Dr David Ganz

USAID Lowering Emissions in Asia's Forests (LEAF)

Chief of Party

Liberty Square, Suite 2002
287 Silom Rd. Bang Rak
Bangkok 10500, THAILAND

Telephone: +66 (0) 2 631 1259
Email: DGanz@field.winrock.org

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Abbreviations, definitions & acronyms

Activity leading	A practice, in a defined area over a given period of time, to deforestation, degradation, or forest enhancement.
Activity Data	Data on the magnitude of human activity resulting in emissions or removals taking place during a given period of time. The IPCC Guidelines describe three different approaches for representing the activity data, usually reported as ha per year.
AFOLU	Agriculture, Forestry, and Other Land Use
A/R	Afforestation/Reforestation
Approaches	IPCC refers to three approaches for representing activity data. They are presented in order of increasing information content, increasing from 1 to 3.
Carbon pool	IPCC recognized reservoirs containing carbon: above and below-ground biomass, dead wood, litter, soil organic carbon, and harvested wood products.
Carbon stock	The quantity of carbon in a pool.
CDM	Clean Development Mechanism
Driver	Causes of forest and land use change, both positive (e.g. carbon stock enhancement) and negative (deforestation and forest degradation)
Emission Factor	The emissions and removals of greenhouse gases per unit of activity data, often expressed in units of t CO_2/ha or t CO_2 per unit of activity (e.g. m3 of timber or fuelwood extracted).
Forest	Forest is a minimum area of land of 0.05 - 1.0 hectares with tree crown cover (or equivalent stocking level) of 10-30%, and minimum height at maturity in situ of 2-5 m.
Gain-loss method	Method to calculate changes in carbon stocks by estimating gains in carbon based on typical growth rates and losses from activities such as harvesting for timber and fuelwood.
GIS	Geographic Information System
IPCC	Intergovernmental Panel on Climate Change
Historical Reference Period	The period from which data on past changes in forest area are established, analyzed, and projected into the future.

Abbreviations, definitions & acronyms (Continued)

LiDAR	Light Detection and Ranging
MRV	Measuring, Reporting, and Verification
NFI	National Forest Inventory
NFMS	National Forest Monitoring System
REDD+	Reduced Emissions from Deforestation and forest Degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries
RL/REL	Reference Level or Reference Emission Level
ROC	Relative Operating Characteristic
R-PP	Readiness Preparation Plan
RS	Remote Sensing
Stratification	The subdivision of a population into strata or sampling blocks, which are more homogenous than the population as a whole
Stock-difference method	Method to calculate changes in carbon stocks as the difference in estimated carbon stocks pre and post forest cover change.
Tier	IPCC-defined levels of accuracy in estimating GHG emissions, increasing from 1 to 3.
UNFCCC	United National Framework Convention on Climate Change

Executive Summary

Reference levels (RLs) are essential to develop and implement programs for Reducing Emissions from Deforestation and Forest Degradation, and the Role of Conservation of Forest Carbon Stocks, Sustainable Management of Forests and Enhancement of Forest Carbon Stocks (REDD+). Reference Levels (RLs) depict business-as-usual (BAU) greenhouse gas emissions from forest and other land cover changes, thereby providing a benchmark for estimating emission reductions due to REDD+ implementation. A RL depict what the emissions scenario would be in the absence of REDD+ implementation, and thus provides the basis for measuring its success. Reference Levels are based on greenhouse gases (GHG) historically emitted, and can potentially be adjusted for specific national circumstances in cases where historical emissions alone are not a reliable predictor of future emissions. In this report we summarize guidelines and/or criteria for the establishment of RLs in keeping with UNFCCC decisions, and develop a historical trend reference scenario for Lam Dong Province, Vietnam for the time period 1990 to 2010. Lam Dong's key decisions related to developing a RL include:

1. The scope of the REDD+ RL will include deforestation, forest degradation and the enhancement of forest carbon stocks;
2. Forests are defined using minimum thresholds of tree cover, tree height and area as 30%, 3 m and 0.5 ha, respectively;
3. Carbon dioxide (CO_2) will be included and other non-CO_2 gases (N_2O and CH_4) will be excluded in the RL; and the carbon pools included in the RL are specific to the REDD+ activity under consideration
4. Data used for development of the RL were collected under the national forest inventory;
5. The RL may be adjusted for provincial circumstances if appropriate data and documentation can be compiled to provide justification;

The 20-year period 1990 to 2010 was used to establish the historical emissions upon which the RL will be based, as this is the length of time that a complete set of data are available, covering deforestation, forest degradation and enhancement of forest stocks (data for other forms of degradation such as shifting cultivation are not available).

Emissions from deforestation from 1990-2010 were 49.2 million tons CO_2e; emissions from degradation were 20.3 million tons CO_2e, and removals from A/R were 9.0 million tons CO_2e. Total combined net emissions for the province from 1990-2010 were 60.5 million tons CO_2e, with an annual average of 3.02 million t CO_2e.

The REDD+ jurisdiction is free to identify and assess the specific local circumstances and, if used to adjust the historical emissions, they need to include details on how these circumstances were considered. Pending further guidance from the UNFCCC, and based on existing guidance, the assessment of jurisdictional circumstances for Lam Dong, could consider the following information:

- Geographical characteristics (climate, forest area, land use, other environmental characteristics);
- Population (growth rates, distribution, density, etc.);
- Economy (energy, transport, industry, mining, tourism, agriculture, fisheries, waste, health, services)

Any adjustments to the historical emissions that proposes that the historical emissions will increase under a business-as-usual scenario (that is without any interventions motivated by a REDD+ mechanism) will have to be fully justified. Possible and credible business as usual scenarios and alternative low emission scenarios that could impact forest lands would need to be developed and justified, and spatially displayed on the forest land cover so that the associated emission could be determined.

1 Background

1.1 REDD+ in the UNFCCC

Reference Levels (RLs) are a key component of developing a national or subnational forest monitoring system (NFMS) for REDD+ (Figure 1).[1] They are estimates of greenhouse gas emissions from forest and other land cover changes over time and portray the emissions that would have occurred under a business as usual (BAU) scenario without REDD+ interventions. They are used to measure the performance of REDD+ interventions in reducing emissions. The BAU scenario is a projection of greenhouse gases (GHG) historically emitted, and can potentially be adjusted for specific national or subnational circumstances in cases where historical emissions alone are not a reliable predictor of future emissions.

Figure 1: Key components for developing a national or subnational forest monitoring system for REDD+ program.

1.2 REDD+ in Vietnam

The Government of Vietnam (GVN) has been and is supporting and engaging in the international efforts for reducing emissions and mitigation of changing climate, including the REDD+ initiative. Vietnam submitted the Readiness Plan Idea Note (R-PIN) in 2008 to the World Bank Forest Carbon Partnership Facility (FCPF) indicating its interest in the REDD mechanism, and it was one of the first countries to receive approval for its R-PIN by the FCPF. Vietnam is also one of the nine initial countries identified under the UN-REDD Programme, an initiative of the United Nations in developing countries building on the expertise of the Food and Agriculture Organization of the United Nations (FAO), the United Nations Development Programme (UNDP) and the United Nations Environmental Programme (UNEP).

The GVN has issued and implemented a number of programs and policies on forest protection and development to contribute to the GHG reduction goals and support the development of the national REDD+ scheme. Some of the key policies are:

- **Decree No. 99/2010/NĐ-CP** of the Government on Payment for Forest Environmental Services, dated 24 September 2010.

1. Brown S., F. Casarim F., K.M. Goslee, A.M. Grais, T.H. Pearson, S. Petrova, E. Swails, and S.M. Walker. 2013. Technical Guidance Series for the Development of a National or Subnational Forest Monitoring System for REDD+. Developed by Winrock International under USAID's LEAF Program.

- **Decision No. 57/QĐ-TTg** of the Prime Minister on approving the Forest Protection and Development Plan for the period 2011-2020, dated 09 January 2012.
- **Decision No. 799/QĐ-TTg** of the Prime Minister on approving a National Action Program on "Reducing Emissions from Deforestation and Forest Degradation, Sustainable Forest Management, Conservation and Enhancement of Carbon Sink" for the period 2011-2020 (National REDD+ Action Programme (NRAP), dated 27th June 2012.

The government institutions related to forestry and REDD+include:[2]

- The Ministry of Agriculture and Rural Development (MARD)
- The Ministry of Natural Resources and environment (MONRE)
- The Ministry of Planning Investment (MPI)
- The Ministry of Finance (MoF)
- The State Committee for Ethnic Minority and Mountainous Area Affairs (CEMMA)

In 2010 MARD established a National REDD+ Network, a REDD+ working group, and sub-technical working groups with Decision 2614/QĐ-BNN-LN. The REDD+ Network is responsible for providing awareness of REDD+, building capacity at the national and subnational levels and coordinating all REDD+ related activities in the country. The network's members include representatives from MARD, VNFOREST, research institutes, NGOs and international organizations.

In 2011, the Vietnam REDD+ Steering Committee, chaired by the Minister of MARD and the National REDD+ office, was established to coordinate REDD+ implementation between all government agencies, private organizations, and NGOs, and to manage the process of development of tools to implement Vietnam's National REDD+ program.

According to Decision No. 799/QĐ-TTg, (the National REDD+ Action Plan (NRAP)), Reference Emission Levels (RELs) and Forest Reference Levels (FRLs) will be established at national and provincial levels in compliance with the UNFCCC and IPCC guidelines. In parallel with the establishment of national Reference Levels (RLs), various subnational efforts are being implemented to test different methods and approaches. Currently two provinces - Lam Dong and Dien Bien are developing RLs with the support of USAID's Lowering Emissions in Asia's Forest (LEAF) project and JICA, respectively.

In terms of measuring and monitoring their forests for the RL and their MRV, Vietnam has made progress in developing a National Forest Monitoring System (NFMS) and a National Reporting Information System (NRIS). The two ministries, MONRE and MARD, are collaborating to derive information on land use changes, including changes on forest land, and emissions of

2. http://www.vietnam-redd.org

GHG emissions and removals. Current efforts are underway to improve the consistency between the National Forest Inventory (NFI) (currently employed by the Forest Inventory and Planning Institute (FIPI) and Forest Protection Department (FPD) under MARD) and Land Monitoring System (currently employed by the General Department of Land Administration under MONRE).

The REDD+ readiness activities and projects in Vietnam are supported by the UNREDD with the support of the Government of Norway, the WB and the FCPF, the governments of Australia, Japan, Germany, the Netherlands, the US and various NGOs.

1.3 REDD+ in Lam Dong

Through the LEAF project, Winrock International is assisting the province of Lam Dong to develop its RL for REDD+. LEAF has helped build the technical capacity in the province through a “learning by doing approach”, which has included trainings on forest carbon stratification, forest carbon stock assessment, and estimating historical emissions for Lam Dong. The aim of these capacity building efforts is to develop local stakeholder’s capacity to develop a forest monitoring system (FMS) for Lam Dong that is integrated within national efforts and can be sustained in Vietnam.

Carbon stocks in Lam Dong’s forests were developed based on the National Forest Inventory (NFI) Cycle 4 data that included Lam Dong. Forest and land cover maps were created by the Forest Resources and Environment Center (FREC) of FIPI for the years 1990, 1995, 2000, 2005 and 2010 using Landsat and SPOT 5 satellite imagery. The NFI used the forest land cover maps to estimate the activity data. The outcomes of this system as described below feed into the historical emission component of the RL and also into the future MRV system for Lam Dong province.

The RL is to be approved by the Provincial People’s Committee in 2014. The Vietnam Department of Agriculture and Rural Development (DARD) will use this reference level to account for forest-based greenhouse gas emissions. It will serve as the core of the Lam Dong Provincial REDD+ Action Plan, one of the first subnational models in the region for integrated low emissions development planning from the forestry sector.

2 Guidelines and Criteria for the Establishment of Reference Levels

Participation in a REDD+ mechanism will require countries to develop their RLs. Winrock International developed a draft methodological framework for the World Bank's Forest Carbon Partnership Facility (FCPF) to assist participant countries in enhancing their near-term capacity for producing RLs at the national or subnational scale as part of their eventual REDD+ Readiness Package. The framework enables countries to become more familiar with methods, available data, and tools so that participant countries can be better prepared in the near term to engage in analytic activities proposed in their FCPF country Readiness Preparation Plans (R-PPs). Seven key decisions are included in the framework and are shown in Figure 2.

Figure 2: Key decisions to be made by countries when developing their reference levels for REDD+ (based on a methodological framework for developing RLs produced by Winrock International for the World Bank's Forest Carbon Partnership Facility

Most of the key decisions have been addressed by Lam Dong, following a workshop held under LEAF late in 2012. The decisions made at that time represent an ideal scenario that cannot be attained in all areas at present. Table 1 summarizes the decisions made in the development of the RL described in this report. The remainder of this section provides additional background and justification about how each decision was made, and how it might differ under an ideal scenario.

Table 1: Summary of key decisions for establishing Lam Dong REDD+ reference level

Key Decision for REDD+ RL/REL	Lam Dong Decisions
1. Determine Scope of Activities	Include deforestation Include forest degradation Include forest enhancement
2. Finalize Forest Definition	Minimum tree cover: 30% Minimum height: 3 m Minimum area: 0.5 ha
3. Scale of REDD+ RL	Subnational
4. Pools/Gases	Measured Pools: Live tree aboveground biomass Pools using default values: Dead wood, litter, soil carbon, and live tree belowground biomass Gases: CO_2
5. Link REDD+ to National Forest Inventory?	Yes
6. Adjust for National Circumstances?	To be determined. This is expected to be based on specific detailed identification of events, and conservative assessment of the likely impacts
7. Location Analysis?	Possibly in the future, to be determined

2.1 Determine Scope of Activities

Many land use activities are incorporated into REDD+, and all fall into broad categories of deforestation, forest degradation, sustainable management of forests, or enhancement of carbon stocks. There are many drivers of deforestation, including conversion to agriculture, mineral extraction, infrastructure expansion, etc. but the end result is generally the same regardless of driver: a reduction in forest cover below thresholds that define a forest. There are also many drivers of forest degradation, but these are considered separately by degradation source because the impacts of different activities can degrade forests to different degrees, and the data needed to estimate emissions vary by activity. The same is true for enhancement of forest carbon stocks, which include activities such as planting new forests and enriching existing forests.

Because a stepwise approach to developing the RL is possible, for some countries it may make sense to begin with including in the RL only the REDD+ interventions that will have the most significant impacts, adding in additional activities (as well as intervention programs to address these) as time, data, and resources allow. This is appropriate in Lam Dong, where there are no data available for some drivers of degradation, and data are limited for forest enhancement.

Include Deforestation

The World Bank's draft methodological framework recommends that all countries include deforestation in their RLs. Emissions from deforestation are typically significant, remote sensing data are available at low cost for estimating historic rates of deforestation, and emission factors can be developed cost effectively with an efficient sampling design.

Include Degradation

Coarse-scale estimates of emissions from deforestation can be used as a benchmark against which to compare emissions from different forest degradation activities. This allows a decision to be made about which degradation sources are most significant over the historical reference period in terms of greenhouse gas emissions and therefore which degradation sources should be included in the RL.

Sources of forest degradation in Lam Dong include:

1. Timber harvesting
2. Fuelwood collection
3. Human-induced fires
4. Land-use change

All four of these are potentially significant sources of emissions in Lam Dong, and ideally it may be most appropriate to include all of these sources in the reference level. To do this it is necessary to determine the activity data for each driver, and these are not currently available for Lam Dong. For the RL developed here, activity data for degradation are simply identified as a change from one forest type to a lower quality of that same forest type, for example from rich coniferous forest to medium coniferous forest. This basic method allows estimation of emissions from degradation, but does not specify which activity was the cause. Ultimately, emissions should be identified by activity, and those that are insignificant need not be included.

Further detail on the sources (or drivers) of deforestation and forest degradation are provided in Section 3.1.

Include Enhancement

Agricultural land and bare land are being converted to forest land at a substantial rate. Area of forest plantation is increasing, and remote sensing data show that previously non-forested land has returned to naturally regenerated forest. The RL will therefore include enhancement from afforestation/reforestation. While activity data showed instances of change from poor to medium forest and medium to rich, these land use changes were not ground-truthed, and it is not possible to confirm that they are the result of human intervention. These changes are therefore not included as enhancement. If ground-truthing can be conducted in the future it may be appropriate to include such enhancements as an improvement to the RL.

2.2 Finalize forest definition

The Durban SBSTA text indicates that Parties should "provide information on the definition of forest used in the construction of forest RL/RELs and, if appropriate, in case there is a difference with the definition of forest used in the national greenhouse gas inventory or in reporting to other international organizations, an explanation of why and how the definition used in the construction of forest RL/RELs was chosen."

Vietnam has chosen to define forest following the definition as outlined in the Marrakech Accords (UNFCCC 2001). Under this agreement forest is defined as having a minimum area of land of 0.05 – 1 ha with tree crown cover (or equivalent stocking level) of more than 10-30% with the potential to reach a minimum height of 2-5 m at maturity in situ. Specifically, the Ministry of Agriculture and Rural Development, in the Circular of 34/2009/TT-BNNPTNT on 10/6/2009 defined forest as land that meets the following criteria:[3]

- Tree cover of minimum 10%
- Minimum height of 5 m
- Minimum area of 0.5 ha, with minimum width of 20 meters and 3 rows of trees
- Including bamboo and palm

3. Under CDM, Vietnam classifies forests as minimum tree cover of 30%, minimum height of 3 meters, and minimum area of 0.5 ha

2.3 Determine Scale

The basic decisions and steps for developing RLs are relevant at both national and subnational scales. Countries may opt to work on their historic emissions and removals data in a stepwise fashion, starting with selected states or provinces where changes in forest cover have historically been high; and/or on one activity such as deforestation.

Further decisions were made on the scale issue of RLs in 4/CP.17 as follows:

"…that subnational to national forest reference emission levels and/or forest reference levels development may be elaborated as an interim measure, while transitioning to a national forest reference emission levels and/or forest reference levels. …the interim forest reference emission levels and/or forest reference levels of a Party may cover less than its entire national territory of forest area."

Vietnam has developed a National Action Program on "Reducing greenhouse gas emissions through efforts to limit deforestation and forest degradation, sustainable management of forest resources, conserve and enhance forest carbon stocks - Period 2011-2020." According to the action plan, Vietnam will select at least 8 provinces that have the potential to reduce greenhouse gas emissions and are representative of ecological areas appropriate for REDD+ projects, in accordance with the specific conditions of Vietnam and international funding. Lam Dong has been designated as such a province to participate in a step-wise approach, beginning at the subnational level and eventually expanding to a national RL.

2.4 Determine Pools/Gases

The Durban SBSTA text indicates that Parties should give reasons for omitting a pool or a gas from the construction of forest RL/RELs and that significant pools and gases should not be excluded. Pools selected for Lam Dong are shown in Table 2, with an indication of whether they will be measured or default values. The selection of pools was based on available data. The selection of greenhouse gases for Lam Dong currently includes CO_2 only.

Table 2: Carbon pools included in the RL

Carbon Pools	Measured	Default
Aboveground Live Biomass	X	
Belowground Live Biomass		X
Dead Wood		X
Litter		X
Soil Organic Carbon		X

2.5 Link REDD+ to a National Forest Inventory?

The RL described in this report is based on data from the existing National Forest Assessment (NFA). However, the NFA is currently being revised and updated methods and data should be used when available.

2.6 Adjust for National Circumstances?

The methodological framework for developing RLs produced by Winrock offers three potential options for how to take into consideration national socio-economic circumstances as it projects its historic emissions into the future:

1. A direct correlation with historic emissions (i.e., no adjustment);
2. A statistical association of emissions with national data on socio-economic and geographic factors;
3. A third party analysis of how the implementation of new policies and programs would affect future emissions

The decision of which approach Lam Dong and Vietnam will use depends in part on whether or not historic trends are evident and justifiable, and which factors, if any, can justifiably be used to adjust the historic RL. Section 3.5 below describes the total historical emissions, which display a slight decreasing trend. The projections described in Section 4 below are based on a direct correlation with historic emissions, rather than an adjustment. If there are known future activities that are likely to result in increased emissions, those should be assessed to determine their likelihood of occurrence and their full impact.

2.7 Include a Location Analysis?

A location analysis identifies specific areas within a country where emissions or removals are projected to occur in any given year in the future. For deforestation, estimates of emissions per unit area are high; thus potential for errors in the predicted emissions estimate is also high if emissions are incorrectly predicted to occur in areas under no threat of deforestation.

Analysis of historical data will allow calculation of a rate at which deforestation has occurred, and this information can be used to extrapolate a future deforestation rate. However, the projected rate cannot be applied broadly to any selected area of forest in Lam Dong or Vietnam and used to project future emissions if forest carbon stocks vary significantly across the landscape.

A location analysis that predicts likely areas of future deforestation within a country can be performed in different ways, using different modeling techniques, and at different spatial scales. A location analysis can be useful for projecting broad areas or “zones” where emission reduction efforts could be targeted, or can be used in a more detailed manner to project specific pixels of future deforestation.

Vietnam has already identified priority provinces to develop subnational reference levels, which is essentially a location analysis. It may be appropriate to conduct a further analysis within Lam Dong, given that the carbon stocks are not uniform.

3 Estimation of Lam Dong's Historical Emissions

For estimating the historical emissions we developed a calculator tool in Microsoft Excel (enclosed as a separate file). The Excel tool has different tabs for the input of activity data and emission factors by deforestation, degradation and afforestation/reforestation. Then the calculator tool combines activity data (AD) with emission factors (EF) to produce estimates of emissions over different time frames for each activity.

A historical reference period was selected based on the availability of activity data from a forest cover change assessment conducted by the Vietnamese Forest Resources and Environment Center (FREC) of the Forest Inventory and Planning Institute (FIPI). Thus the period 1990 to 2010 was chosen, a 20 year period for which all needed data were available. This timeframe is in line with the timeframe proposed in Vietnam's REDD+ Readiness Preparation Proposal (RPP) to the Forest Carbon Partnership Facility (FCPF).[4]

Activity Data for deforestation, forest degradation and afforestation/reforestation for the historical periods (1990-1995, 1995-2000, 2000-2005, 2005-2010) were derived from pairwise comparison of the land cover maps for 1990, 1995, 2000, 2005 and 2010, created by FREC. The properties of Landsat and SPOT satellite images and the extensive forest knowledge from local partners combined with technical expertise of FREC were used to characterize the thirteen forest types in Lam Dong Province. Table 3 provides descriptions of the forest/land cover classed developed by FREC.

Emission Factors for deforestation, degradation, and afforestation/reforestation are based on carbon stock estimates (mean and uncertainty) for the live tree carbon that were estimated based on NFIMAP Cycle IV raw field data (2006-2010) collected by FIPI.[5] Carbon stocks for other carbon pools (litter, dead wood and soil) were based on IPCC defaults as described in the sections below.

In developing the historical emissions estimate, we assume that EFs were constant from year to year over the 20 year period of analysis.[6] The methodologies used to estimate emissions for Lam Dong are based on IPCC methods for specific types of land-use conversions from forests[7] and the LEAF Technical Guidance Series for the Development of a National or Subnational Forest Monitoring System for REDD+.[8]

4. Socialist Republic of Vietnam's FCPF RPP. 2011. Available at: https://www.forestcarbonpartnership.org/vietnam

5. For the report on the methodology and results on converting the NFI data to carbon stock estimates please refer to report by Dr. Nguyen Dinh Hung, Analysis of the Raw Data of Sample Plots in NFIMAP – Cycle IV (2006-2010) in Lam Dong Province, to be made through LEAF.

6. This assumption is flawed, as carbon stocks and therefore emission factors are highly unlikely to be constant for a 20 year period. The RL should be improved when possible by using earlier NFI data for pre-2000 EFs, or by limiting the historical period to post-2000.

7. 2006 IPCC Guidelines for National GHG Inventories, Volume 4: Agriculture, Forestry and Other Land Use. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html.

8. Brown S., F. Casarim F., K.M. Goslee, A.M. Grais, T.H. Pearson, S. Petrova, E. Swails, S.M. Walker. 2013. Technical Guidance Series for the Development of a National or Subnational Forest Monitoring System for REDD+. Developed by Winrock International under USAID's LEAF Program.

Table 3: Forest and land cover classes, derived by the Forest Resources and Environment Center (FREC), and their descriptions

Forest/ land cover class	Description
Evergreen - Broadleaf - Rich	Forests that remains green throughout the year with timber reserve of standing trees between 201 and 300 m^3/ ha *
Evergreen - Broadleaf - Medium	Forests that remains green throughout the year with timber reserve of standing trees between 101 and 200 m^3/ ha *
Evergreen - Broadleaf - Poor	Forests that remains green throughout the year with timber reserve of standing trees between 10 and 100 m^3/ ha *
Evergreen - Broadleaf - Regrowth	No clear definition
Deciduous	Forests with trees which shed leaves during certain season accounting for 75% or more of the total number of trees*
Bamboo forest	Forests consisting of tree species of the bamboo family *
Mixed Wood and Bamboo	Forests with timber trees accounting for more than 50% of their canopy *
Coniferous - Rich	Forests of these kind of trees accounting for more than 75% of total number of trees with timber reserve of standing trees between 201 and 300 m^3/ ha *
Coniferous - Medium	Forests of these kind of trees accounting for more than 75% of total number of trees with timber reserve of standing trees between 101 and 200 m^3/ ha *
Coniferous - Poor	Forests of these kind of trees accounting for more than 75% of total number of trees with timber reserve of standing trees between 10 and 100 m^3/ ha *
Coniferous - Regrowth	No clear definition
Mixed Broadleaf and Coniferous	Forests of each kind of these trees accounting for between 25% and 75% of the total number of trees*

Plantation	Forests formed through plantation including (1) on land without forests; (2) on land after exploitation of existing plantations; (3) forest naturally regenerated after exploitation of forest plantations *
Bared land	Land without regenerated timber trees not planned for forestry purpose *
Agricultural and other land	Land for planting annual crop, perennial crop, aquaculture and other agriculture land stipulated by the Government **
Water area	Area cover of water such as lake, reservoir, big rivers
Residential area	Land compromising residential land in rural and urban areas **

** Description based on Circular 34 (34/2009/TT-BNNPTNT)*[9]

*** Description based on Article 13 of the law on land use (No. 13-2003-QH11)*[10]

3.1 Drivers of Deforestation and Forest Degradation

The human activities that result in deforestation and forest degradation are usually referred to as “drivers”. Each activity (or driver) results in different levels of emissions, though the associated carbon stocks prior to deforestation or degradation do not necessarily differ by driver. The main drivers that cause deforestation and forest degradation in Lam Dong between 1990 and 2010 were defined in detail and their impact analyzed by FREC’s Forest Cover Change Assessment (FCCA) work.[11] Below we present a brief summary of these drivers. It is important that the post deforestation land use is known, as this establishes the post deforestation C stocks and thus emissions (calculated as the difference between pre and post stocks).

The available activity data used to develop the RL described in this report only establish a change from one land use to another, and do not necessarily identify the specific driver of change. Therefore while the drivers described below are the main causes of deforestation and degradation, they cannot at this time be used to identify post deforestation or degradation carbon stocks for specific areas of change.

9. MARD. Circular No. 34/2009/TT-BNNPTNT of June 10, 2009, on criteria for forest identification and classification
10. http://www.vietnamlaws.com/freelaws/Lw13na26Nov03Land%5BX2865%5D.pdf
11. FIPI/ FREC. 2013. Land use and forest cover change and historical GHG emissions from 1990 to 2010 in Lam Dong Province, Vietnam. Report submitted to USAID LEAF project

Drivers of Deforestation

Agriculture

During the period from 1990 to 2000, the Lam Dong province experienced a shortage of land for food production. The provincial (as well as the central) government encouraged the expansion of agriculture to meet the population's needs for food leading to increased conversion of forest land to agriculture land. The key agriculture practices during this period were slash and burn cultivation and cash crops such as coffee, cashew, pepper and some fruit trees. With the soaring coffee prices during this period many migrants from other parts of Vietnam relocated to Lam Dong and cleared forest, mostly illegally, to plant coffee and other crops.

During the 2000-2010 period, the Government authorities at all levels enforced polices to protect the remaining forest, but deforestation for conversion to agriculture land continued, although at lower rate compared to the previous period.

Plantation

Conversion of poor forest to plantation such as acacia has been seen as driver of deforestation in Lam Dong province. During 2005-2010, private companies leased poor forest land with the goal of converting to economic plantation projects, but in fact some of the poor forest land was converted to other uses instead of acacia plantations leading to permanent loss of forest cover.

Infrastructure and hydropower projects

Infrastructure projects such as construction of factories for processing forest products, road construction and other social sites led to approximately 2,000 hectares of forest loss between 2005 and 2010 in Lam dong province. The construction of hydropower plants increased after 2000 and led to clearing of forests for plant sites as well as associated roads for maintaining infrastructure.

Logging

Logging activities leading to deforestation were prominent primarily during the period from 1990 to 1995 when agriculture and forestry state enterprises were established to carry out clear-cutting logging activities in Lam Dong. Along with legal logging, conducted by the forestry state enterprises, illegal logging was conducted by local and migrated population for housing construction and sale for additional income. In the early 1990s GVN imposed a partial ban on logging, and most logging that occurs at present is illegal.

Degradation drivers

Timber extraction

The removal of trees for timber extraction (whether legal or illegal) and the incidental damage – broken branches and snapped or uprooted trees – caused by felling timber trees leads to forest degradation through the loss of carbon stocks in standing live trees. In addition, the creation of skid trails (trails created by bulldozer type skidders to extract the log out of the forest), log markets (landings or decks where logs are piled when extracted from the forest), and logging roads in concessions decrease canopy cover with resultant emissions.

All timber extraction in Lam Dong province after 2000 is based on annual plans for natural and plantation forests. According to FIPI/FREC, 2013, the annual approved extraction quota for 2000-2005 from natural forest was 30,000 m^3yr^{-1} and 13,300m^3yr^{-1} from plantation forest. These quotas for 2005-2010 were 20,000 m^3yr^{-1} and 16,000m^3yr^{-1} for natural and plantation forest, respectively. We assume that the activation of these quotas partially accounted for the forest degradation observed in the imagery and reported as AD.

Non-timber forest products extraction

Extraction of non-timber forest products (NTFP) can lead to the decrease of initial forest carbon stocks and associated emissions. The main NTFP activity in Lam Dong province is bamboo extraction, with annual extraction of 14,910 t yr^{-1} for 2000-2005 and 4,716 t yr^{-1} for 2005-2010. As with the timber extraction quotas, we assume that these extractions are captured in the AD for degradation of bamboo forests.

3.2 Forest Statification

Ecological factors such as soil, climate, and species composition affect the amount and rate at which forests sequester carbon, but anthropogenic factors such as human disturbance, management practices and historical land use affect the carbon stocks in the forest as well. Therefore forest carbon stratification aims to divide the forests into distinct relatively homogeneous groups (strata) with respect to carbon stocks accounting for ecological and anthropogenic factors. Appropriate stratification improves the efficiency of sampling across the population of interest, and reduces uncertainties in the EFs.

Given the mosaic pattern of forests in Lam Dong, only the ecological factors used to define the forest types according Circular 34[12] were used for forest stratification. Details on how the forest types/strata were delineated can be found in FREC, 2013.[13] Table 3 above provides descriptions of the forest/land cover classed developed by FREC. Availability of National Forest Inventory (NFI) data, cycle 4, was combined with the forest cover types to estimate the average carbon stock in live trees per forest stratum.

12. MARD. Circular No. 34/2009/TT-BNNPTNT of June 10, 2009, on criteria for forest identification and classification
13. FREC. 2013. Establishment of forest status map during the period 1990-2010 for Lam Dong Province. Report submitted to LEAF Viet Nam.

3.3 Emissions from Deforestation

3.3.1 Activity Data

Activity data for deforestation were derived from pairwise comparison between two land cover maps (basically subtracting the two maps from each other), developed by FREC, to define the net area change from each forest type to agriculture, bare land, and residential area for each time period (Table 4). Based on the methodology used to obtain area change data, the changes in area are net changes rather than gross area changes. By only tracking net change the estimated value of deforestation could be higher.[14] Bamboo forests experienced the most deforestation, accounting for 22.5% of all deforestation, followed by poor evergreen-broadleaf forests at 14.8%, evergreen-broadleaf regrowth at 13.8%, and mixed broadleaf and coniferous at 13.2%. Most deforestation resulted in agriculture, accounting for 72.3% of all post-deforestation land uses. Bare land accounted for 27.5% of all deforestation and residential land accounted for 0.2%.

Table 4: Activity data for deforestation (ha) per 5 year time period. These values are the net change in forest area not gross

Forest carbon Stratum/ Forest type	Post deforestation Stratum	Activity Data (ha)				
		1990-1995	1995-2000	2000-2005	2005-2010	1990-2010
Evergreen - Broadleaf - Rich	Agriculture land	60	150	63	222	495
Evergreen - Broadleaf - Medium	Agriculture land	836	535	326	1,196	2,893
Evergreen - Broadleaf - Poor	Agriculture land	7,392	5,001	3,422	7,614	23,429
Evergreen - Broadleaf - Regrowth	Agriculture land	5,257	6,351	5,189	4,986	21,783
Deciduous	Agriculture land	1,523	1,316	1,544	1,205	5,588
Bamboo	Agriculture land	11,472	7,603	6,268	10,162	35,505
Mixed Broadleaf and Coniferous	Agriculture land	1,620	2,101	910	997	5,628
Coniferous - Rich	Agriculture land	249	245	663	730	1,887
Coniferous - Medium	Agriculture land	1,001	1,125	1,785	2,666	6,577
Coniferous - Poor	Agriculture land	6,665	3,506	4,746	4,040	18,957

14. Brown, S. and D Zarin. 2013. What does zero deforestation mean? Science 342:805-807,

Coniferous - Regrowth	Agriculture land	330	176	126	455	1,087
Mixed Wood and Bamboo	Agriculture land	6,936	2,124	2,892	7,467	19,419
Plantation	Agriculture land	1,710	2,725	2,712	8,105	15,252
Evergreen - Broadleaf - Rich	Bare land	93	89	40	39	261
Evergreen - Broadleaf - Medium	Bare land	852	406	373	250	1,881
Evergreen - Broadleaf - Regrowth	Bare land	2,452	3,142	2,192	607	8,393
Deciduous	Bare land	735	316	640	853	2,544
Bamboo	Bare land	6,802	2,675	3,542	706	13,725
Mixed Broadleaf and Coniferous	Bare land	2,008	359	478	203	3,048
Coniferous - Rich	Bare land	176	185	596	308	1,265
Coniferous - Medium	Bare land	397	364	1,778	833	3,372
Coniferous - Poor	Bare land	780	1,243	2,056	755	4,834
Coniferous - Regrowth	Bare land	230	299	131	80	740
Mixed Wood and Bamboo	Bare land	3,677	1,862	3,141	901	9,581
Plantation	Bare land	373	380	512	601	1,866
All forest types	Residential area	99	78	176	135	488

3.3.2 Emission Factors

An emission factor is an estimate of the change in carbon stocks in all carbon pools impacted by the land use change. The emissions resulting from deforestation in Lam Dong are expressed as emissions per unit area of change, i.e., tonnes of carbon dioxide per hectare (t CO_2e ha-1).

The emission factors (EFs) from deforestation were developed for each relevant stratum by driver or cause of deforestation (i.e. conversion to cropland, conversion to settlement, and conversion to bareland), using the stock-
difference method.[15]

Under the stock-difference method, C emissions are estimated as the difference between carbon stocks before deforestation and the carbon stocks following deforestation. For Lam Dong we used equation 1 below.

$$EF_{def(t,x,y)} = (C_{bio.pre(x)} - C_{bio.post(t,y)} + \Delta SOC_{(t)}) * 44/12 \quad \text{Eq.1}$$

Where:[16]

$EF_{def(t,x,y)}$	=	Emission factor for year t for deforestation for stratum x and river y, t CO_2e ha^{-1}
$C_{bio.pre(x)}$	=	Carbon stock in biomass in stratum x, prior to deforestation, t C ha^{-1}
$C_{bio.post(t,y)}$	=	Carbon stock in biomass in year t post-deforestation, for driver y, t C ha^{-1}
$\Delta SOC_{(t)}$	=	Change in soil carbon stocks in year t following deforestation, t C ha^{-1}
44/12	=	Conversion factor from carbon to CO_2

Emissions that occur from post-deforestation land uses are not accounted for in the Lam Dong RL. Such emissions are outside of the accounting boundary and are assumed to be accounted for in the appropriate sector.

Pre-deforestation biomass carbon stocks estimates for each stratum are the sum of carbon stocks from all included biomass pools (Eq. 2), excluding soil carbon pool, which is reported separately.

$$C_{bio.pre(x)} = (C_{agb(x)}+C_{bgb(x)}+C_{dw(x)}+C_{lit(x)}+C_{veg(x)}) \quad \text{Eq.2}$$

15. 2006 AFOLU Guidelines, Chapter 2 Generic Methodologies Applicable to Multiple Land-Use Categories, http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_02_Ch2_Generic.pdf

16. Neither carbon stored in harvested wood products nor emissions from fire were included in the emission factor, due to a lack of data. These should be assessed and incorporated into future versions of the RL if possible.

Where:

$C_{bio.pre(x)}$	=	Carbon stock in biomass in stratum x, prior to deforestation, t C ha^{-1}
$C_{agb(x)}$	=	Carbon stock in aboveground live tree biomass in stratum x, t C ha^{-1}
$C_{bgb(x)}$	=	Carbon stock in belowground live tree biomass in stratum x, t C ha^{-1}
$C_{dw(x)}$	=	Carbon stock in deadwood pools in stratum x, t C ha^{-1} (includes both standing and lying deadwood)
$C_{lit(x)}$	=	Carbon stock in litter in stratum x, t C ha^{-1}
$C_{veg(x)}$	=	Carbon stock in non-tree vegetation in stratum x, t C ha^{-1} (includes shrubs, sapling, and herbaceous understory)

For Lam Dong, aboveground live tree carbon was estimated based on NFIMAP Cycle IV raw field data (2006-2010) collected by FIPI and belowground carbon stocks were estimated using a ratio developed by Mokany et al (2006).[17] The combined above and belowground live tree carbon stocks are summarized in table 5 below.[18] Carbon stocks for litter and dead wood were developed using IPCC default factors, as described below. There are no defaults for non-tree vegetation, so this carbon pool was assumed to be zero.

17. Mokany, K., Raison, J.R. and Prokushkin, A.S. (2006). Critical analysis of root:shoot ratios in terrestrial biomes. Global Change Biology 12:84-96.

18. A description of the complete analysis of FIPI data is available in a report by Dr. Nguyen Dinh Hung, Analysis of the Raw Data of Sample Plots in NFIMAP – Cycle IV (2006-2010) in Lam Dong Province

Table 5: Live tree carbon stock means (above and below ground) in t C.ha^{-1} and uncertainty (95% confidence interval as a percent of the mean) based on NFIMAP Cycle IV (2006-2010) raw field data collected by FIPI

Forest Carbon Stratum/ Forest type	Live Tree Carbon Stock (t C.ha^{-1})	Uncertainty (%)
Evergreen - Broadleaf forest - Rich	123.53	11.7
Evergreen - Broadleaf forest - Medium	97.28	13.7
Evergreen - Broadleaf forest - Poor	56.28	29.3
Evergreen - Broadleaf forest - Regrowth	46.28	43.3
Deciduous forest	40.42	148.4
Bamboo forest	2.12	213.0
Mixed Broadleaf and Coniferous forest	72.07	79.5
Coniferous forest - Rich	80.64	20.7
Coniferous forest - Medium	67.67	13.5
Coniferous forest - Poor	48.02	41.7
Coniferous forest – Regrowth*	40.28	43.3
Mixed Wood and Bamboo forest	40.10	22.0
Plantation forest	22.86	96.1

** No measured carbon stocks are available for the coniferous regrowth strata, but activity data do exist. Therefore, we applied the percent difference between evergreen broadleaf poor and evergreen broadleaf regrowth (approximately 18%) to estimate the difference between coniferous poor and coniferous regrowth as a proxy for the coniferous regrowth carbon stock. The error given is that for evergreen broadleaf regrowth.*

For dead wood and litter the default factors are estimated based on equations 3 and 4, respectively:

$$C_{DW,I,t} = C_{TREE,i,t} * DF_{DW} \qquad \text{Eq.3}$$

Where:

$C_{DW,I,t}$ = Carbon stock in dead wood in stratum i at a given point of time in year t; t CO_2e

$C_{TREE,i,t}$ = Carbon stock in trees biomass in stratum i at a point of time in year t; t CO_2e

DF_{DW} = Conservative default factor expressing carbon stock

		in dead wood as a percentage of carbon stock in tree biomass; this equals 6%, derived from CDM A/R Methodological tool Version 03.0 [19]
i	=	1, 2, 3, … biomass estimation strata within the study area's boundary
t	=	1, 2, 3, … years elapsed since the start of the activity

$$C_{LI,I,t} = C_{TREE,i,t} * DF_{LI} \qquad \text{Eq.4}$$

Where:

$C_{LI,I,t}$	=	Carbon stock in litter in stratum i at a given point of time in year t; t CO_2e
$C_{TREE,i,t}$	=	Carbon stock in trees biomass in stratum i at a point of time in year t; t CO_2e
DF_{LI}	=	Conservative default factor expressing carbon stock in litter as a percentage of carbon stock in tree biomass; this equals 1%, derived from CDM A/R Methodological tool Version 03.0[20]
i	=	1, 2, 3, … biomass estimation strata within the study area's boundary
t	=	1, 2, 3, … years elapsed since the start of the activity

Carbon stock data on post deforestation land was not measured and estimated for this report; we assume that all post deforestation carbon stocks for live trees, litter and dead wood to be zero. In the case of woody crops, the actual carbon stocks will not be zero; future analyses should identify post-deforestation land uses with more specificity and establish appropriate carbon stocks for each land use.

Changes in soil carbon stocks are related to the post deforestation land use. We estimate the changes by using the IPCC 2006 guidelines. The change in soil carbon stocks is assumed to occur over a 20 year time period, at which time a new steady state for a given land use is reached. However, as with the change in C stocks of vegetation, it is assumed that the total change in soil C occurs at the time of the event – that is committed emissions.

This IPCC method estimates the changes in soil carbon stocks based on the use of soil factors that account for how the soil is tilled, the method of management, and inputs in the post deforestation land use, as demonstrated in equation 5.

19. *A/R Methodological tool: Estimation of carbon stocks and change in carbon stocks in dead wood and litter in A/R CDM project activities Version 03.0 http://cdm.unfccc.int/methodologies/ARmethodologies/tools/ar-am-tool-12-v3.0.pdf. The default IPCC factors for the litter and dead wood carbon pools used to estimate EF/RF based on the CDM A/R Methodological Tool take into consideration the rainfall in Lam Dong exceeds 1600 mm.yr-1 on average and the vast majority of the forest in the province is found at an elevation under 2000m.*

20. Ibid

$$\Delta SOC = C_{soil} - (C_{soil} * F_{LU} * F_{MG} * FI) \quad \text{Eq.5}$$

Where:

ΔSOC = Soil carbon emitted over 20 years, t C ha^{-1}

C_{soil} = Carbon stock in soil organic matter pool (also called the reference stock) to 30 cm depth; t C ha^{-1}

F_{LU} = Stock change factor for land-use systems for a particular land-use, dimensionless (IPCC AFOLU GL)

F_{MG} = Stock change factor for management regime, dimensionless (IPCC AFOLU GL)

F_{I} = Stock change factor for input of organic matter, dimensionless (IPCC AFOLU GL)

Soil carbon stocks for this study are derived from the Harmonized World Soil Database (HWSD). The soil carbon stock per each forest type represents the area weighted average value. Soil carbon stocks per forest type are summarized in Table 6 below.

Table 6: Soil carbon stocks in t C.ha^{-1} estimated based on the Harmonized World Soil Database

Forest Carbon Stratum/ Forest type	Soil Carbon Stock (t C.ha^{-1})
Evergreen - Broadleaf forest - Rich	43
Evergreen - Broadleaf forest - Medium	44
Evergreen - Broadleaf forest - Poor	43
Evergreen - Broadleaf forest - Regrowth	42
Deciduous forest	41
Bamboo forest	45
Mixed Broadleaf and Coniferous forest	43
Coniferous forest – Rich	40
Coniferous forest – Medium	39
Coniferous forest – Poor	40
Mixed Wood and Bamboo forest	43
Plantation forest	43

The post deforestation land uses identified for Lam Dong in this study are agriculture land, settlements, and bare land. The appropriate stock change factors for each is summarized in Table 7 below.

Table 7: Values of FLU, FMG and FI for the identified deforestation activities in Lam Dong[21]

Post deforestation land use		F_{LU}	F_{MG}	F_I
Conversion to agriculture (assumes continuous cultivation for 20 yrs, full annual tillage, and <30% of ground covered with residues, and medium inputs typical of annual crops)		0.48	1.00	1.00
Bareland (assumes temporary set aside of annual cropland or other idle cropland that has been revegetated with perennial grasses, full tillage, and low inputs)		0.82	1.00	0.92
Settlements (assumes majority of settlement area is paved over)		0.8	1.00	1.00

Using equation 1, based on the carbon stocks described above we can estimate the EF for deforestation as summarized in Table 8 below.

Table 8: Emission factors and uncertainty (95% confidence interval as a percent of the mean) for deforestation in Lam Dong, Vietnam in t CO_2e.ha^{-1}

Forest Carbon Stratum/ Forest type	Post deforestation Stratum	EF (t CO2e ha-1)	Uncertainty (%)*
Evergreen - Broadleaf - Rich	Agriculture land	567	11.7
Evergreen – Broadleaf - Medium	Agriculture land	466	13.7
Evergreen - Broadleaf - Poor	Agriculture land	303	29.3
Evergreen - Broadleaf - Regrowth	Agriculture land	262	43.3
Deciduous	Agriculture land	237	148.4
Bamboo	Agriculture land	94	213.0
Mixed Broadleaf and Coniferous	Agriculture land	365	79.5
Coniferous - Rich	Agriculture land	393	20.7
Coniferous - Medium	Agriculture land	340	13.5
Coniferous - Poor	Agriculture land	265	41.7
Coniferous – Regrowth**	Agriculture land	243	43.3
Mixed Wood and Bamboo	Agriculture land	239	22.0

21. From Table 5.5 in IPCC 2006 GL, Vol. 4, Ch. 5 for agriculture and bare land and Ch. 8 for settlements.

Plantation	Agriculture land	172	96.1
Evergreen - Broadleaf - Rich	Bare land	523	11.7
Evergreen – Broadleaf - Medium	Bare land	421	13.7
Evergreen - Broadleaf - Poor	Bare land	260	29.3
Evergreen - Broadleaf - Regrowth	Bare land	219	43.3
Deciduous	Bare land	195	148.4
Bamboo	Bare land	49	213.0
Mixed Broadleaf and Coniferous	Bare land	321	79.5
Coniferous - Rich	Bare land	346	20.7
Coniferous - Medium	Bare land	294	13.5
Coniferous - Poor	Bare land	218	41.7
Coniferous – Regrowth*	Bare land	196	43.3
Mixed Wood and Bamboo	Bare land	239	22.0
Plantation	Bare land	172	96.1
Evergreen - Broadleaf - Rich	Residential area	516	11.7
Evergreen – Broadleaf - Medium	Residential area	414	13.7
Evergreen - Broadleaf - Poor	Residential area	252	29.3
Evergreen - Broadleaf - Regrowth	Residential area	212	43.3
Deciduous	Residential area	189	148.4
Bamboo	Residential area	41	213.0
Mixed Broadleaf and Coniferous	Residential area	314	79.5
Coniferous - Rich	Residential area	346	20.7
Coniferous - Medium	Residential area	294	13.5
Coniferous - Poor	Residential area	218	41.7
Coniferous – Regrowth*	Residential area	189	43.3
Mixed Wood and Bamboo	Residential area	189	22.0
Plantation	Residential area	121	96.1

**Uncertainty is based only on uncertainty of pre-deforestation live tree carbon stocks*

*** No measured carbon stocks are available for the coniferous regrowth strata, but activity data do exist. Therefore, we applied the percent difference between evergreen broadleaf poor and evergreen broadleaf regrowth (approximately 18%) to estimate the difference between coniferous poor and coniferous regrowth as a proxy for the coniferous regrowth carbon stock.*

3.3.3 Emissions from Deforestation

To estimate the historical emissions due to deforestation we multiply the AD (Table 4) by the EF (Table 8). The total emissions for the period between 1990 and 2010 were estimated at 32.6 Million t CO_2e, with annual average of 1.6 Million t CO_2e (Table 9). The largest percentage (15%) of total emissions is a result of transition from poor evergreen broadleaf forest to agriculture land while many transitions accounted for less than a percent of deforestation including all transitions to settlements.

Table 9: Total emissions and uncertainty from deforestation in Lam Dong, Vietnam in thousand t CO_2e from 1990-2010, and the percent of total emissions each transition represents

Forest Carbon Stratum/ Forest type	Post deforestation Stratum	Emissions (1000 t CO_2e)	Percent of Total (%)	Uncertainty (%)
Evergreen - Broadleaf - Rich	Agriculture land	280	<1	11
Evergreen – Broadleaf - Medium	Agriculture land	1,347	3	12
Evergreen - Broadleaf - Poor	Agriculture land	7,094	14	20
Evergreen - Broadleaf - Regrowth	Agriculture land	5,700	12	26
Deciduous	Agriculture land	1,323	3	72
Bamboo	Agriculture land	3,342	7	104
Mixed Broadleaf and Coniferous	Agriculture land	2,053	4	25
Coniferous - Rich	Agriculture land	741	2	14
Coniferous - Medium	Agriculture land	2,235	5	13
Coniferous - Poor	Agriculture land	5,017	10	25
Coniferous – Regrowth*	Agriculture land	264	<1	18
Mixed Wood and Bamboo	Agriculture land	4,647	9	33
Plantation	Agriculture land	2,618	5	54
Evergreen - Broadleaf - Rich	Bare land	137	<1	11
Evergreen – Broadleaf - Medium	Bare land	792	2	15
Evergreen - Broadleaf - Poor	Bare land	2,308	5	24
Evergreen - Broadleaf - Regrowth	Bare land	1,841	4	29
Deciduous	Bare land	497	1	75
Bamboo	Bare land	670	1	121
Mixed Broadleaf and Coniferous	Bare land	980	2	32
Coniferous - Rich	Bare land	437	<1	15
Coniferous - Medium	Bare land	992	2	16
Coniferous - Poor	Bare land	1,053	2	26
Coniferous – Regrowth*	Bare land	145	<1	20
Mixed Wood and Bamboo	Bare land	2,293	5	34
Plantation	Bare land	320	<1	47
All forests	Residential area	86	<1	16
	Total Emissions	**49,213**		

** No measured carbon stocks are available for the coniferous regrowth strata, but activity data do exist. Therefore, we applied the percent difference between evergreen broadleaf poor and evergreen broadleaf regrowth (approximately 18%) to estimate the difference between coniferous poor and coniferous regrowth as a proxy for the coniferous regrowth carbon stock.*

3.4 Emissions from Forest Degradation

3.4.1 Activity Data

Activity data for forest degradation were derived from pairwise comparison between two land cover maps, derived by FREC, to define the area change based on the quality for evergreen broadleaf and coniferous forest for each time period (Table 10). As with deforestation, the change in area is net rather than gross, and as with deforestation this could give erroneous estimates of the area change. Degradation is defined here as the decrease of forest quality from rich to medium, medium to poor, and poor to regrowth. This latter situation is called degradation because the regrowth forest had lower carbon stocks than the poor forest and is unlikely to recover to a more vigorous condition.

Table 10: Activity Data for forest degradation in ha per 5 year time period. Values are estimates of net change not gross change

Forest carbon stratum/ forest type	Post degradation stratum	Forest degradation AD (ha)			
		1990-1995	1995-2000	2000-2005	2005-2010
Evergreen - Broadleaf - Rich	Evergreen - Broadleaf - Medium	15,005	15,318	5,746	8,532
Evergreen - Broadleaf - Rich	Evergreen - Broadleaf - Poor	2,039	1,810	1,662	2,279
Evergreen - Broadleaf - Rich	Evergreen - Broadleaf - Regrowth	378	698	203	259
Evergreen - Broadleaf - Medium	Evergreen - Broadleaf - Poor	14,360	16,096	10,406	9,237
Evergreen - Broadleaf - Medium	Evergreen - Broadleaf - Regrowth	3,142	2,031	1,835	1,546
Evergreen - Broadleaf - Poor	Evergreen - Broadleaf - Regrowth	5,801	7,471	5,668	5,696
Coniferous - Rich	Coniferous - Medium	4,419	9,352	7,219	2,712
Coniferous - Rich	Coniferous - Poor	1,379	2,016	2,462	1,333
Coniferous - Rich	Coniferous - Regrowth	168	8	4	11
Coniferous - Medium	Coniferous - Poor	1,352	4,906	5,330	7,163
Coniferous - Medium	Coniferous - Regrowth	149	65	52	13
Coniferous - Poor	Coniferous - Regrowth	763	928	297	96

3.4.2 Emission Factors

Emission factors for forest degradation were estimated by calculating the difference in carbon stock in the live tree carbon stocks between different transitions within the evergreen broadleaf and within the coniferous forest types (Table 11). Only carbon stocks for live trees were taken into account here as we assume other pools remain constant.

Table 11: Emission factors and uncertainty (95% confidence interval as a percent of the mean) for degradation in Lam Dong, Vietnam in t CO_2e.ha^{-1}

Forest Carbon Stratum/ Forest type	Post Degradation Stratum	EF (t CO_2e ha^{-1})	Uncertainty (%)
Evergreen - Broadleaf - Rich	Evergreen - Broadleaf - Medium	96	8.9
Evergreen - Broadleaf - Rich	Evergreen - Broadleaf - Poor	247	12.2
Evergreen - Broadleaf - Rich	Evergreen - Broadleaf - Regrowth	283	14.5
Evergreen - Broadleaf - Medium	Evergreen - Broadleaf - Poor	150	13.8
Evergreen - Broadleaf - Medium	Evergreen - Broadleaf - Regrowth	187	16.7
Evergreen – Broadleaf - Poor	Evergreen - Broadleaf - Regrowth	37	28.7
Coniferous - Rich	Coniferous - Medium	48	12.8
Coniferous - Rich	Coniferous - Poor	120	20.3
Coniferous – Rich	Coniferous – Regrowth*	151	28.7
Coniferous - Medium	Coniferous - Poor	72	19.0
Coniferous – Medium	Coniferous – Regrowth*	103	28.7
Coniferous – Poor	Coniferous Regrowth*	31	28.7

** No measured carbon stocks are available for the coniferous regrowth strata, but activity data do exist. Therefore, we applied the percent difference between evergreen broadleaf poor and evergreen broadleaf regrowth (approximately 18%) to estimate the difference between coniferous poor and coniferous regrowth as a proxy for the coniferous regrowth carbon stock. The uncertainty is from evergreen broadleaf regrowth.*

3.4.3 Emissions from Degradation

To estimate the historical emissions due to forest degradation we multiply the AD (Table 10) by the EF (Table 11). The total emissions for the period between 1990 and 2010 were estimated at 20.3 million t CO_2e, with annual average of 1 million t CO_2e (Table 12). The largest percentage (37%) of total emissions is a result of transition from medium to poor evergreen broadleaf forest. Emissions from rich to regrowth and medium to regrowth transitions account for about 0.1% each of the total emissions.

Table 12: Total emissions and uncertainty from forest degradation in Lam Dong, Vietnam in thousand t CO_2e from 1990-2010, and the percent of total emissions each transition represents

Forest Carbon Stratum/ Forest type	Post Degradation Stratum	Emissions (1000 t CO_2e)	Percent of total (%)	Uncertainty (%)
Evergreen - Broadleaf - Rich	Evergreen - Broadleaf - Medium	4,293	21	11
Evergreen - Broadleaf - Rich	Evergreen - Broadleaf - Poor	1,921	10	13
Evergreen - Broadleaf - Rich	Evergreen - Broadleaf - Regrowth	436	2	23
Evergreen - Broadleaf - Medium	Evergreen - Broadleaf - Poor	7,532	37	15
Evergreen - Broadleaf - Medium	Evergreen - Broadleaf - Regrowth	1,600	7.9	19
Evergreen – Broadleaf - Poor	Evergreen - Broadleaf - Regrowth	903	5	24
Coniferous - Rich	Coniferous - Medium	1,128	6	14
Coniferous - Rich	Coniferous - Poor	860	4	17
Coniferous – Rich	Coniferous – Regrowth*	29	0.1	43
Coniferous - Medium	Coniferous - Poor	1,500	7	17
Coniferous – Medium	Coniferous – Regrowth*	29	0.1	30
Coniferous – Poor	Coniferous Regrowth*	65	0.3	30
	Total Emissions	20,290	100	

3.5 Removals from Afforestation/Reforestation

3.5.1 Activity Data

Activity data for A/R were derived from pairwise comparison between two land cover maps, derived by FREC, to define the area of agriculture and bare land converted to forest classes (Table13) The areas given are for net change not gross.

Table 13: Activity data for A/R (ha) for the 5-year period. Values are for net change in area rather than gross

Land cover class	Post forest type	Activity Data (ha)			
		1990-1995	1995-2000	2000-2005	2005-2010
Agriculture land	Evergreen - Broadleaf - Regrowth	367	1,171	398	146
Agriculture land	Bamboo	2,238	2,528	1,120	1,095
Agriculture land	Coniferous - Regrowth	-	-	-	1
Bare land	Mixed Wood and Bamboo	1,822	2,886	2,080	2,604
Agriculture land	Plantation	1,102	3,724	6,573	9,494
Bare land	Evergreen - Broadleaf - Regrowth	2,256	3,303	1,749	1,675
Bare land	Bamboo	3,691	5,368	2,746	1,963
Bare land	Mixed Wood and Bamboo	1,822	2,886	2,080	2,604
Bare land	Coniferous - Regrowth	94	476	47	79
Bare land	Plantation	1,540	3,284	8,606	4,491

3.5.2 Removal Factors

Removal factor for afforestation/reforestation were estimated by calculating the difference in live tree carbon stocks between transitions that we assumed were realistic (Table 14). Only carbon stocks for live trees were taken into account here as we assume other pools remain constant. For this section, it is assumed that only land change from agriculture land and bare land to the bamboo, mixed wood and bamboo, regrowth and plantation forest classes underwent an afforestation/reforestation transition. We assumed that other AR transitions (e.g. agriculture land to evergreen broadleaf rich forest) could not occur in the given timeframes and are attributed to remote sensing uncertainty.

Table 14: Removal factors and uncertainty (95% confidence interval as a percent of the mean) for afforestation/reforestation (AR) in Lam Dong, Vietnam in t CO_2e.ha^{-1}

Forest Carbon Stratum/ Forest type	Post AR	EF (t CO_2e ha^{-1})	Uncertainty (%)
Agriculture land	Evergreen - broadleaf - regrowth	-182	43
Agriculture land	Bamboo forest	-8	213
Agriculture land	Mixed wood and bamboo forest	-283	80
Agriculture land	Coniferous forest - regrowth	-155	unknown
Agriculture land	Plantation Forest	-90	96
Bare land	Evergreen - broadleaf - regrowth	-182	43
Bare land	Bamboo forest	-8	213
Bare land	Mixed wood and bamboo forest	-283	80
Bare land	Coniferous forest - regrowth	-155	unknown
Bareland	Plantation forest	-90	96

3.5.3 Emissions removed from Afforestation/ Reforestation

To estimate the historical emission removals due to AR we multiply the AD (Table 13) by the removal factor (Table 14). The total removals for the period between 1990 and 2010 were estimated at 8.6 million t CO_2e, with annual average of 430 thousand t CO_2e (Table 15). The largest percentage (29%) of total removals is a result of transition from bare land to mixed wood and bamboo forest, while removals from agriculture land to bamboo forest represent less than 1% of total removals between 1990 and 2010.

Table 15: Total removals and uncertainty for afforestation/reforestation (AR) in Lam Dong, Vietnam in thousand t CO_2e from 1990-2010 and the percent of total removals each transition represents

Forest Carbon Stratum/ Forest type	Post AR	Removals (1000 t CO_2e)	Percent of total (%)	Uncertainty (%)
Agriculture land	Evergreen - broadleaf - regrowth	378	4	37
Agriculture land	Bamboo forest	58	1	114
Agriculture land	Mixed wood and bamboo forest	591	7	42
Agriculture land	Coniferous forest - regrowth	0.2	0	25
Agriculture land	Plantation forest	1,874	21	57
Bare land	Evergreen - broadleaf - regrowth	1,631	18	31
Bare land	Bamboo forest	115	1	115
Bare land	Mixed wood and bamboo forest	2,656	29	43
Bare land	Coniferous forest - regrowth	108	1	31
Bare land	Plantation forest	1,607	18	57
	Total Removals	**9,018**	**100**	

3.6 Total Historical Emissions

Emissions from deforestation from 1990-2010 were 49.2 million t CO_2e, with an annual average of 2.46 million t CO_2e (Table 16 and Figure 3).

Emissions from degradation over the historical period were 20.3 million t CO_2e, with an annual average of 1.01 million t CO_2e (Table 16 and Figure 3).

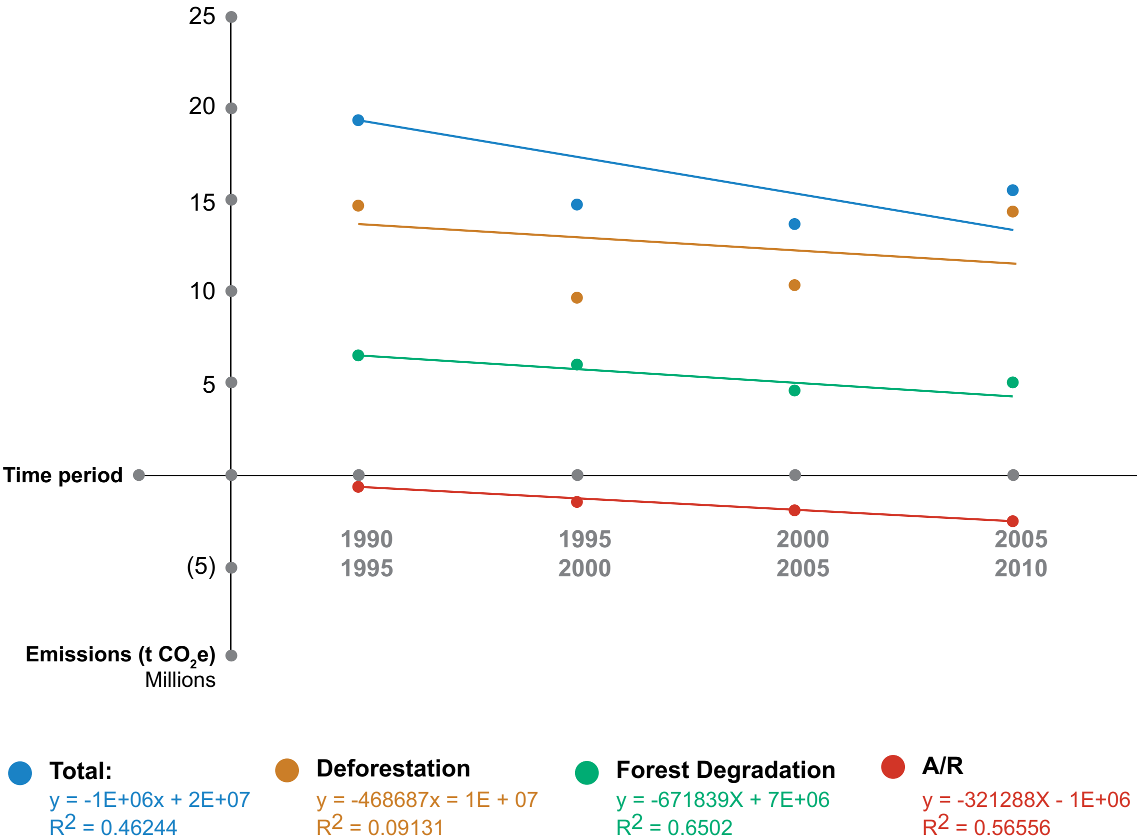
Removals from A/R over the historical period were 9.0 million t CO_2e, with an annual average of 450 thousand t CO_2e (Table 16 and Figure 3).

Total combined net emissions for the province from 1990-2010 were 60.5 million tons CO_2e, with an annual average of 3.02 million t CO_2e. Emissions were highest in the period 1990-1995, then decreased in the next two 5-year periods and rose slightly in the period 2005-2010 (Table 16). Figure 3 shows the trend and the regression equation for annual emissions across the historical period. However, based on the R-squared values, there is not a strong fit for any of the activities, indicating that there is not a real trend. This is particularly true for deforestation, which has a very poor fit.

Table 16: Total historical emissions across all activities and historical periods

REDD+ Activity	Total Emissions and Removals (CO2e) Historical Period				
	1990-1995	1995-2000	2000-2005	2005-2010	1990-2010
Deforestation	14,767,443	10,503,907	10,853,386	13,088,661	49,213,398
Forest Degradation	5,694,716	6,268,710	4,173,124	4,153,780	20,290,329
Total Degradation and Deforestation Emissions	20,462,159	16,772,617	15,026,510	17,242,441	69,503,727
Annual Degradation and Deforestation Emissions	4,092,432	3,354,523	3,005,302	3,448,488	3,475,186
A/R	(1,427,722)	(2,560,921)	(2,514,839)	(2,514,042)	(9,017,523)
Net Emissions	19,034,437	14,211,696	12,511,671	14,728,400	60,486,204
Annual Net Emissions	3,806,887	2,842,339	2,502,334	2,945,680	3,024,310

Figure 3: Lam Dong historical emissions and removals by activity class (based on total emission and removal per time period)



3.7 Uncertainty

To estimate the uncertainty for each activity (deforestation, degradation, and enhancement through A/R) we use the simple error propagation method given in Chapter 5 of the IPCC GPG (2003).[22]

The error propagation equation for the product of uncertainties, as is the case when combining EF and AD, is:

$$U_{total} = \sqrt{(U_1^2 + U_2^2 + U_n^2)} \qquad \text{Eq.6}$$

Where:

U_{total} = percentage uncertainty in the product of the quantities (half the 95% confidence interval divided by the total and expressed as a percentage);

U_i = percentage uncertainties associated with each of the quantities, i = 1, …, n

The error propagation equation for the sum of uncertainties, such as the overall uncertainty from summing deforestation, degradation, and A/R, the equation is:

$$UE = \{\sqrt{((U_1 * E_1)2 + (U_2 * E_2)^2 + \ldots\ldots(U_n * E_n)2)}\}/(E_1 + E_2 + \ldots.E_n) \qquad \text{Eq.7}$$

Where:

U_E = percentage uncertainty of the sum

U_n = percentage uncertainty associated with each source i

E_n = emission estimate for source i

3.7.1 Uncertainty in AD

The accuracy for each of the land cover classes in all land cover maps was assessed and reported by FREC.[23] FREC used the NFI data for each of the cycles coinciding with the years of the land cover maps to assess the overall and per land cover class accuracy. To estimate the accuracy for each land cover class we used the error of commission[24] (uncertainty) per class to estimate the uncertainty of AD per land cover transition.

22. This is a Tier 1 method, and future uncertainty calculations would be improved with the use of Monte Carlo simulation.

23. FIPI/FREC. 2013. Accuracy assessment for forest and land use maps in the period of 1990-2010 for Lam Dong province. Report submitted to USAID LEAF , Vietnam

24. Error of commission (%) = 100% - Accuracy level (%), with accuracy levels as reported by FIPI.

3.7.2 Uncertainty in Emissions from Deforestation

The uncertainty on the biomass EFs for deforestation were calculated separately for each land use change, and are provided in table 8. These uncertainties are based only on the uncertainty in the live tree carbon stocks, as the contribution of litter, deadwood, and soil are small compared to live tree and therefore we propose that their contribution to total uncertainty is negligible and will be assumed to be zero.

Substituting the uncertainties for AD and EF for each land use class into Eq. 6 and summing across all land use classes using Eq. 7 results in a total estimated uncertainty on the total deforestation emissions of ±10%[25] of the total for 1990-2010.

3.7.3 Uncertainty in Emissions from Forest Degradation

The uncertainty on the biomass EFs for degradation were calculated separately for each land use change, and are provided in table 11. These uncertainties are based only on the uncertainty in the live tree carbon stocks, the only carbon pool included in the degradation EF.

Substituting the uncertainties for AD and EF for each land use class into Eq. 6 and summing across all land use classes using Eq. 7 results in a total estimated uncertainty on the degradation emissions of ±7% of the total for 1990-2010.

3.7.4 Uncertainty in Emissions Removals from Afforestation/Reforestation

The uncertainty on the biomass EFs for A/R were calculated separately for each land use change, and are provided in table 14. These uncertainties are based only on the uncertainty in the live tree carbon stocks, as the contribution of litter and deadwood are small compared to live tree and therefore we propose that their contribution to total uncertainty is negligible and will be assumed to be zero.

Substituting the uncertainties for AD and EF for each land use class into Eq. 6 and summing across all land use classes using Eq. 7 results in a total estimated uncertainty on the A/R emissions of ±21% of the total for 1990-2010.

25. This is a good demonstration of the value of using a Monte Carlo analysis rather than simple propagation of errors. The error for each individual land use change was much greater than 10%; however, the formula for simple propagation of errors results in a much lower overall uncertainty, likely greatly underestimating the actual uncertainty. This is true for the total uncertainty estimate for degradation and afforestation/reforestation as well.

4. Development of the Reference Level

4.1 Overview of potential options for creating RLs

Among the international community, the following options for projections have been discussed as being applicable for national and subnational RL: (1) historical average, (2) continuation of the historical trend and (3) adjusted to national (subnational) circumstances.

The **average RL** is set as continuation of historical average, which can have different implication for countries or provinces. Countries or provinces with rapidly increasing emissions from deforestation will have difficulties to achieve deep emission cuts necessary to maintain their historical average, while countries or provinces with historically decreasing emissions will achieve their emissions cuts with fewer efforts.

The **continuation of historical trend RL** requires assessment of the historical data for presence of a statistical trend. Countries with increasing emissions will project increasing trend for the RL, while countries with decreasing historical emissions will project decreasing trend for RL, making the cuts in emissions for both scenarios more affordable.

The **adjusted for national (subnational) circumstances RL** requires more detailed analysis and justification that the historical drivers of deforestation and forest degradation are expected to change in the future that will result in an increase of emissions. However, for most countries an upward adjustment may be difficult to justify and will likely affect only those countries that have high forest cover and historically low rates of deforestation and emissions.

The choice of options for developing a RL would be influenced not only by the ability of the country or province to compile and analyze data from multiple time points in the past (trend RL would require more data points than average RL), but also by the set international standards for RL requirements. The current draft of the Carbon Fund Methodological Framework[26] developed by the WB Forest Carbon Partnership Facility (FCPF) allows for average RL or adjusted upward or downward average RL. Although the final requirements for projection of RL are not yet regulated by the international financial bodies for providing performance-based payments, it is possible that different international funding bodies may have different criteria for development of the RL.

26. Published for review on September, 5, 2013
https://www.forestcarbonpartnership.org/sites/fcp/files/2013/Dec2013/FCPF%20Carbon%20Fund%20Meth%20Framework%20-%20Final%20December%2020%202013%20posted%20Dec%2023rd.pdf

4.2 Options for setting Lam Dong's RL

The options here presented for a projected RL are until 2020 or 10 years from the base year (2010). Regardless of the RL that Lam Dong decides to follow, the emissions after 2010 (the start year of REDD+) must fall below the trend line for Lam Dong to demonstrate successful performance.

Historical Average RL

The average RLs are set as a continuation of the historical average. The average annual historical emissions from deforestation for Lam Dong is estimated at 2.46 million t CO_2e yr^{-1} (green line in Figure 4); the average annual historical emissions from forest degradation is estimated at 1.01 million t CO_2e yr^{-1} (red line in Figure 5); and the average annual removals from A/R is estimated at 0.45 million t CO_2e yr^{-1} (orange line in Figure 6).

Figure 4: Historical average deforestation RL for Lam Dong province. The start year of REDD activity is assumed to be 2010; the annual historical emissions are shown for the mid-point of the analyzed time periods

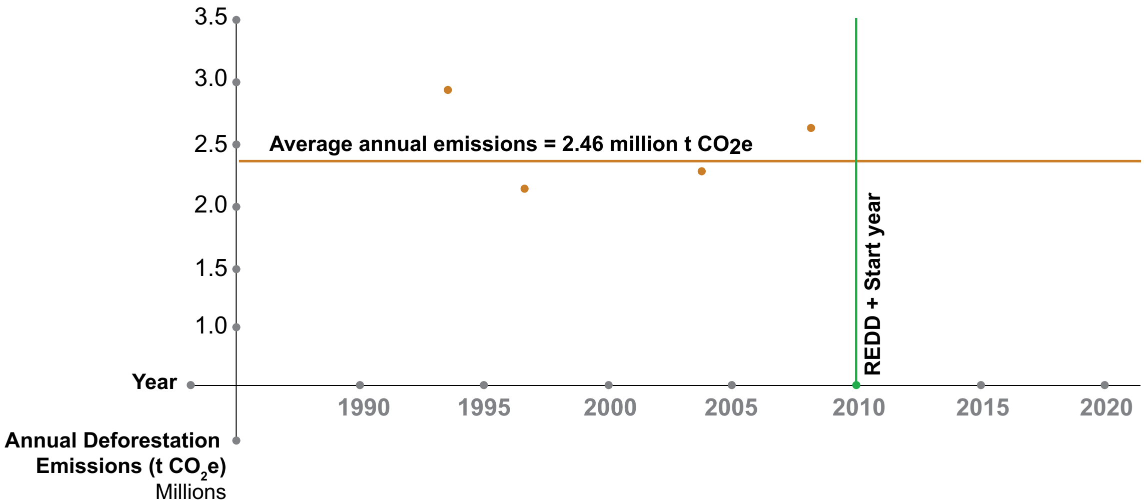


Figure 5: Historical average degradation RL for Lam Dong province. The start year of REDD activity is assumed to be 2010; the annual historical emissions are shown for the mid-point of the analyzed time periods

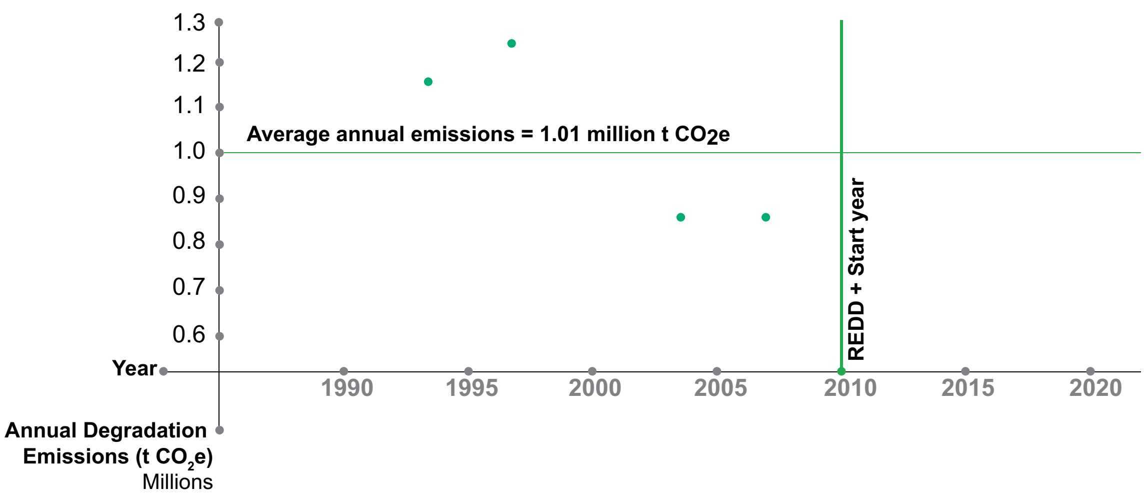
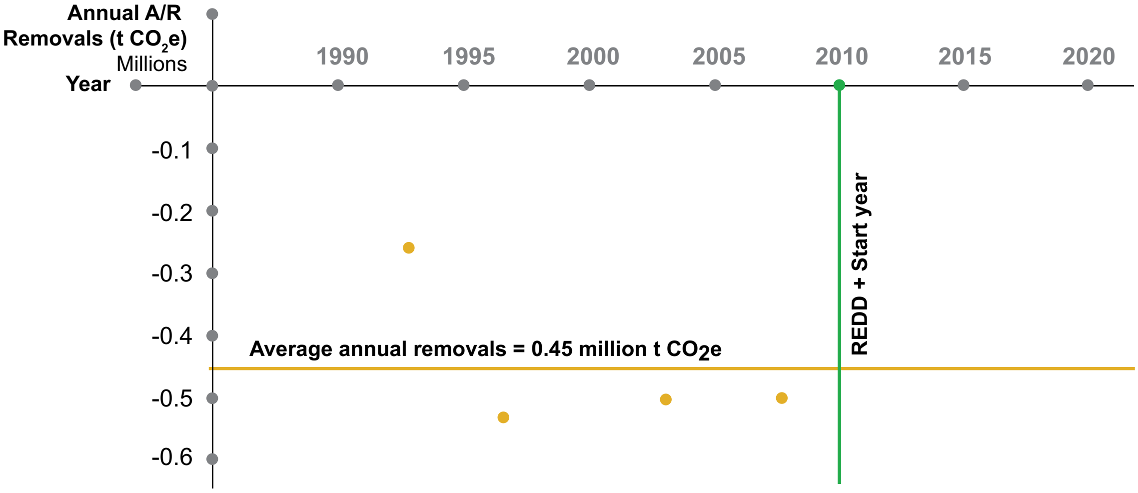


Figure 6: Historical average A/R RL for Lam Dong province. The start year of REDD activity is assumed to be 2010; the annual historical emissions are shown for the mid-point of the analyzed time periods



A Reference Level based on the continuation of historical trend requires assessment of historical data to determine the statistical trend. The historical annual emissions show a non-significant decreasing trend for deforestation (Figure 7), a significant trend for forest degradation (Figure 8), and a non-significant trend for A/R (Figure 9).

Figure 7: Historical trend deforestation RL for Lam Dong province (based on average annual emissions per time period). The start year of REDD activity is assumed to be 2010; post - 2010 emissions are projected based on historical trend

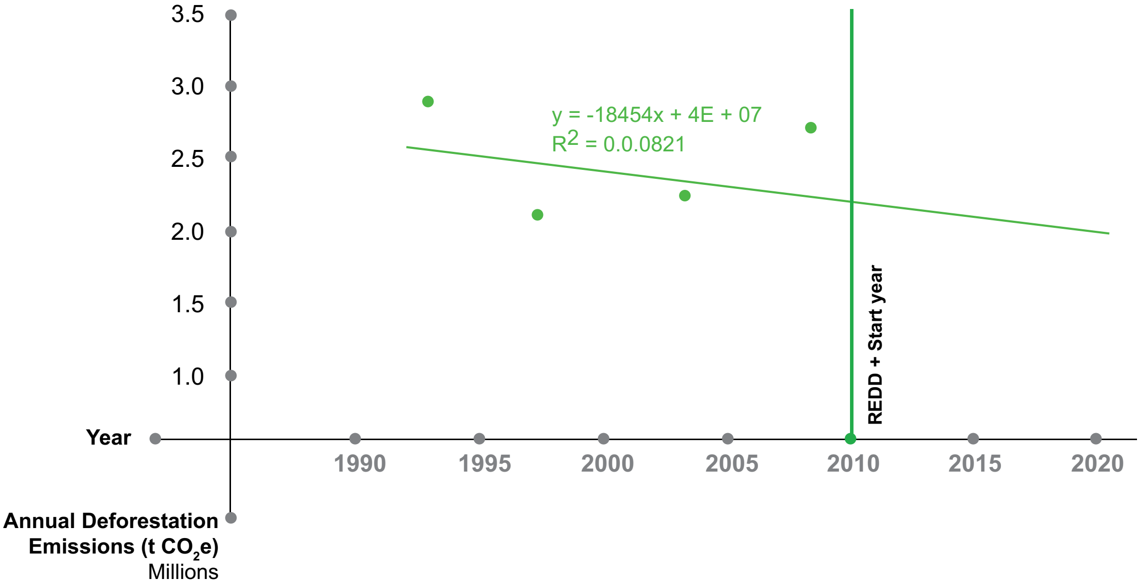


Figure 8: Historical trend degradation RL for Lam Dong province (based on average annual emissions per time period). The start year of REDD activity is assumed to be 2010; post - 2010 emissions are projected based on historical trend

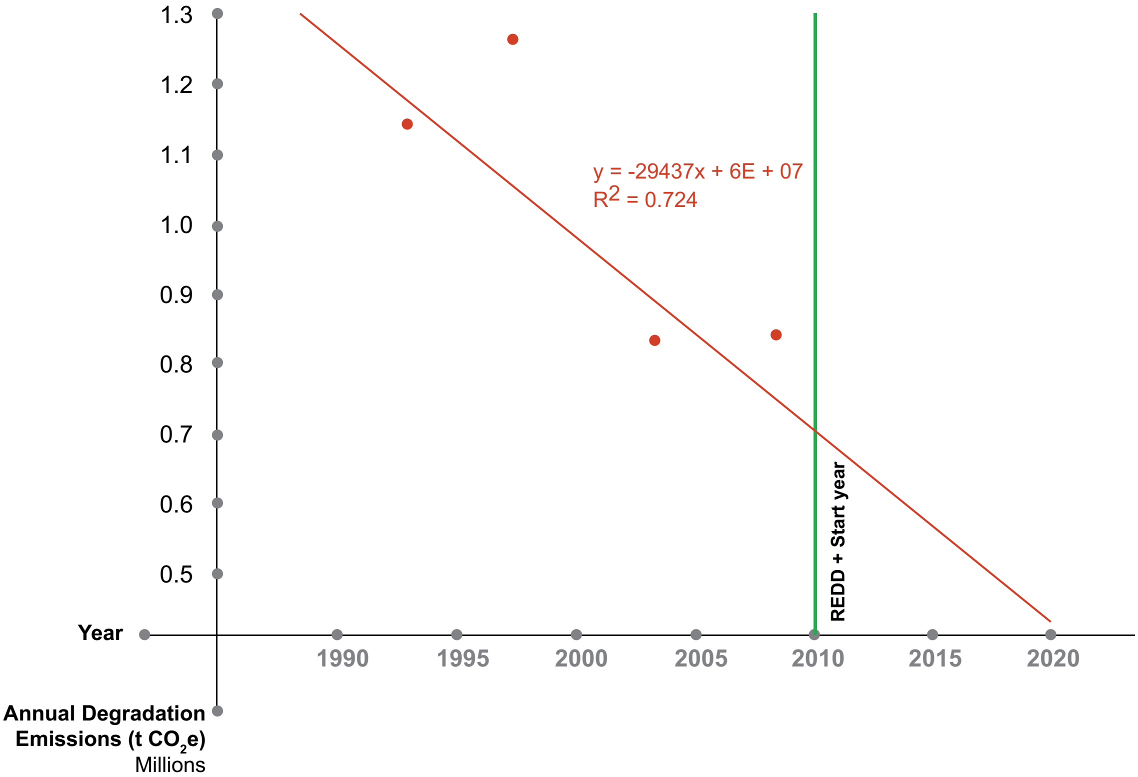
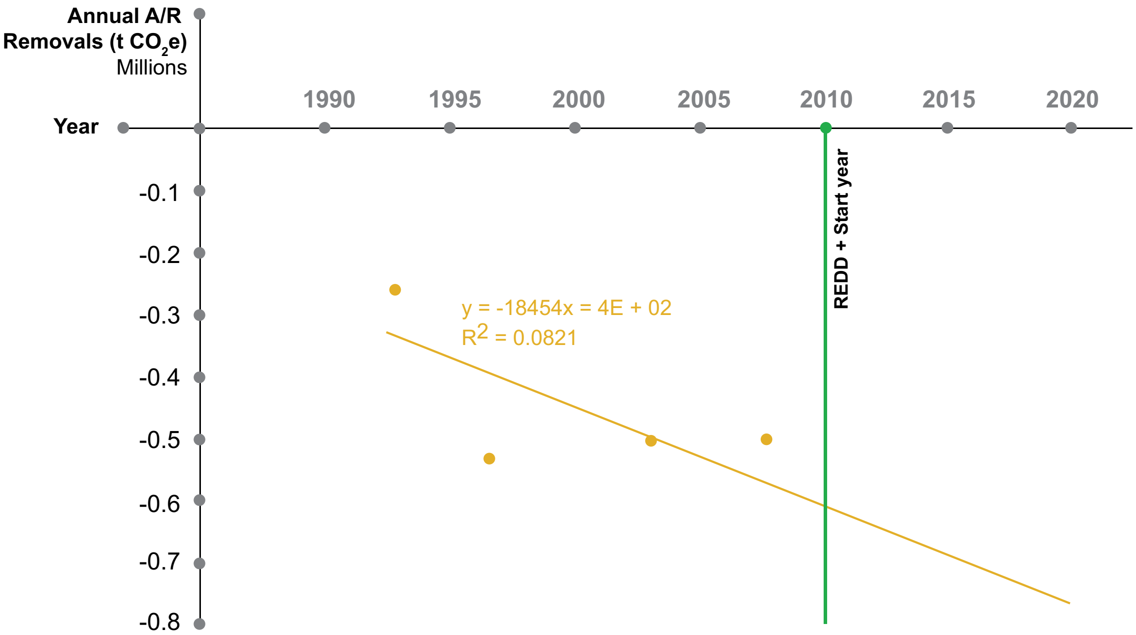


Figure 9: Historical trend A/R RL for Lam Dong province (based on average annual emissions per time period). The start year of REDD activity is assumed to be 2010; post - 2010 emissions are projected based on historical trend



5. Improvements and Next Steps

This assessment of Lam Dong's historical GHG emissions and removals provides a useful overview of the land-use history and related emissions in the province between 1990 and 2010. However, there are improvements that would lead to emission estimates with lower uncertainties, both related to the EF and AD.

As noted above, the carbon stock estimates are based primarily on NFIMAP Cycle IV raw field data (2006-2010) collected by FIPI. These data were not originally collected with the intent of estimating carbon stocks. Therefore, there are understandably certain limitations in using them to assess GHG emissions and removals for the purposes of REDD+ in Lam Dong. One such limitation is that much of the uncertainty of the carbon stocks in the live tree pool can be attributed to the lack of a sufficient number of plots measured in certain strata where most change has occurred. For instance, there were no plots taken in the coniferous regrowth stratum, so an assumption was made regarding the carbon stocks for this stratum (as explained in section 3). Now that a greater understanding of the forest cover change exists from the remote sensing data, this information can be used to strategically select which strata are undergoing the most change and to collect additional field data to reduce the uncertainty in their carbon stock estimates.

Moreover, only data for the most recent Cycle of field data collection were used and assumed to be applicable for the whole 20 year period (1990-2010). Clearly over such a long time period the C stocks in the forests will have changed. Given that other field data have been collected these need to be analyzed to arrive at EFs for the period 1990-2000, with the latest Cycle IV used for estimating EFs for the period 2001-2010.

Also, a lack of data in the post deforestation land use classes led to the assumption that all three classes had a biomass carbon stock of zero, which affects the EF estimations. This is particularly troublesome in those areas where forests are converted to tree crops. In the interim, such data gaps may be addressed by collecting additional data from neighboring provinces that have similar forest classes. Increasing the amount of data for specific strata may lower the uncertainty.

This analysis would also benefit from gathering additional information on the strata identified. For instance, the carbon stock estimates for the plantation strata could be improved with better knowledge of the different plantation species in Lam Dong and identification of the location of plantations of different species or the total area that each species covers in the province.

Uncertainty for each carbon stratum can also be attributed to the use of default values for carbon pools other than live trees in both the pre- and post-deforestation land use classes. This assessment could benefit from an analysis of existing data of the soil, litter, dead wood and non-tree vegetation pools in

Lam Dong from other projects. These data might serve as proxies, so that Lam Dong may assess whether these carbon pools represent substantial carbon stocks and in the future make an informed decision on the opportunity cost associated with gathering sufficient data to estimate the carbon stocks for these pools.

The analysis of remotely sensed data used to determine forest change results in net change during the historical period. This is a major limitation and the analysis needs to be improved to determine gross change so that there is an accurate representation of each activity: deforestation, degradation, and enhancement.

Although overall accuracy and the accuracy level for each land cover class in the maps were assessed, the ground truth data used to validate the maps were limited for earlier years. FREC used data from the NFIMAP cycles from 1990 to 2010 to assess the accuracy of mapped category, but due to the use of different methods among the NFIMAP cycles, the quality and quantity were limited. Additional ground truth data (e.g. areal imagery, high resolution images) might be needed to improve the accuracy assessment of the land cover categories for the 1990 to 2005 maps.

In addition, the accuracy of the area change needs to be assessed, to ensure that the transition shown from the comparison of the two maps is real. For example, the comparison of current maps shows transition from agriculture and bare land to evergreen broadleaf rich forest during one time period—this is clearly unreal. The analysis of land use change could be improved by assessing these transitions in more detail to determine whether they are related to a possible misclassification in the forest cover change. Also, the analysis of AR land would benefit from tree growth curves for the forest types studied, so that we may better assess carbon stock increases over time instead of at five year intervals. It will be advisable for future monitoring events to use change detection RS techniques and map the area change.

In the case of Lam Dong, the delineation and change in state of the poor, medium and rich forest was used to define degradation. The boundaries between these quality classes are not easily detectable from the satellite images and some misclassification due to annual variability of the satellite images could have contributed to the uncertainty of the AD for degradation. Ancillary spatial data (e.g. areas of logging practices and other degradation activities) might be helpful to verify the historical AD for degradation.

The current analysis takes into account the qualitative assessment of drivers of deforestation and degradation, but it would be improved with a clear determination of the causes of deforestation. More detailed spatial analysis would be needed to identify the land use of the post-deforestation land (e.g. forest converted to rice paddy vs. forest converted to soy beans field vs. forest converted to rubber plantation). Conversion from forest to different land uses is associated with different EF, therefore such analysis can be used to refine the EF and emissions from deforestation.

Many of the data gaps identified above can be addressed in the future by establishing a system that takes both the sampling design and geospatial aspects of this analysis into consideration from the early stages. A forest monitoring system that is designed with REDD+, or reducing emissions from land use (RELU) more generally, as one of its goals will enable those implementing it to better understand what data must be collected and how they can be applied to GHG emission estimates. Ideally, those responsible for the design of any data collection plan will also be involved in the analysis and reporting of that data.

Dr David Ganz

USAID Lowering Emissions in Asia's Forests (LEAF)

Chief of Party

Liberty Square, Suite 2002
287 Silom Rd. Bang Rak
Bangkok 10500, THAILAND

Telephone: +66 (0) 2 631 1259
Email: DGanz@field.winrock.org

Ms Ly Thi Minh Hai

USAID Lowering Emissions in Asia's Forests (LEAF)

Viet Nam USAID LEAF Country Manager, SNV REDD+ Sector Leader

6th floor, Building B, La Thanh Hotel,
218 Doi Can, Ba Dinh, Hanoi, VIET NAM

Telephone: +84 (4) 3846 3791 /108
Email: HLyThiMinh@snvworld.org