GIS and Remote Sensing Support for the Assessment of Historic Forest Cover Change and GHG Emissions in Xamtai and Viengxay Districts, Lao PDR

(October, 2014)

GIS and Remote Sensing Support for the Assessment of Historic Forest Cover Change and GHG Emissions in Xamtai and Viengxay Districts, Lao PDR

Forest Carbon Partners Laos

October 2014

The USAID Lowering Emissions in Asia's Forests (USAID LEAF) Program is a five-year regional project (2011-2016) focused on achieving meaningful and sustainable reductions in greenhouse gas (GHG) emissions from the forest-land use sector across six target countries: Thailand, Laos, Vietnam, Cambodia, Malaysia and Papua New Guinea.

Report prepared by: Forest Carbon Partners Laos

Version: Final

Disclaimer: The analyses in this report were prepared by Forest Carbon Partners Laos on behalf of SNV Laos and are based on data provided at the time of the contract as part of the USAID Lowering Emissions in Asia's Forests Program (USAID LEAF). The views, opinions and analyses do not necessarily reflect the views or opinions of SNV or USAID LEAF.

Table of Contents

1 INTRODUCTION **4**

2 HISTORICAL DEFORESTATION RATES AND GHG EMISSIONS **5**

2.1 SELECTION OF MOST APPROPRIATE DATASET 5

2.2 CALCULATION OF HISTORICAL DEFORESTATION RATES 6

2.3 CALCULATION OF HISTORICAL GHG EMISSIONS 12

2.4 FUTURE UPDATING OF DATASETS 14

3 DRIVERS, SOURCES AND AGENTS OF DEFORESTATION AND FOREST DEGRDATION **15**

4 RECOMMENDED MITIGATION ACTIONS TO REDUCE DEFORESTATION AND FOREST DEGRADATION **18**

ANNEX 1: SELECTION OF MOST APPROPRIATE DATASET **21**

AVAILABLE DATASETS 21

Date and imagery available *21*

Dataset approach to change detection *23*

Limitations of datasets *23*

COMPARISON OF DATASETS 24

Methodology *24*

Assessment of symptomatic problems for each dataset *27*

4.1.1 Conclusion on most appropriate change detection dataset *38*

ANNEX 2: REPORTS CONSULTED FOR THE DRIVERS ANALYSIS **41**

1 INTRODUCTION

The five year, USAID funded Lowering Emissions in Asia's Forests (USAID LEAF) program's goal is to "strengthen the capacity of target countries to achieve meaningful and sustained reductions in greenhouse gas emissions from the forestry-land use sector, thus allowing these countries to benefit from the emerging international REDD+ framework". The USAID LEAF program operates in 6 countries, including Cambodia, Thailand, Vietnam, Malaysia, Papua New Guinea and Lao PDR. It is being implemented by Winrock International (Winrock), in partnership with the SNV Netherlands Development Organization (herewith SNV), Climate Focus and The Center for People and Forests (RECOFTC). In Lao PDR, USAID LEAF's target landscapes include: Xamtai and Viengxay Districts and the adjoining Nam Xam National Protected Area (NPA) in Houaphan Province and Sanamxay District in Attapeu Province.

During the course of the program, USAID LEAF has reviewed existing studies and commissioned new ones to better understand the land use and forest cover change dynamics in its target districts in Lao PDR. These include remote sensing and GIS based analyses of forest cover change as well as studies on the drivers of forest loss. Additionally, several new external studies quantifying forest cover change in USAID LEAF's target districts have become available recently. This information has yet not been collated into a summary resource document for the USAID LEAF program and its key stakeholders.

This report has two purposes:

1. To synthesize the current state of available knowledge on forest cover change dynamics and associated greenhouse gas (GHG) emissions in Xamtai and Viengxay districts[1] and the Nam Xam NPA (located within Xamtai and Viengxay districts), and therefore their REDD+ relevance; and
2. To offer recommendations on potential mitigation measures that could be employed to reduce deforestation and forest degradation in the district.

In so doing, the report provides a resource for the USAID LEAF program and its stakeholders as they develop approaches to reduce forest based GHG emissions, thus supporting Lao PDR's efforts to participate and benefit from the emerging international REDD+ framework.

Following this introduction, Section 2 outlines the results of Forest Carbon's analysis to select the most appropriate dataset to calculate deforestation rates and forest based GHG emissions in the district. Section 3 then outlines the various drivers causing forest loss in the district before recommending a series of potential mitigation measures in Section 4 to address these drivers.

[1] Xamtai district was divided into two districts in 2012 and now includes Xamtai and Kouan districts. The datasets analyzed for this report include the full extent of the three districts (Xamtai, Viengxay and Kouan), however final results relating to rates of forest loss and GHG emissions are presented only for Xamtai and Viengxay districts.

2 HISTORICAL DEFORESTATION RATES AND GHG EMISSIONS

The following section briefly describes the process Forest Carbon undertook to select the most appropriate dataset to capture forest cover change dynamics (a more extensive discussion is provided in Annex 1) before calculating the historical rates of deforestation and associated GHG emissions in Xamtai and Viengxay districts.

2.1 SELECTION OF MOST APPROPRIATE DATASET

For Xamtai and Viengxay districts three datasets that assessed forest cover change were made available: (i) the USAID LEAF commissioned study conducted by Aruna Technologies entitled "Forest Cover Stratification and Forest Cover Change Mapping for the Lowering Emissions of Asia's Forest (LEAF) Project"; (ii) the University of Maryland's Global Forest Change project led by Dr. Matthew Hansen (referred to as Hansen in this report); and (iii) the Climate Protection through Avoided Deforestation (CliPAD) commissioned study conducted by the Wildlife Conservation Society (WCS) entitled "Assessment and Conceptualization of a Jurisdictional REDD+ Approach in Houaphan Province, Lao PDR". The CliPAD project is currently in the process of conducting an updated land and forest cover change analysis for all of Houaphan province; however, this dataset still only exists in draft form and was therefore not assessed. Forest Carbon undertook a qualitative assessment of these datasets to determine which best captured the forest cover change dynamics in the target area.

The Aruna dataset identified deforestation over three periods of time between 1995 – 2010 (1995 – 2000, 2000 – 2005 and 2005 – 2010) while the Hansen dataset considered both forest cover, forest gain and forest loss on a yearly basis between 2000 – 2012. The WCS dataset created land cover classifications for 2000, 2005 and 2010 in addition to calculating forest losses and gains between each of these periods. The methods to identify changes in forest were different between these three datasets (as explained in Annex 1), necessarily resulting in differences in their interpretation of change.

Forest Carbon analyzed the two datasets according to the following steps:

1. Identify 6 clusters of dynamic forest cover change that in total represent approximately 10% of the district on which to focus the initial analysis.
2. Identify the 25 largest polygons of change for each dataset within each of the clusters.
3. Review the polygons' ability to accurately capture the underlying change dynamics through visual inspection of the available satellite imagery.
4. Identify symptomatic issues in the identification of forest change dynamics.
5. Assess the impact of the symptomatic issues on the overall ability of the dataset to accurately represent forest cover change dynamics through a broader review of the dataset within each cluster and throughout the district at large.

Based on the review of the symptomatic issues across the entire district, the Hansen and WCS datasets were considered to be less accurate than Aruna. The WCS dataset tended to underestimate forest loss too much while the Hansen dataset exhibited inaccuracies both in over and underestimating loss. The Aruna dataset was the more accurate both in terms of identifying the correct extent of forest loss as well as the locations.

Although both the Hansen and WCS datasets have the advantage of also showing forest cover gain, and therefore forest cover changes associated with the swidden cycle, this was not deemed a sufficient reason to select either of these datasets over Aruna. The Hansen dataset forest gain layer also demonstrated symptomatic problems with the accurate identification of actual reforestation. Many areas classified as forest gain were associated with bare land returning to a higher vegetative state – but not to forest. The WCS dataset on the other hand showed very little forest cover gain throughout the area of analysis and, therefore, does not provide a great deal of additional information over the Aruna dataset.

As a result, Forest Carbon used the Aruna dataset to estimate the amount of historical deforestation in the district. However, this must be under the strict understanding that the Aruna dataset provides values for gross deforestation only. Net deforestation would be lower since some areas of swidden are likely to return to forest.

This trend, however, is currently decreasing as land use intensifies and fallow cycles are shortened (as explained in Section 3). Amounts of actual reforestation are therefore not expected to create a major difference between gross and net deforestation rates.

While the Aruna dataset does contain errors it provides a more realistic and accurate view on the amount of deforestation occurring in the district. For this reason, it is more helpful in terms of supporting the USAID LEAF program and its counterparts to identify deforestation hotspot areas in the target area.

2.2 CALCULATION OF HISTORICAL DEFORESTATION RATES

Once a decision on the most appropriate dataset was made, it was possible to calculate rates of deforestation for the relevant periods of analysis. This provided the activity data required to calculate historical GHG emissions caused by forest loss.

A limitation of the Aruna dataset was that it did not produce its own forest and land cover classifications for each year of analysis. Instead Aruna made use of the classifications produced by WCS in order to calculate rates of deforestation as a percentage of the standing forest area; the WCS land and forest cover classification were deemed to be superior to those produced by the FIM project.

The WCS 2005 land cover classification was the starting point upon which Aruna calculated rates of change[2]. The classification was aggregated into three land cover classes, as follows: Natural Forest; Other Vegetation; and Agricultural Land. From this it was possible to know the amount of forest area in 2005 and, in combination with the known amount of forest loss per period, calculate forest areas for 1995, 2000 and 2010 through additions or subtractions.

A summary of the initial 2005 land cover classes for the target area is provided below in Table 1. Below this, in Figure 1, is a 2010 map of the land cover classes in the target district created by modifying the 2005 classification to account for deforestation between these two years. Figure 2 maps the location of the identified deforestation over the three periods of analysis.

Table 1: Summary of land cover classes in the target area in 2005

Land cover class	Xamtai		Viengxay		Nam Xam NPA*
	Area (ha)	% of Total Area	Area (ha)	% of Total Area	Area (ha)
Natural Forest	107,508	46.2%	62,642	41.6%	42,109
Other Vegetation	3,786	1.6%	1,505	1.0%	605
Agricultural Land	121,562	52.2%	86,588	57.4%	23,966
Total	**232,857**	**100.0%**	**150,735**	**100.0%**	**66,590**

* Nam Xam NPA values are for only the clipped area for which Aruna conducted analysis and therefore do not add up to the actual area of the Nam Xam NPA.

[2] See Aruna's report entitled "Forest Stratification and Forest Cover Change Mapping for the Lowering Emission of Asia's Forest (LEAF) Project" for more details.

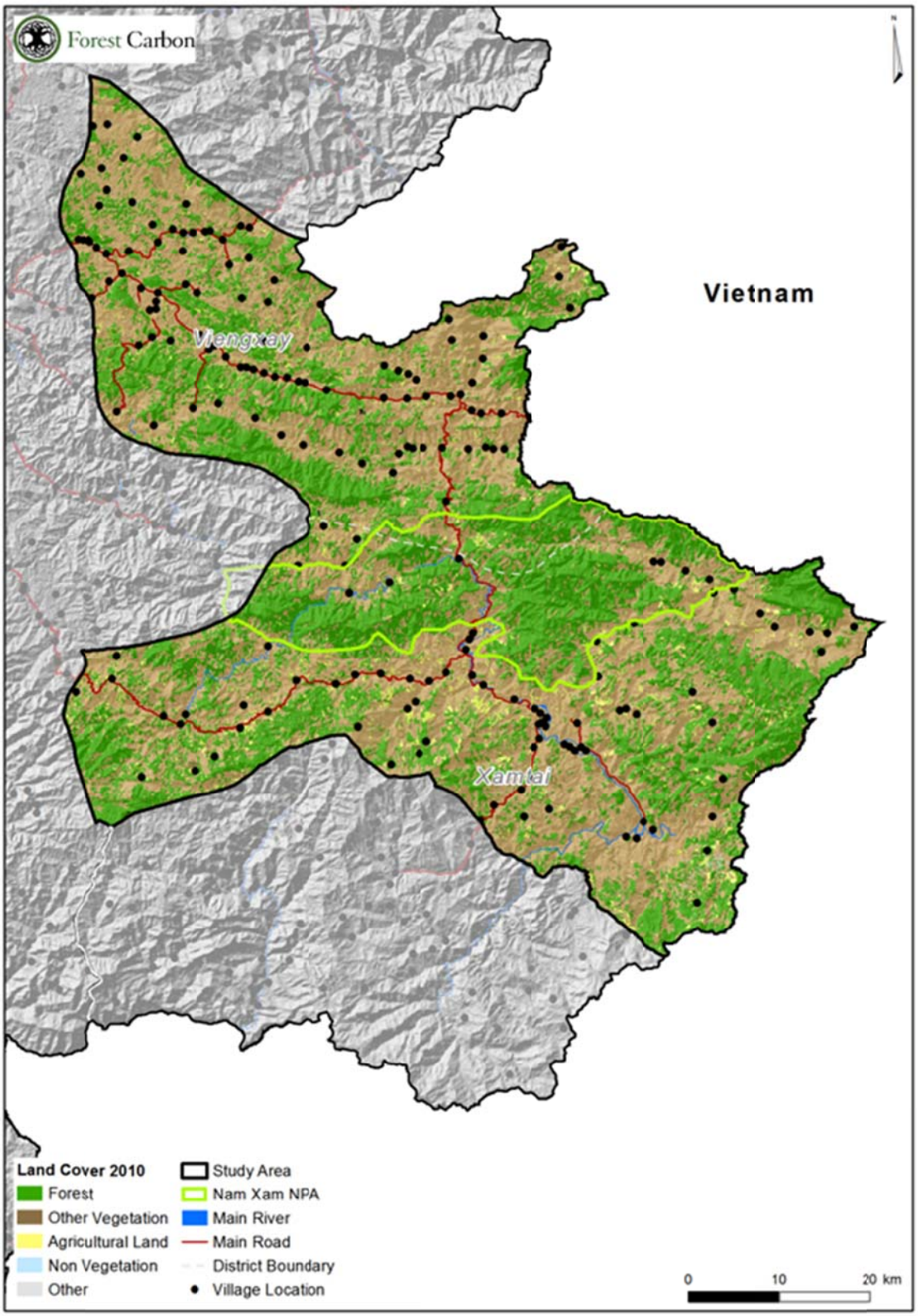


Figure 1: 2010 Land cover map for the target area

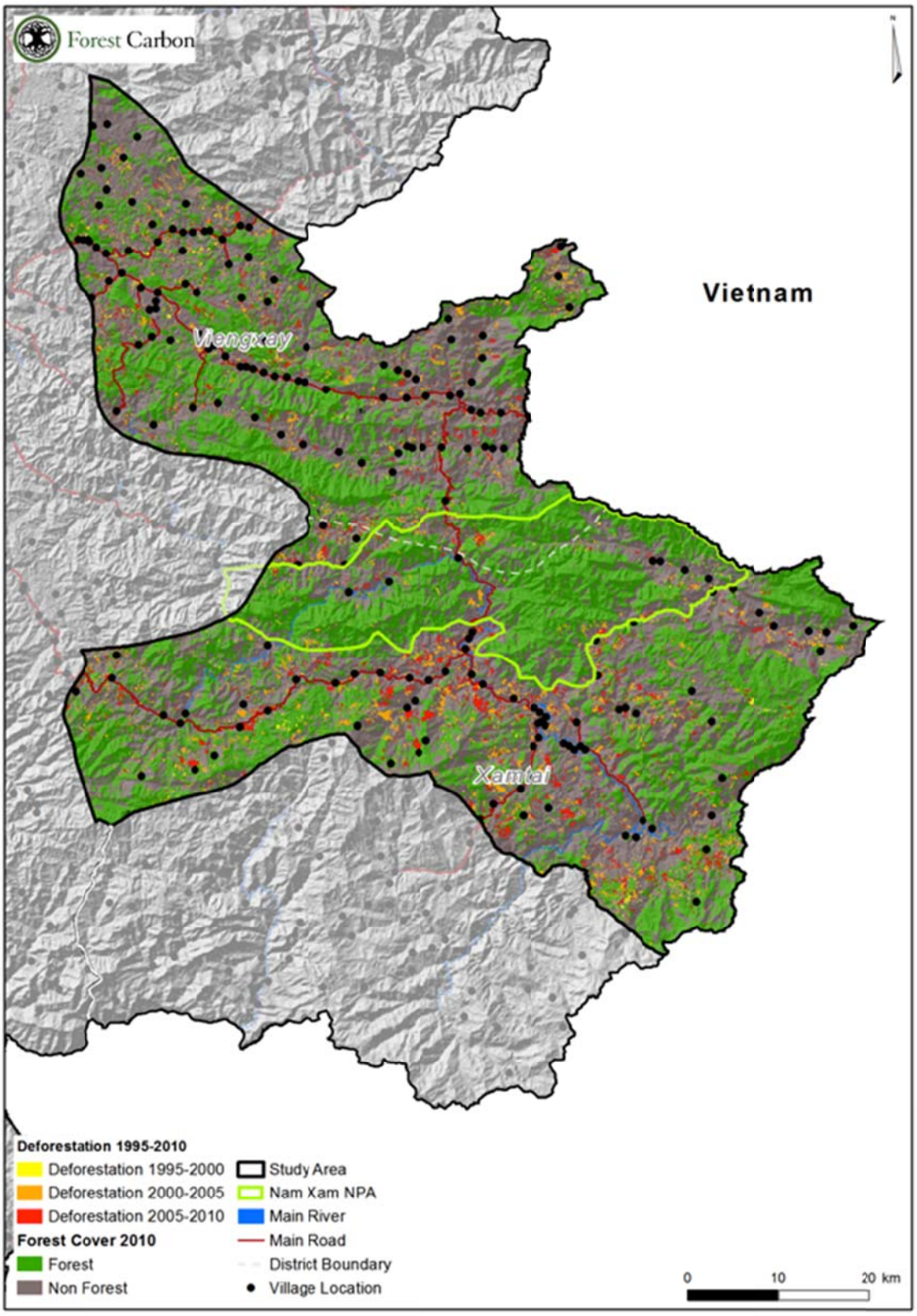


Figure 2: Gross deforestation per period of analysis for the target area

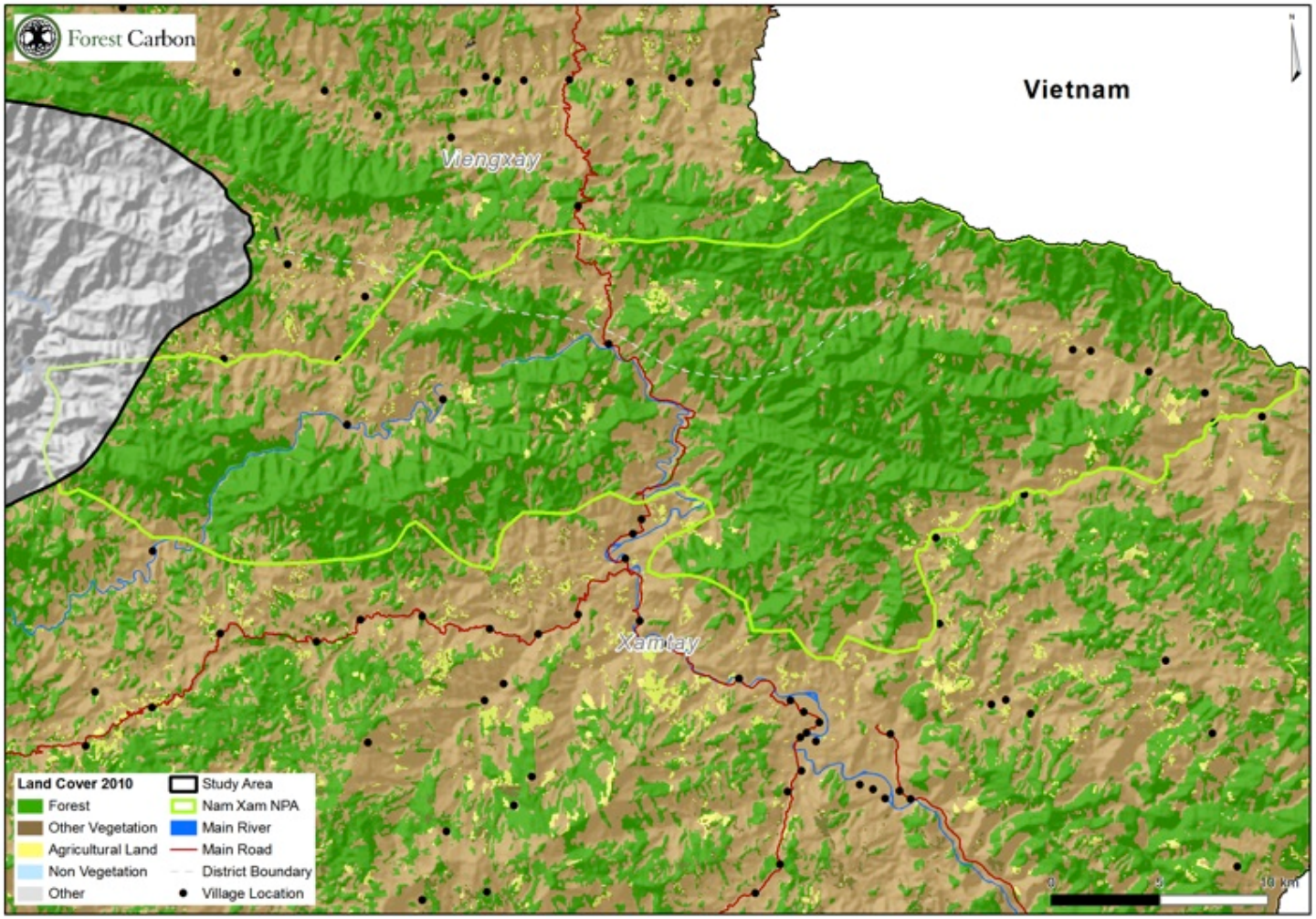


Figure 3: 2010 Land cover map of the Nam Xam NPA

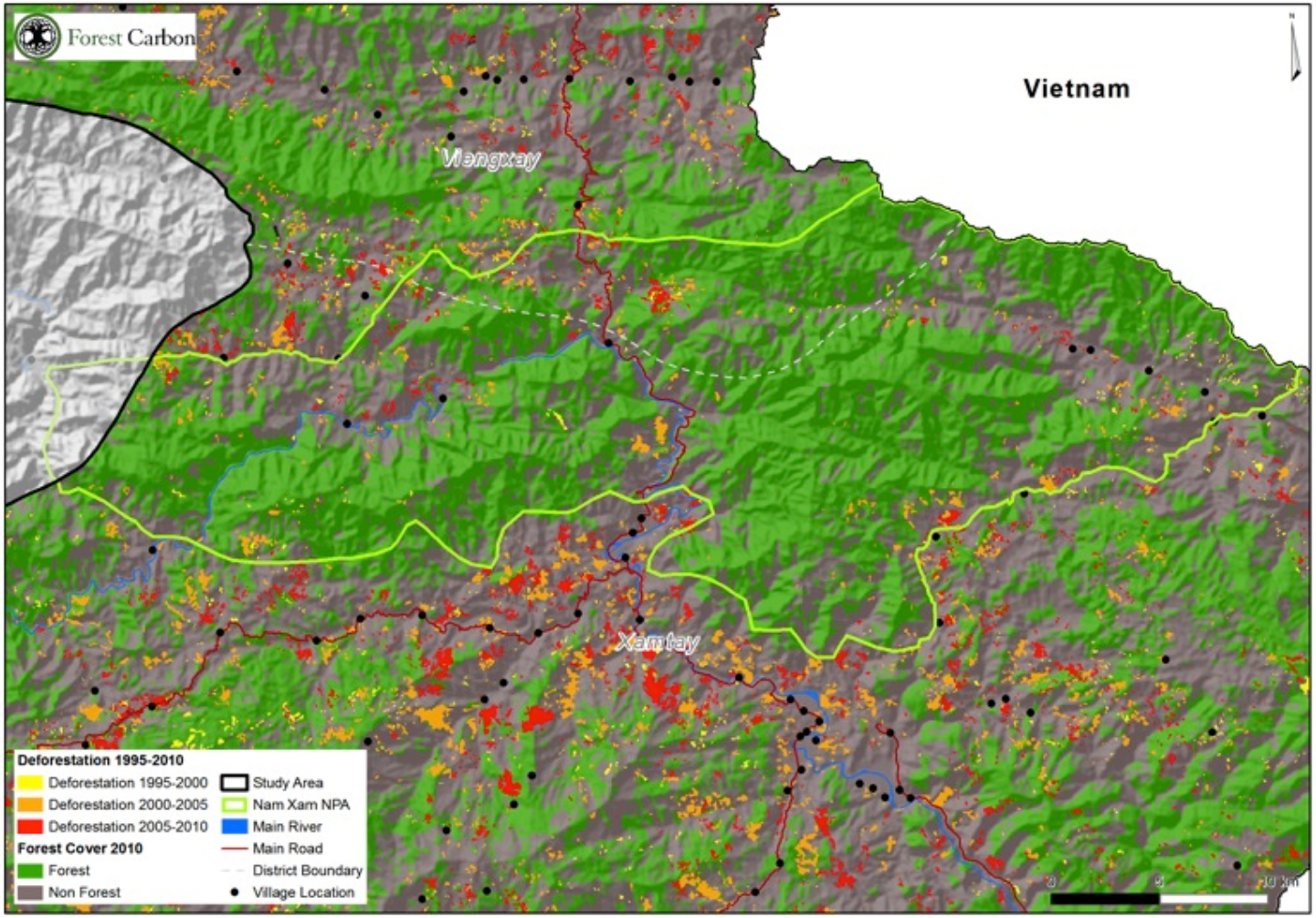


Figure 4: Gross deforestation per period of analysis for the Nam Xam NPA

From the information in Table 1 it was possible to calculate rates of deforestation for each period of assessment, as summarized in Table 2 and Figure 5.

Table 2: Amounts of deforestation in the target area between 1995 - 2010

Nominal Year	Actual Dates	Δ in Years	Forest Area (Ha)	Forest Loss		Rate of Loss	
				Ha	%	Ha/yr	%/yr
1995	1994-04-09 (W)		183,620				
	1993-12-27 (E)						
2000	2000-09-17 (W)	~6	180,856	2,765	1.5	442	0.24
	1999-12-27 (E)						
2005	2002-12-22 (W)	~7	170,150	10,706	5.9	1,447	0.80
	2007-11-08 (E)						
2010	2010-12-27 (W)	~4	161,800	8,351	4.9	2,198	1.29
	2011-03-21 (E)						
Total		**~17**		**21,821**	**11.9**	**2,122.1**	**0.82**

Gross deforestation totaled 21,821 ha for the fifteen-year period of analysis, equating to almost 12% of the forest area in 1995. Gross rates of forest loss were 442 ha/yr between 1995 – 2000, increased to 1,447 ha/yr between 2000 – 2005 and then increased even further to 2,198 ha/yr between 2005 – 2010. This is a worrying trend showing an intensification of pressure on the forest resources in the target area. These rates of loss equate to 0.24%, 0.80% and 1.29% of the available forest area at the start of each period. These rates of loss, expressed as percentages, appear disquietingly high especially for the last period. It should be remembered, however, that these percentage values should be seen as indicative considering the different methodological approaches taken by WCS and Aruna.

The gross deforestation trends in the Nam Xam NPA similarly increased between the first and second period, from 35.6 ha/yr to 133.5 ha/yr. However, rates decreased slightly in the third period to 112.4 ha/yr. Total loss between 1995 – 2010 was 1,599 ha, representing approximately 3.7% of the original forest area in 1995. Summary results for Nam Xam NPA can be found in Table 3.

Table 3: Amount of deforestation in the Nam Xam NPA between 1995 - 2010

Nominal Year	Actual Dates	Δ in Years	Forest Area (Ha)	Forest Loss		Rate of Loss	
				Ha	%	Ha/yr	%/yr
1995	1993-12-27		43,166				
2000	1999-12-27	6	42,953	213.7	0.5	35.6	0.1
2005	2007-11-08	7	42,019	933.6	2.2	133.5	0.3
2010	2011-03-21	4	41,568	451.5	1.1	112.4	0.3
Total				1,598.7	3.7	94.0	0.2

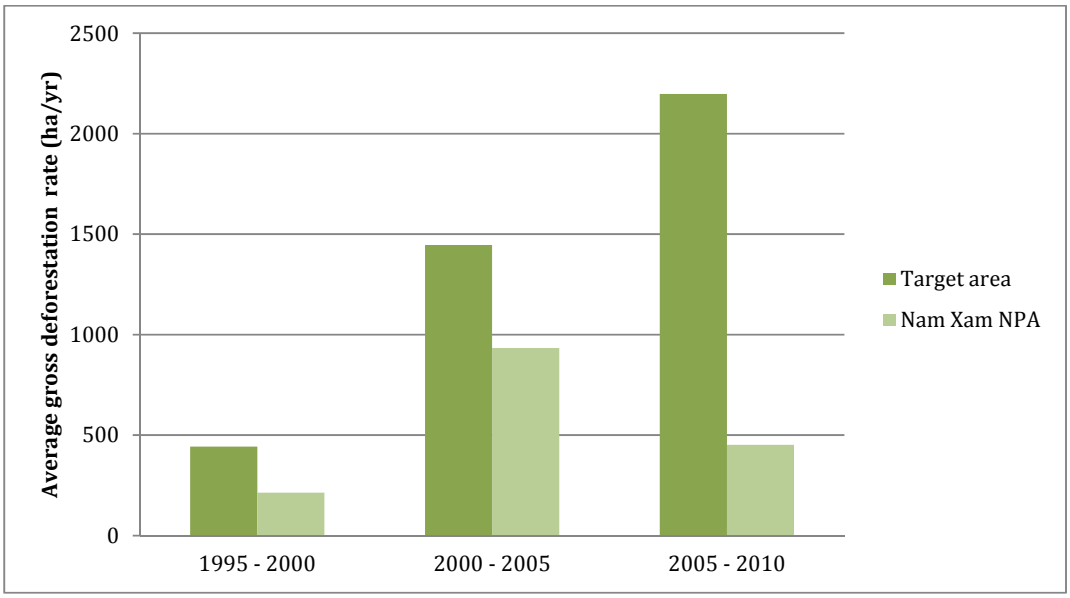


Figure 5: Average rates of gross deforestation in the target area and the Nam Xam NPA for the three periods of analysis

As detailed in Section 3, the intensity of drivers of deforestation and forest degradation are expected to either remain the same or increase in the near future. Therefore, assuming sufficient available forest rates are available, rates of forest loss are likely to continue within the target area and the Nam Xam NPA at the same pace as the last two period of analysis. For the purposes of calculating future baseline emissions, an average of these last two periods were used for the overall target area and the Nam Xam NPA, equating to 1,701 ha/yr and 126 ha/yr respectively.

2.3 CALCULATION OF HISTORICAL GHG EMISSIONS

To estimate the historical amounts of GHG emissions from deforestation in the target area required an understanding of the differences in carbon stock between forest and non-forest classes – typically known as emission factors. The global dataset of forest carbon stocks in tropical forest areas produced by Saatchi et al. was made available by USAID LEAF as a potential source to calculate these emission factors. Forest Carbon, however feels that this dataset is too coarse (100 ha pixel size) to adequately capture the differences in carbon stocks in the heterogeneous and highly fragmented Lao landscapes. It was therefore decided to use IPCC default values and information gleaned from Lao specific studies to obtain carbon stock data for the forest and non-forest classes. This is the same approach that numerous REDD+ feasibility studies in Lao PDR have taken to date. For the purposes of these initial GHG emission estimates only the above and below ground biomass pools were considered.

For the forest class, a default value of 130 tons of dry matter per hectare (t.d.m./ha) for Tropical Dry forests in Asia was used as per the IPCC Guidelines for National Greenhouse Gas Inventories. The IPCC's default root-to-shoot ratio of 0.28 for Tropical Dry forests and a carbon fraction of 0.47 were used to arrive at total carbon stock in above and below ground biomass pools of 78.2 tC/ha. This equates to 287 tCO_2e/ha.

A study by Kiyono et al. (2007)[3] investigating chronosequential changes in carbon stocks in regenerating fallows in northern Lao PDR provides an equation to estimate total biomass in a system based on the number of years since the last slash-and-burn event and therefore particularly useful when estimating carbon stocks in fallow systems post-clearance. Agricultural Lands were assumed to have regenerated an average of two years, equating

[3]Kiyono, Y. et al (2007*), Predicting chronosequential changes in carbon stocks of pachymorph bamboo communities in slash-and-burn agricultural fallow, northern Lao People's Democractic Republic*, Journal of Forest Research 12: 371-383

to 13 tC/ha, while Other Vegetation an average of six years (an assumed length for the fallow period), equating to 28tC/ha. Non-Vegetation was assumed to contain no carbon.

The updated WCS 2010 classification was consulted to understand the land cover classes present in the deforested areas. However, this dataset indicated that many of the deforested areas were still forest, which is not surprising considering the two datasets were produced independently. Using these values would therefore likely misrepresent the carbon stocks present in the post-deforestation land cover class. Instead, an average age of four years – representing the half way of an eight-year swidden cycle – was assumed for the post-deforestation class. Although this is likely longer than a typical rotation based on current cycles, it can be considered a conservative assumption. According to the Kiyono model this would equate to 21.2 tC/ha, 78 tCO2e/ha and, therefore, an emission factor of 209 tCO2e/ha.

Using the activity data from Table 2 and Table 3 and the emission factors calculated above it was possible to determine historical GHG emissions from gross deforestation in the target area and the Nam Xam NPA. Baseline estimates of future emissions were also calculated assuming the same emission factors and that average historical rates of deforestation from the last two years of analysis continue for the next ten years. These results are presented below in Table 4 and Figure 6.

Table 4: Historical and baseline GHG emissions from gross deforestation in the target area and Nam Xam NPA

Year	Target Area			Nam Xam NPA		
	Annual Forest Loss (Ha)	Annual GHG Emissions (tCO2e)	Cumulative Emissions (tCO2e)	Annual Forest Loss (Ha)	Annual GHG Emissions (tCO2e)	Cumulative Emissions (tCO2e)
1995						
1996	442	92,378	92,378	36	7,440	7,440
1997	442	92,378	184,756	36	7,440	14,881
1998	442	92,378	277,134	36	7,440	22,321
1999	442	92,378	369,512	36	7,440	29,762
2000	442	92,378	461,890	36	7,440	37,202
2001	1,447	302,423	764,313	134	27,902	65,104
2002	1,447	302,423	1,066,736	134	27,902	93,005
2003	1,447	302,423	1,369,159	134	27,902	120,907
2004	1,447	302,423	1,671,582	134	27,902	148,808
2005	1,447	302,423	1,974,005	134	27,902	176,710
2006	2,198	459,382	2,433,387	112	23,492	200,201
2007	2,198	459,382	2,892,769	112	23,492	223,693
2008	2,198	459,382	3,352,151	112	23,492	247,184
2009	2,198	459,382	3,811,533	112	23,492	270,676
2010	2,198	459,382	**4,270,915**	112	23,492	**294,168**
2011	1,701	355,509	4,626,424	126	26,334	320,502
2012	1,701	355,509	4,981,933	126	26,334	346,836
2013	1,701	355,509	5,337,442	126	26,334	373,170
2014	1,701	355,509	5,692,951	126	26,334	399,504
2015	1,701	355,509	6,048,460	126	26,334	425,838
2016	1,701	355,509	6,403,969	126	26,334	452,172
2017	1,701	355,509	6,759,478	126	26,334	478,506
2018	1,701	355,509	7,114,987	126	26,334	504,840
2019	1,701	355,509	7,470,496	126	26,334	531,174
2020	1,701	355,509	**7,826,005**	126	26,334	**557,508**

GHG emissions from gross deforestation in the target area totaled 4,270,915 tCO2e over the 15-year historical period. Annual emissions during this period directly correlate to the rate of deforestation calculated for that period and average 284,728 tCO2e/year. Estimated baseline emissions for the 10-year period from 2010 to 2020 total 3,555,090 tCO2e. For the Nam Xam NPA the 15-year total equated to 294,168 tCO2e (an average of 19,611 tCO2e/year) while the 2010 to 2020 period anticipates an additional 259,160 tCO2e being emitted.

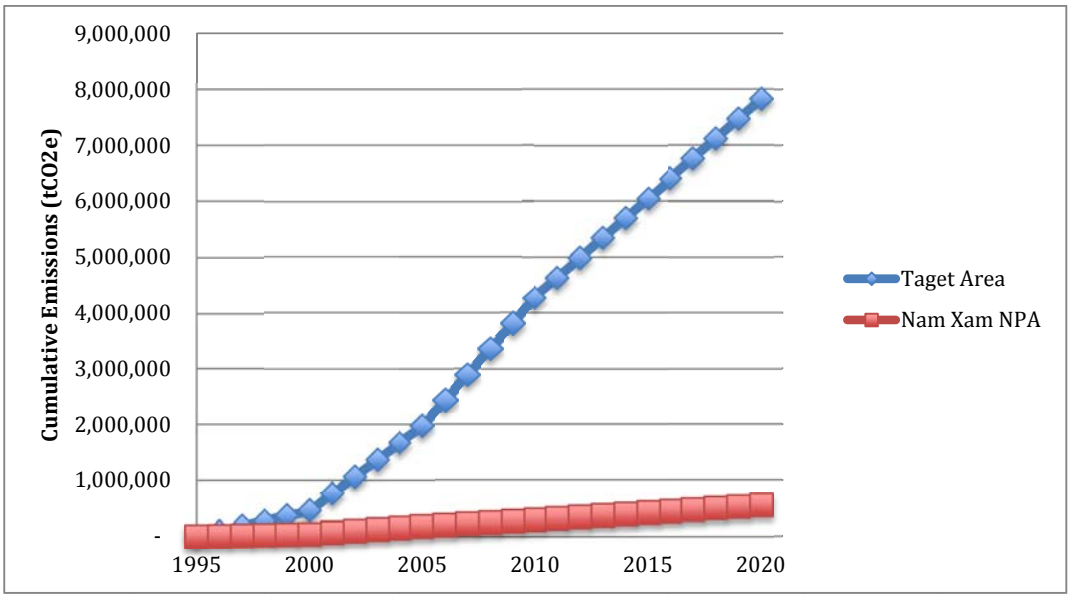


Figure 6: Cumulative historical and baseline GHG emissions from gross deforestation in the target area

2.4 FUTURE UPDATING OF DATASETS

The Aruna dataset was selected for the purposes of calculating historical deforestation rates and associated GHG as this dataset represents the best current source of data. However, as noted previously, the CliPAD project is currently producing updated, high accuracy historical forest and land cover change analyses for the entirety of Houaphan province. This is in preparation to establish a province-wide reference emission level against which provincial performance can be assessed. For this, CliPAD has also initiated biomass and carbon stock inventories of the land cover classes present in the province. The expected delivery dates for the land cover maps and Reference Emission Level (REL) are the end of 2014 and mid-2015 respectively.

Once produced, these datasets will be the de-facto standard for all areas within Houaphan province in view of the province becoming officially verified against the the Verified Carbon Standard (VCS) Jurisdictional and Nested REDD+ (JNR) requirements. As such, all areas within the province will make use of this dataset and USAID LEAF and its target stakeholders should be sure to update all calculated number for their target area as soon as these CliPAD datasets become available.

3 DRIVERS, SOURCES AND AGENTS OF DEFORESTATION AND FOREST DEGRDATION

The success of REDD+ interventions is predicated on a deep understanding of the multiple drivers of forest degradation and deforestation affecting a given location. It is upon this understanding that responses to these drivers that are locally appropriate, targeted and effective can be designed and implemented.

To determine what these drivers are, the USAID LEAF program made available numerous existing reports outlining the drivers and agents of deforestation and forest degradation in Xamtai and Viengxay districts. In addition, Forest Carbon conducted online searches for additional, freely available literature on land and forest use dynamics that impact the target district. While this search provided general results at the national and/or provincial level, it did not result in any additional, specific reports or information on drivers of deforestation for Xamtai and Viengxay districts. A list of the reports consulted is provided in Annex 1.

Provided below is a summary of the relevant drivers, sources and agents of change affecting Xamtai and Viengxay districts, as gleaned from the review of the literature and Forest Carbon's existing knowledge and experience from working in Lao PDR. Where appropriate, factors particularly relevant for the Nam Xam NPA have been highlighted.

Underlying drivers of deforestation and forest degradation influence why deforestation and forest degradation is occurring but are not the immediate factors that cause forest loss. While these drivers are often beyond the scope of local level REDD+ interventions it is important that they are understood when designing effective mitigation strategies. The most relevant underlying drivers of forest loss in Viengxay and Xamtai districts are:

- **International demand for agricultural commodities:** The growing demand for maize in Vietnam has led local farmers to change their land-use practices as they seek to satisfy this demand, lured in part by the opportunity to enter the cash economy. The presence of Vietnamese traders willing to enter into contract farming arrangements with local farmers greatly facilitates the transition of agricultural systems away from upland rice to maize cultivation.

- **International and domestic demand for timber:** High demand from international and domestic markets for high value timber fuels entities and individuals to the log districts' production and protected forests. As explained later, this happens both illegally and semi-illegally. This commercial logging, however, does not appear to feature in the Nam Xam NPA.

- **Population growth**: Population numbers are increasing in both districts meaning an increasing demand for energy, food and agricultural land, as well as construction materials for traditional timber homes.

- **Low government capacity**: Inadequate human, technical and financial capacities within government agencies limit their ability to perform their management and/or enforcement responsibilities in the forest and agricultural sectors.

- **National policy:** Government policies also have a direct influence on the use and amount of pressure on forests. National priorities, such as village relocations, improved road access and the establishment of the Nam Xam NPA have all contributed to increased, localized forest pressure. Concession approvals for mining and hydropower have also resulted in forest loss.

Immediate drivers of deforestation and forest degradation more directly cause forest loss and, therefore, should be the focus of REDD+ interventions. The following are considered to be the most relevant immediate drivers in Viengxay and Xamtai districts:

- **Incidence of poverty:** Both districts have a high incidence of poverty with the majority of the rural population reliant upon the natural resource base to satisfy food, fiber, energy and construction needs.

As populations grow and the drive to increase rural incomes increase, so has the intensification of natural resource exploitation to satisfy livelihood needs.

- **Income generation:** In addition to the needs of local populations to generate rural incomes, other individuals wishing to maximize incomes and profit also engage in the exploitation of natural resources. Often not local to the area, these outsiders primarily act as aggregators and traders of agricultural products or engage in commercial exploitation of NTFPs and illegal logging.

- **Absence of natural resource management plans:** Without clear management prescriptions on the use of natural resources at both the village level and higher (i.e. the Nam Xam NPA) there is no basis to limit the overexploitation of land and forest resources. This driver dovetails closely with the next two regarding limited law enforcement and the limited provision of extension services.

- **Limited law enforcement:** The limited government capacities within relevant line agencies means only sporadic and partial enforcement of land and forest use regulations occurs. Without this enforcement, there is little to discourage the unsustainable exploitation of resources, particularly in areas where quotas or management plans would typically be followed.

- **Limited provision of extension services:** Related to the above point, the lack of capacity also means technical line agencies are limited in their ability to provide communities with extension services in the forestry and agricultural sector. This limits the uptake of new and more effective methods of agriculture that could reduce pressure on forests. Similarly, improved fire management techniques are not being promulgated.

- **Issuance of logging quotas:** These can be both legal and quasi-legal. In addition to official quotas, special quotas have been granted to generate supplemental government revenues or as favors to influential personalities.

- **Limits on village production lands:** The creation of the Nam Xam NPA has, in some cases, reduced the amount of land available for certain communities. While it is unknown the extent to which the creation of the NPA resulted in forest increases, villagers have reported an intensification of land use within the remaining available land and consequently a loss of forest.

- **Local development goals:** Some of the actions taken to stimulate local economic development have affected forest loss. The promotion of cash crop production has generated short-term, local economic growth but has also resulted in greater pressure on forests. Similarly, infrastructure projects, such as road construction, have improved local transport options yet also provide better access to previously remote areas. The issuance of mining and hydropower concessions has also had impacts on forests to date.

The **actual sources of land-use change** are the activities that cause forest to be lost or degraded. These activities occur in response to the various drivers outlined above.

- **Agricultural expansion (deforestation and degradation)**: Forestland is being lost as farmers both increase the amount of area being converted for agricultural production and shorten their fallow cycles. This is both to satisfy the increasing demand for food from growing populations and national and international demand for cash crops. Maize production, in particular, is more land intensive than upland rice production leading to larger areas under cultivation and increasingly degraded agricultural lands that, in turn, necessitates further expansion into forested areas. The increasing availability of mechanized agriculture, made available by middlemen and traders, also greatly increases the ability of farmers to expand the area under cultivation.

- **Logging (degradation)**: Both legal and illegal logging occur within the districts. It is mostly selective logging for species needed for village construction purposes or to satisfy market demands for high value

timber species. Overexploitation at both the village level and for commercial purposes is causing forests across the districts to gradually undergo degradation as stocks of valuable species become increasingly rare. Logging occurs legally within production forest areas but also illegally in areas not designated for logging purposes.

- **Fires (degradation)**: Fire use is a prevalent feature of the local cropping cycle in order to clear fields in preparation for the growing season. Without proper fire management techniques these fires can burn beyond the field boundary can have spillover effects in the surrounding forests, thus causing degradation. Fires are not considered to be a major cause of forest loss, at least in the vicinity of the Nam Xam NPA, but impactful nonetheless.

- **Infrastructure development (deforestation and degradation)**: The construction of roads, mines and hydropower dams all result in forest loss. Land must be cleared for these projects while improved access results in secondary deforestation or degradation in the vicinity. To date, these impacts have not resulted in major losses, however this could change quickly depending on future trajectory of concession approvals.

Understanding who the **actors that cause deforestation and forest degradation** are is critical for any REDD+ initiative so that adequate activities and incentives can be directed to the appropriate groups of people. Primary actors are those whose actions directly cause forest loss while secondary actors influence why forest loss occurs yet do not cause it themselves.

- **Primary actors**: The main actors causing deforestation in the districts are local farmers who clear land for agriculture and log forests to either satisfy their construction and energy needs or to satisfy demand from national and international timber markets. As such, they should also be the primary targets and beneficiaries of any REDD+ interventions. Also contributing to forest loss are illegal loggers and government entities and/or private companies who undertake infrastructure projects.

- **Secondary actors**: Several actors fall into this category. Local and national authorities have enacted policies that have directly caused increased pressure on forests in certain areas, for example through the promotion of cash crop production or issuance of concessions. Agricultural traders and other business intermediaries also influence deforestation by providing an avenue through which farmers and others can sell their cash crops or illegally sourced timber and/or NTFPs.

While the above presents drivers present in the districts to date it is important to consider the trajectory of these drivers into the future. Based on the current situation, it is unlikely that the influence of the immediate drivers of deforestation will decrease in the near future while others may, in fact, increase over time. Population growth is on an upward trend, government capacities will likely remain low, and as farmers become increasingly integrated into the cash economy the desire and opportunity to sell cash crops will increase. Only limited activities in the mining and hydropower sectors are present in these districts, however changes in the number or scale of projects approved could drastically change their contribution to forest loss. These are developments that will have to be closely monitored to better understand potential future forest loss trajectories.

4 RECOMMENDED MITIGATION ACTIONS TO REDUCE DEFORESTATION AND FOREST DEGRADATION

In order to reduce the decline in forest carbon stocks, REDD+ interventions must be implemented that effectively incentivize the known agents and address the drivers of deforestation and forest degradation. Proposed below are recommendations on appropriate policies and measures to address the agents and drivers identified for Xamtai and Viengxay districts, as described in Section 3. It should be noted that these are initial recommendations and are provided as a basis for further discussions between the USAID LEAF program and its national, provincial, district and village stakeholders as they progress towards developing more comprehensive REDD+ strategies in the target districts. The recommended policies and measures are categorized according to the main level at which they would be implemented, i.e. village or district/province.

The below **village level** recommendations are primarily concerned with addressing those drivers that cause villagers to reduce forest cover and include: incidence of poverty, income generation needs, absence of natural resource management plans, limited law enforcement and limits on village production lands. These include:

1. **Conduct land and forest resource use planning:** Through participatory processes, such as the MAF endorsed Participatory Land Use Planning (PLUP) process, land and forest resource management plans should be developed that will support villages to use their land more rationally, with a view towards sustainable production. These plans support local level land management by: ensuring sufficient productive land is made available and distributed equitably, clearly establishing management zones, placing limits on the exploitation of forest resources and outlining self patrolling mechanisms. This process is also an opportunity to inform villagers of their customary and statutory land and resource rights as a way of supporting them to recognize and exclude outsiders' illegal or over-exploitative use of their resources.

2. **Provide agricultural extension services:** Promoting improved agricultural practices and ensuring that village lands are sufficiently high yielding to meet current and future needs is critical to counter the continuously expanding area under agriculture – currently the greatest cause of forest loss in the districts. Various types of extension activities should be considered and determined in collaboration with participating villages according to their perceived needs. Options include, but are not limited to: no till agriculture; improved ploughing and limiting soil erosion; crop diversification and improved crop rotations; agro-forestry; livestock husbandry; and improved fire management.

   While critical, the financial, technical, human and time resources required to conduct these types of extension services should not be underestimated. Similarly, uptake rates for these improved practices can be slow as initial hesitations to switch from trusted practices must be overcome. The provision of these extension services will need to occur in close collaborate with district level technical line agencies who, in turn, will also require supplemental training. Therefore, while these extension services are crucial for long-term sustainability of agricultural practices, the promulgation of these improved techniques will require time and are unlikely to generate large, initial reductions in forest loss.

3. **Provide livelihood support activities:** The reliance on natural resources for livelihoods is a product of the high rates of poverty throughout the district. The provision of livelihood support activities that both diversify livelihoods and increase incomes could help reduce pressure on forests. The USAID LEAF program and local stakeholders should, however, carefully consider the types of livelihood activities they want to promote and their form of delivery. Improved and diversified incomes may not necessarily translate into a reduction in pressure on forests, but rather a supplement to the existing low incomes. It therefore may be necessary to enter into conservation type agreements with communities whereby the provision of these livelihood alternatives are linked to corresponding forest protection obligations on the part of the community.

4. **Share carbon revenues:** As explained below, more closely integrating USAID LEAF priority areas into the Houaphan provincial REDD+ program could be an option to provide sustained revenues for communities in USAID LEAF target areas that contribute to reducing forest based emissions. Ensuring that communities also benefit from these revenues will help to incentivize villagers to continue to act as custodians of their forests.

Provincial and district level recommendation have been lumped together considering the close working relationship between these two levels; provincial directives are typically executed by district level technical line agencies. Since the following recommendations are primarily aimed at government line agencies, it will therefore necessitate buy-in at both the provincial and district levels. These recommendations primarily target the higher level drivers that are more easily tackled by government agencies, such as: lack of law enforcement, limited provision of extension services, issuance of logging quotas, limits on village production land and local development goals.

1. **Provide technical training and financial means to technical line agencies:** The under capacitated and under resourced technical line agencies are currently unable to perform their mandated duties, particularly in relation to conducting village level land-use planning, providing agricultural extension services, law enforcement and broader forest management. Staff technical capacities need to be improved and financial and material resources provided to allow these line agencies to perform the ongoing training, management and oversight of agricultural and forest use to ensure forest loss is not occurring.

2. **Improve management of the Nam Xam NPA:** Unlike the Nam Et Phou Louey NPA in western Houaphan province, the Nam Xam NPA does not have a functioning management unit. Establishing one, capacitating the staff and elaborating a management plan should therefore be a priority. As with other NPAs, core elements of this management plan should include patrolling and law enforcement, monitoring and community outreach.

3. **Review logging quota issuance procedures:** At both the district and provincial level a transparent review of both existing logging quotas and the process of issuing these quotas should be conducted. Checks and balances should be put in place to limit the issuance of inflated or special interest quotas and improved oversight and monitoring of entities issued with quotas conducted.

4. **Conduct district level land use planning**: It is crucial that the district conduct careful planning on land use and development priorities to minimize impacts both on standing forest and local livelihoods. The siting of potential mines, hydropower dams and large-scale agricultural concessions should be considered in the context of their impact on forests and broader environmental impacts.

5. **Review of district and provincial socio-economic development priorities:** As a way of informing the above district level land use planning, careful consideration should also be given to provincial and district development priorities in terms of their ability to generate sustained economic and environmental returns.

6. **Improved monitoring and enforcement of concessionaire's obligations:** Concession agreements include stipulations on social and environmental mitigation measures. Considering the scale of these concessions careful monitoring and enforcement of their obligations should be conducted to minimize potential spillover impacts.

7. **Support the greater integration of USAID LEAF target districts into the Houaphan provincial REDD+ program:** The CliPAD program is currently supporting Houaphan province to develop and register a provincial wide REDD+ program compliant with the VCS JNR requirements. If registered and the province demonstrates performance with regards to reducing forest based emissions, the province

would be able to generate carbon revenues through the sale of VCS credits. Fully integrating these USAID LEAF target areas into this jurisdictional program, in addition to the CliPAD priority areas in western Houaphan, could be an option to ensure sustained revenues for communities and government agencies in USAID LEAF target areas responsible for reducing forest based emissions.

ANNEX 1: SELECTION OF MOST APPROPRIATE DATASET

Provided below is a more comprehensive description of the analysis Forest Carbon undertook to select the dataset that best captures the forest cover change dynamics in Xamtai and Viengxay districts.

AVAILABLE DATASETS

DATE AND IMAGERY AVAILABLE

Summarized below in Table 5 are the dates and type of underlying imagery used to conduct the change analysis for the three available datasets. It also indicates which imagery was available to Forest Carbon for its analysis.

As Table 5 demonstrates, the periods of analysis and imagery available for the three datasets are not congruent. The Aruna dataset begins in 1995 while Hansen and WCS begin in 2000. On the other hand, the final year of analysis for WCS and Aruna is 2010 while Hansen's extends to 2012.

A further complicating matter is that while nominal years of analysis may match up (for e.g. 2000) the underlying imagery does not. It was not possible to know the actual dates of the Hansen dataset as metadata for the imagery was not available. It was therefore necessary to assume that the nominal and actual years for the Hansen imagery matched up. The WCS imagery matches closely to the stated nominal years. Aruna's nominal years, on the other hand, differ quite significantly from the year of the actual imagery (for e.g. the 2005 nominal year is represented by imagery from 2002 and 2007). As described later, this incongruence affected how the comparison of datasets was conducted both in terms of selecting imagery upon which to conduct the comparison and which change polygons to use to compare forest loss events.

Table 5: Imagery type and dates used for the change analysis for each dataset

Dataset	Nominal Year	Satellite/ Resolution	Image date	Available
Hansen	2000	Landsat, 30m	N/A*	□+
	2001	Landsat, 30m	N/A*	□
	2002	Landsat, 30m	N/A*	□
	2003	Landsat, 30m	N/A*	□
	2004	Landsat, 30m	N/A*	□
	2005	Landsat, 30m	N/A*	□
	2006	Landsat, 30m	N/A*	□
	2007	Landsat, 30m	N/A*	□
	2008	Landsat, 30m	N/A*	□
	2009	Landsat, 30m	N/A*	□
	2010	Landsat, 30m	N/A*	□
	2011	Landsat, 30m	N/A*	□
	2012	Landsat, 30m	N/A*	□+
Aruna	1995^	Landsat, 30m	1994-04-09 (W)	□
			1993-12-27 (E)	□
	2000^	Landsat, 30m	2000-09-17 (W)	□
			1999-12-27 (E)	□
	2005^	Landsat, 30m	2002-12-22 (W)	□
			2007-11-08 (E)	□
	2010	RapidEye, 5m	2010-12-27 (W)	□
			2011-03-21 (E)	□
WCS	2000^	Landsat, 30m	2000-04-01 (W)	□
			2000-01-02 (E)	□
	2004^	Landsat, 30m	2004-03-11 (W)	□
			2003-12-23 (E)	□
	2007^	Landsat, 30m	2006-11-02 (W)	□
			2007-02-01 (E)	□
	2010^	Landsat, 30m	2010-04-13 (W) (Gap filled with 2010-03, 2010-04 & 2010-10)	□
			2010-02-01 (E) (Gap filled with 2010-03, 2010-04 & 2010-10)	□

* Metadata for the available Hansen imagery is not available therefore making it impossible to know the exact date used for each year.
\+ Not available from USAID LEAF but subsequently obtained from earthenginepartners.appspot.com.
^ Due to the projection of Landsat scenes it was necessary to obtain two scenes for each nominal year to have full coverage of the two districts

DATASET APPROACH TO CHANGE DETECTION

The Hansen products consist of three data layers: i) gross forest cover gain, ii) gross forest cover loss, and iii) tree canopy cover. All three layers were derived independently, but using the same input dataset (Landsat time-series) and algorithm (bagged CART). Training data to relate the Landsat inputs were derived from image interpretation methods, including mapping of crown/no crown categories using very high spatial resolution data such as Quickbird imagery, existing percent tree cover layers derived from Landsat data, and global MODIS percent tree cover, rescaled using the higher spatial resolution percent tree cover data sets[4]. Image interpretation on-screen was used to delineate change and no change training data for forest cover loss and gain. From this it was possible to generate the abovementioned annual data layers for each of the twelve years of analysis.

For the Aruna dataset, Aruna selected cloud free Landsat imagery as close to the chosen nominal years of 1995, 2000 and 2005 for the historical analysis, while RapidEye from 2010/11 was re-sampled to 20m for the purposes of the analysis for the 2010 nominal year. The main pre-processing for the imagery included: orthorectification (geometric correction), color calibration and mosaicking and haze removal.

Change mapping was conducted exclusively for the district of interest through an unsupervised classification of the image date pairs with the use of image processing software that automatically separated the image pixels into different classes based on their digital values. Using direction and intensity information, it was possible to classify land cover change into different classes through visual interpretation. This allowed the operators to easily eliminate areas of false change due to spectral errors. This process was conducted for each image pair resulting in forest loss polygons for three total periods of analysis (1995-2000, 2000-2005, 2005-2010).

The WCS dataset covers the entire province of Houaphan and in addition to identifying polygons of change also created land and forest cover classifications for each year of analysis. The 2000 image was taken as the starting point and segmentation techniques used to classify this initial image into seven different land cover classes (Current Agriculture, Fallow, Grassland, Shrub/Bamboo, Mixed Deciduous Forest Low & High, Evergreen Forest). Segmentation techniques and vegetation indexes were then used to identify polygons of change as well as the direction of change. From this, updated land cover classifications for each year of analysis could be created. An accuracy assessment of the 2010 land cover classification ensured the products met minimum accuracy thresholds. To assess forest cover change over the ten-year period, the land cover maps were converted into forest cover maps by combining non-forest and forest classes. By comparing these four forest cover maps it was possible to assess forest cover change trends.

LIMITATIONS OF DATASETS

Prior to assessing which of the datasets best captured the forest cover change dynamics in the landscape, it was important to consider the known limitations of each dataset.

The main limitations of using the Hansen dataset are:

- **Definition of forest and forest loss/gain**: Hansen defines forest as any area with tree cover greater than 25%. Forest loss is defined as the disturbance or complete removal of tree cover to less than 25%. Forest gain is defined as the inverse of forest loss. It is important to note that despite regional calibration undertaken for this dataset, this global definition of forest and forest loss, does not always translate to actual deforestation in specific locales. For example, in some cases, Hansen identified tree loss may actually be associated with the loss of plantations or herbaceous crops – not forest – and can

[4] http://www.nbforest.info/blog/response-dag-lindgrens-blog-entry-deforestation-north

therefore lead the dataset to over or underestimate forest loss in particular geographies[5]. This is of particular concern in a country like Lao PDR where land-use cover change patterns are extremely dynamic due to swidden farming.

- **Ability to refine classification:** Although attempts were made to regionally calibrate this dataset, it remains a global dataset and is therefore limited in its ability to identify localized dynamics. As a global dataset it was not possible to conduct area specific accuracy assessments or post classification refinements based on the experience of operators with local knowledge. This means potential misidentification of change processes would remain as part of the final results. In fact, Hansen recognize that "definitions of the land-cover type or change process, quality of training data, and limitations of Landsat multi-temporal metrics strongly influence output product accuracy."[6]

The main limitations of the Aruna dataset are:

- **Deforestation only mapping**: The dataset only identified areas of deforestation. This limits the dataset's ability to comprehensively capture the dynamic changes in land cover known to occur in Lao PDR.
- **No benchmark forest classification**: The dataset did not create its own land or forest cover classification against which to calculate rates of change as a percentage of original forest cover. It was therefore necessary for Aruna to make use of other existing datasets created by different operators and using different techniques to perform these calculations and produce land and forest cover maps.
- **Clipped analysis does not cover full extent of Nam Xam NPA**: A small portion of the Nam Xam NPA falls outside of Xamtai and Viengxay districts (see Figure 23). Aruna, however, conducted change detection only within the boundaries of this defined Xamtai/Viengxay boundary and therefore does not provide results for the full extent of the Nam Xam NPA. This area is very small, however, and should not influence too strongly on the decision to utilize one dataset over another.

The main limitations of the WCS dataset are:

- **Limited post classification refinement:** The WCS team had only a limited amount of time to conduct post classification refinements of change meaning, as above with Hansen, that potential misidentification of change processes would remain as part of the final results. Additionally, the limited amount of time available for post classification refinements was spread over a much larger area (all of Houaphan province) than the area analyzed by Aruna.

COMPARISON OF DATASETS

Below is a description of the approach taken to qualitatively determine which dataset best captures the forest cover change dynamics in the target landscape.

METHODOLOGY

To provide an objective appraisal of the quality of each dataset, six clusters of dynamic forest loss were visually identified and selected. These areas represented approximately 10% of the combined districts of Viengxay, Xamtai and Kouan districts – the original extent for which Aruna conducted change analysis. This full extent was analyzed in order to understand the validity of the dataset before calculating values specific for Xamtai and Viengxay districts.

[5] Robert Tropek, Ondřej Sedláček, Jan Beck, Petr Keil, Zuzana Musilová, Irena Šímová, David Storch (2014). Comment on "High-resolution global maps of 21st-century forest cover change". Science 30 May 2014: Vol. 344 no. 6187 p. 981, DOI: 10.1126/science.1248753

[6] http://www.nbforest.info/blog/response-dag-lindgrens-blog-entry-deforestation-north

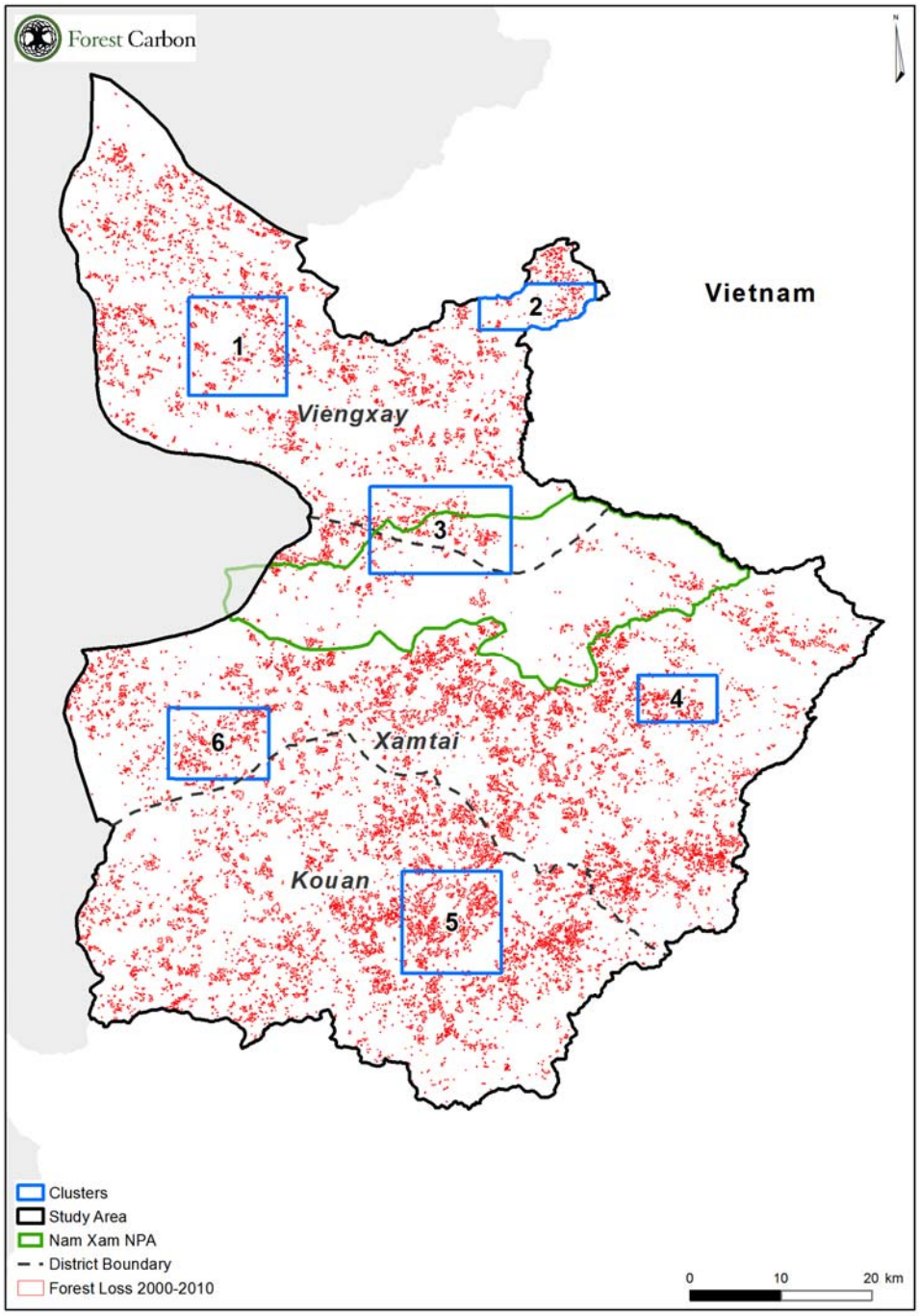


Figure 7: Location of six clusters used to assess the dataset's identification of forest loss areas

The first step taken towards analyzing the validity of each dataset was to select the 25 largest polygons from each cluster for each dataset to assess their accuracy in identifying deforestation. This was done based on a criteria of >50% area classified as loss being correct with respect to the base imagery. A visual assessment was also made to determine whether the area truly represented deforestation, rather than simply loss of vegetation density based on expert local experience identifying land cover change dynamics in Lao PDR. Examples of how this scoring occurred are provided in Figure 8 through Figure 10.

Figure 8: Example of a Hansen polygon in Cluster 5 classified as accurate. More than 50% of the polygon matches with the forest loss event.

Figure 9: Example of a Hansen polygon in Cluster 1 classified as inaccurate. More than 50% of the polygon does not accurately represent the loss event.

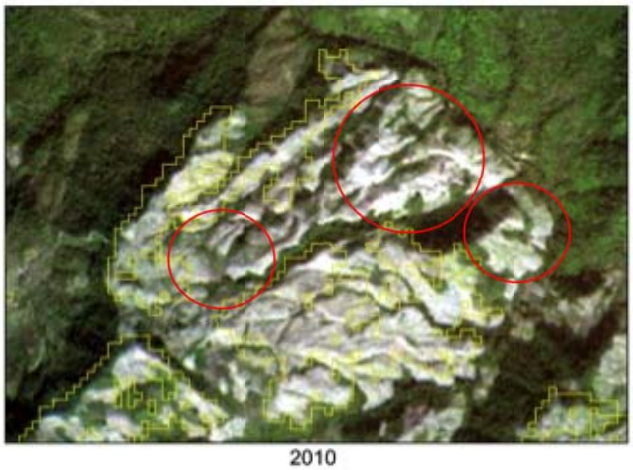


Figure 10: Example of a Hansen polygon in Cluster 1 classified as inaccurate. More than 50% of the forest loss event is not captured by the polygon. The circled areas indicate the extent of the forest loss event not captured by the adjacent polygons.

The initial visual inspection of the largest polygons was intended to provide information that would reveal patterns of under or over-estimation in order to target areas of inconsistency between datasets, allowing for the visual analysis of potential errors in each dataset. From this, a broader scan was conducted outside the clusters in order to assess the extent of potential error throughout the rest of the district[7].

Despite the fact that the Aruna imagery dates differed from Hansen, it was still possible to compare areas consistently classified as change in both datasets. Further, it was possible to determine whether changes identified by Hansen conform to the underlying Aruna imagery was a product of the date differences of the imagery or a misclassification of the Hansen data.

A combination of the LandSat imagery used by WCS and Aruna was used as a basis for identifying whether change polygons in fact represented areas of deforestation. The clearest Landsat imagery for the 2000 and 2005 nominal years were selected so as to facilitate the visual inspection of changes. The Aruna and WCS imagery included all seven spectral bands common to LandSat imagery, including bands 1 and 2, which are necessary for conducting visual inspection. The Hansen imagery on the other and only included four spectral bands and, more critically, did not include those bands that support visual inspection. The 5m RapidEye imagery was used for the 2010 nominal year.

Despite the fact that the imagery dates differed between Hansen, Aruna and WCS it was still possible to compare areas consistently classified as change in both datasets. Further, it was possible to determine whether changes identified by Hansen that do not conform to the underlying imagery was a product of the date differences of the imagery or a misclassification of the Hansen data.

ASSESSMENT OF SYMPTOMATIC PROBLEMS FOR EACH DATASET

Below are the scores attained for each dataset from the visual inspection of the 25 largest polygons of loss for each cluster.

Table 6: Scores assessing the congruence of the largest 25 polygons with observed deforestation events

Cluster	Hansen		Aruna		WCS	
	Correct	% Correct	% Correct	% Correct	Correct	% Correct
1	16	64	21	84	15	60
2	14	56	19	76	15	60
3	11	44	24	96	14	56
4	16	64	25	100	20	80
5	22	88	25	100	20	80
6	13	52	25	100	16	64
Average		**61**		**93**		**67**

As Table 6 shows, the Aruna dataset showed much higher congruence with the observed deforestation events than the Hansen or WCS datasets. The clusters that demonstrated lower congruence for a particular dataset (e.g. 2, 3 and 6 for Hansen and 1, 2, and 3 for WCS) provided important information in terms of identifying

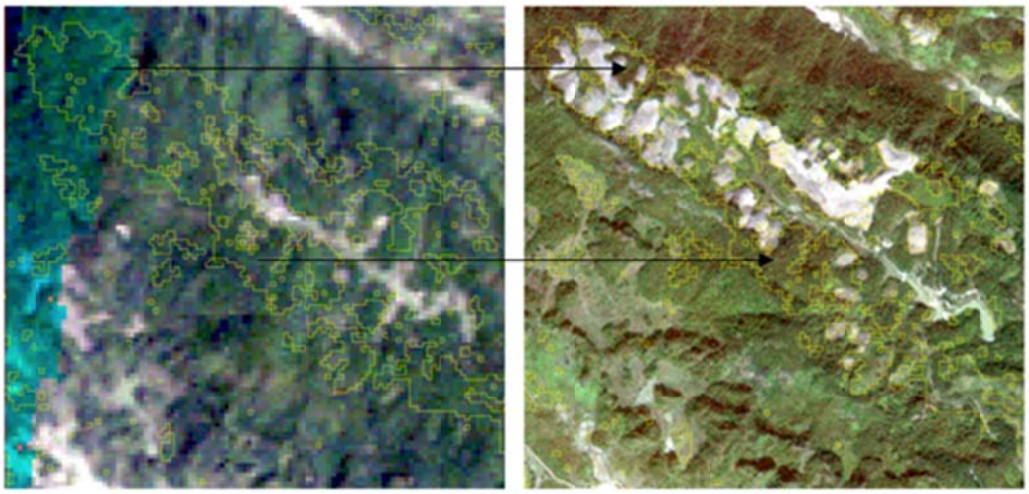
[7] It should be noted that it was only possible to compare the Hansen and Aruna datasets with respect to areas where both areas indicated deforestation since the Aruna dataset did not identify reforestation areas, whereas the Hansen data did. The quality of Hansen's forest gain polygons to capture true reforestation were also reviewed visually and considered in the overall decision on which dataset to select.

symptomatic problems with each dataset. Summarized below are the observations with regards to general failures of either under or over-estimation for all three datasets.

It was observed that Hansen dataset consistently overestimated the amount of forest loss occurring in the clusters. This was due to both overestimating the extent of forest loss (i.e. defining polygons of change larger than the actual change occurring) as well as the location of deforestation (i.e. defining loss where in fact actual deforestation did not occur). Although not frequent, the Hansen data was found to define loss in areas where actually gain had occurred. While the overestimation by extent was particularly noticeable in clusters 1, 4, 5 and 6, the overestimation by location occurred in all clusters and across the entire district.

In addition to these failures of overestimation, the Hansen data also underestimated loss, principally by location. Underestimation by extent was less frequent. This was most noticeable in areas outside of the clusters. Screenshot images of these issues are provided below in Figure 11 through Figure 17.

A review of the Hansen forest gain data layer indicated a similar trend with regards to defining forest gain where, in fact, the change simply relates to increases in vegetative cover following clearance for agriculture. This issue was observed across the district, examples of which are provided in Figure 18 and Figure 19.



2000 2010

Figure 11: Hansen overestimation of forest loss by extent (Cluster 1). Arrows indicate polygons that encompass an area larger than the actual deforestation event.

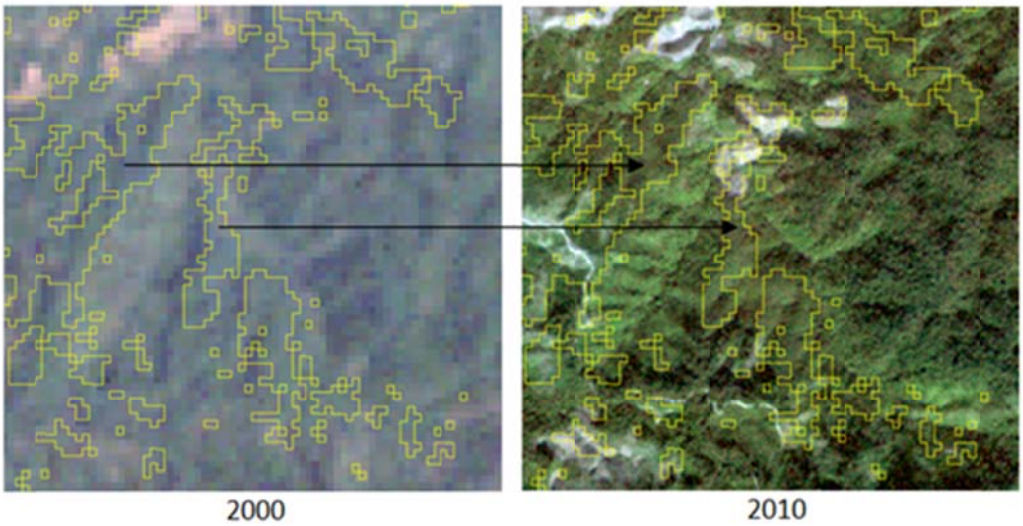


Figure 12: Hansen overestimation of forest loss by extent (Cluster 6). Arrows indicate polygons that encompass an area larger than the actual deforestation event.

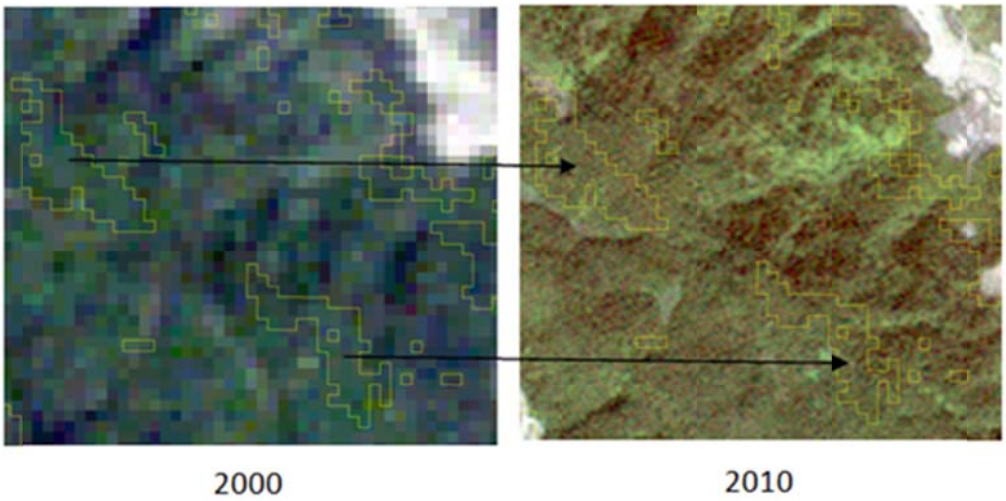


Figure 13: Example 2 of Hansen overestimation of forest loss by location (Cluster 1). Polygon shows loss when none occurred.

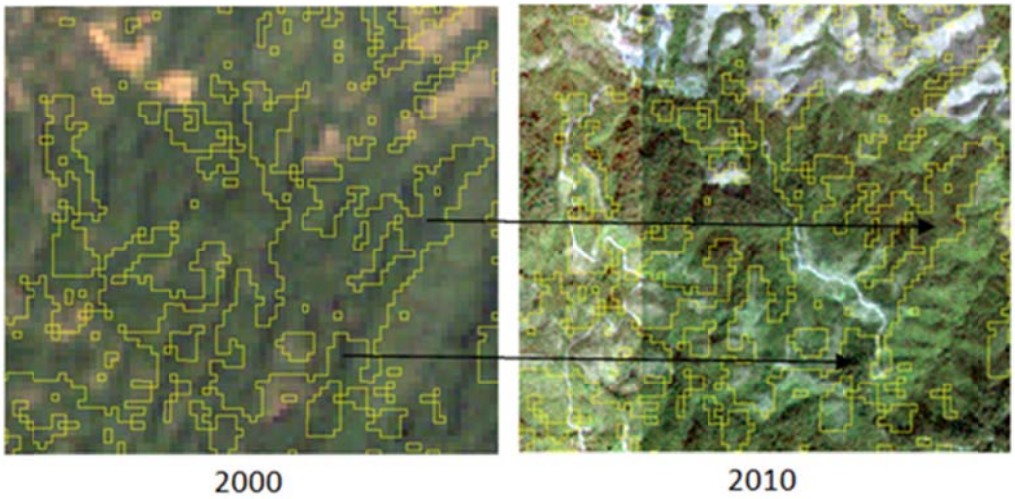


Figure 14: Example 3 of Hansen's overestimation of forest loss by location (Cluster 6). Polygon shows loss when none occurred.

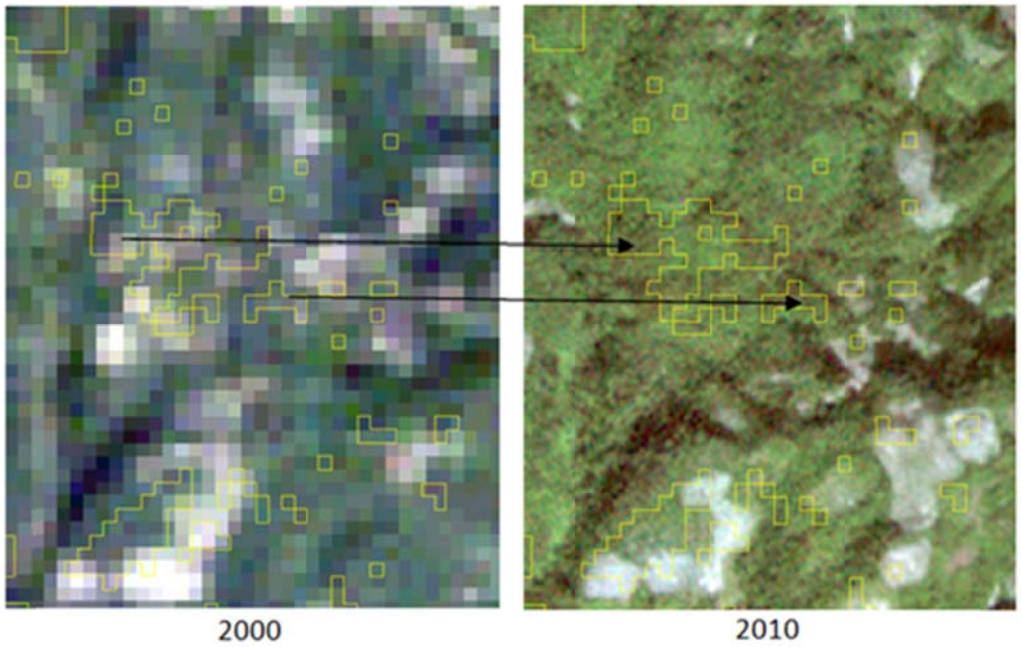


Figure 15: Hansen overestimation of forest loss by location (Cluster 3). Arrows indicate polygons that identify forest loss when in fact gain occurred

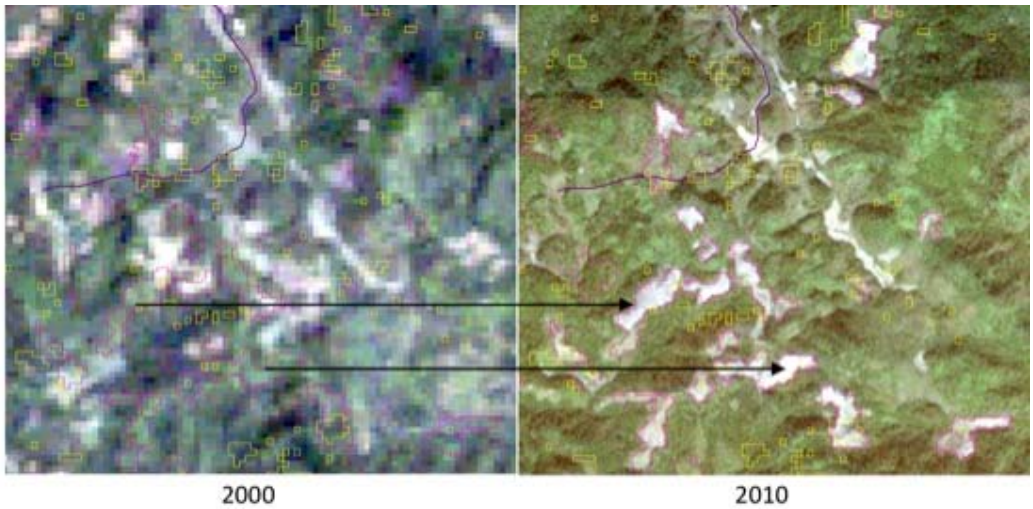


Figure 16: Hansen underestimation of forest loss by location (Cluster 1). Arrows indicate polygons of loss not identified by Hansen yet correctly identified by Aruna (Hansen in yellow, Aruna in magenta)

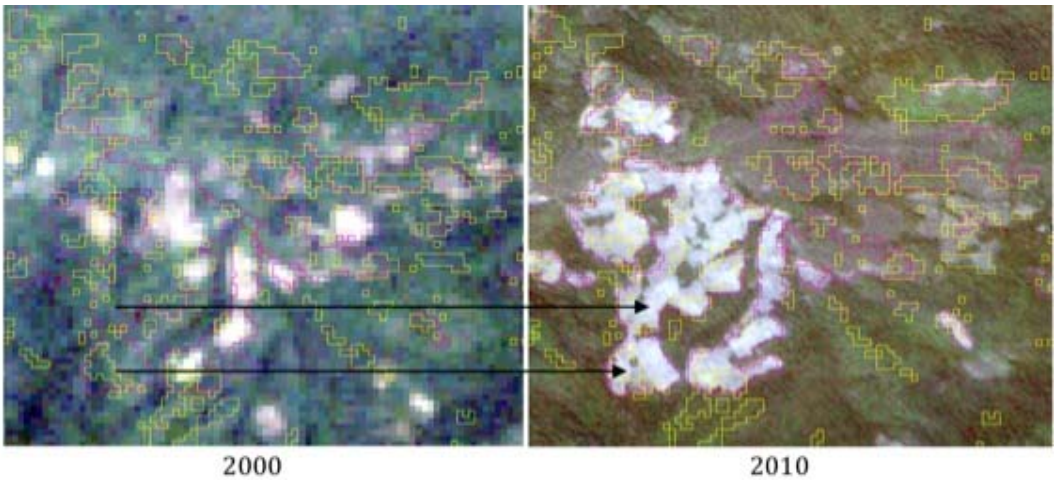


Figure 17: Hansen underestimation of forest loss by location (Cluster 3). Arrows indicate polygons of loss not identified by Hansen yet correctly identified by Aruna (Hansen in yellow, Aruna in magenta)

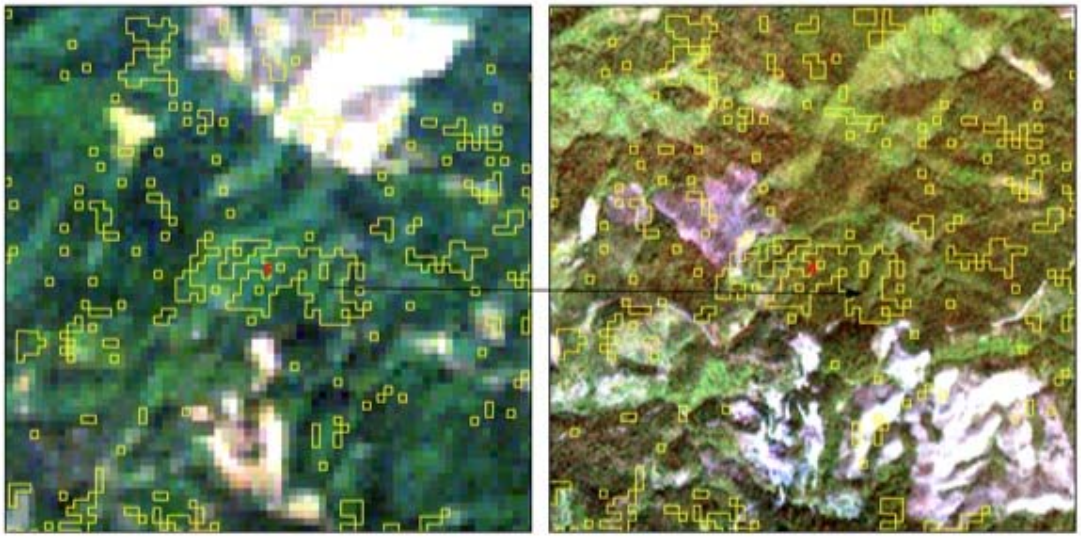


Figure 18: Hansen overestimation of forest gain by location (Cluster 6). Arrows indicate polygons that transitioned from lower to higher vegetative states, but not to forest.

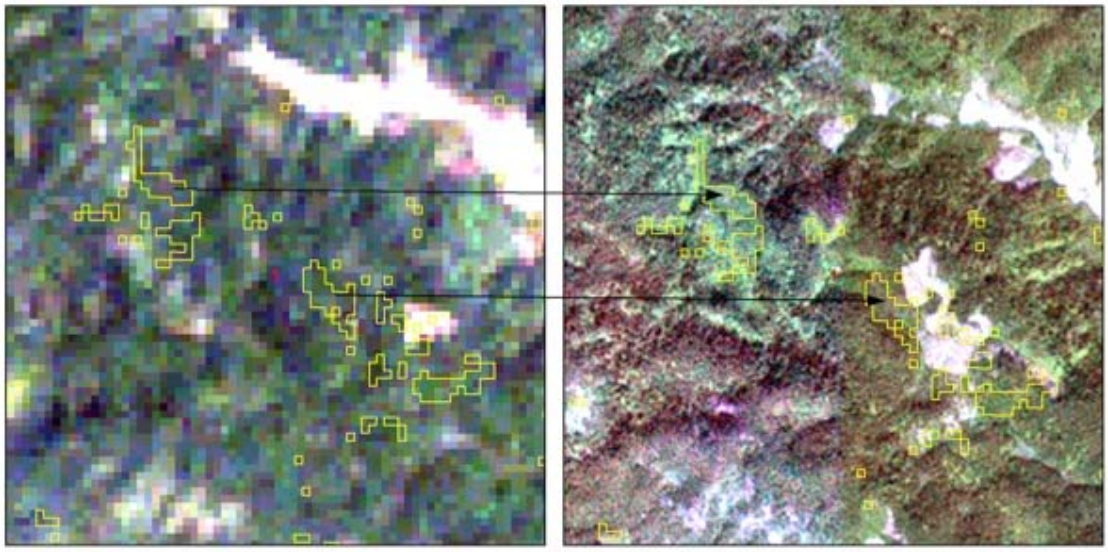


Figure 19: Hansen overestimation of forest gain by location (Cluster 1). Arrows indicate polygons that transitioned from lower to higher vegetative states, but not to forest.

The Aruna dataset also, on occasion, overestimated deforestation by identifying forest loss events where none in fact occurred. Although in some cases these errors were represented by large polygons there were relatively few of these errors. In addition to overestimating, evidence was found of the Aruna dataset tending to underestimate deforestation as well, both by extent as well as by location. Screenshot images of these issues are provided below in Figure 20 through Figure 24.

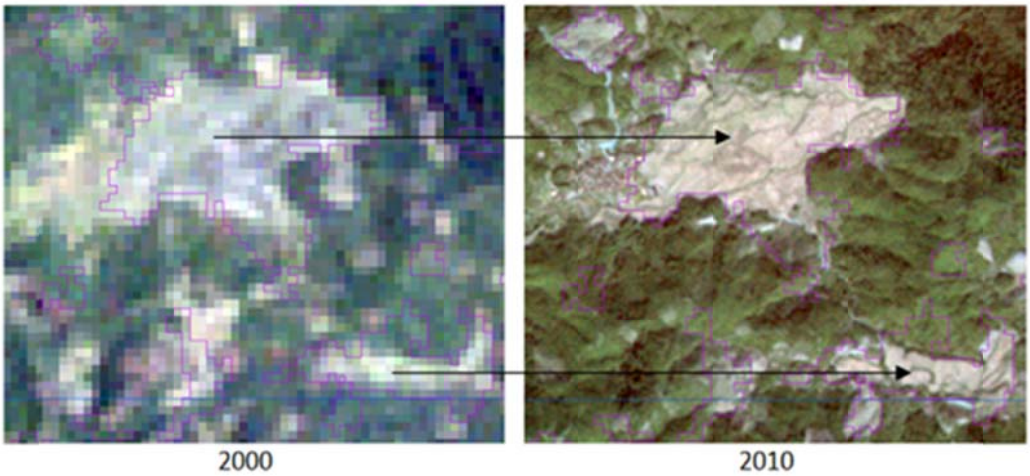


Figure 20: Aruna overestimation of forest loss by location (Cluster 2). Arrows indicate polygons of loss where forest did not exist to begin with.

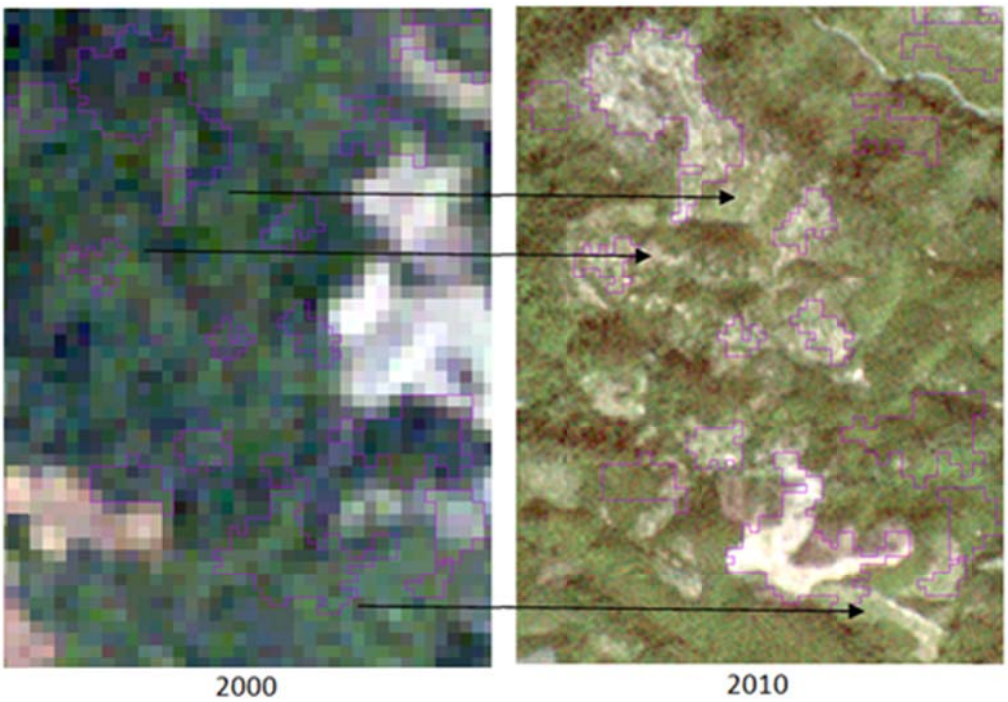


Figure 21: Aruna underestimation of deforestation by extent (Cluster 1). Arrows indicate polygons of loss smaller than the actual loss event.

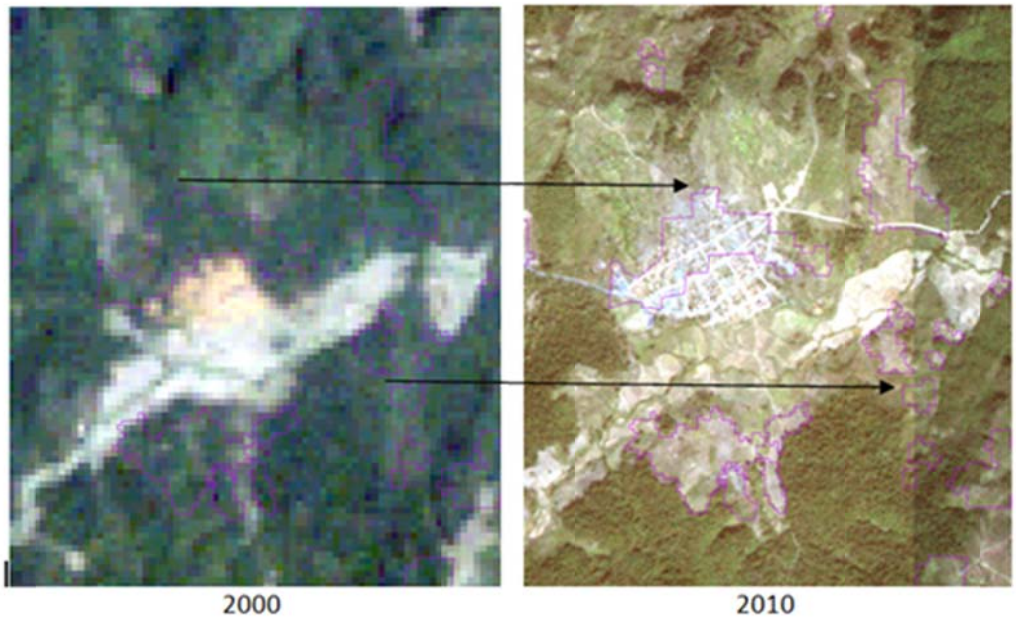


Figure 22: Aruna underestimation of deforestation by extent (Cluster 5). Arrows indicate polygons of loss smaller than the actual loss event.

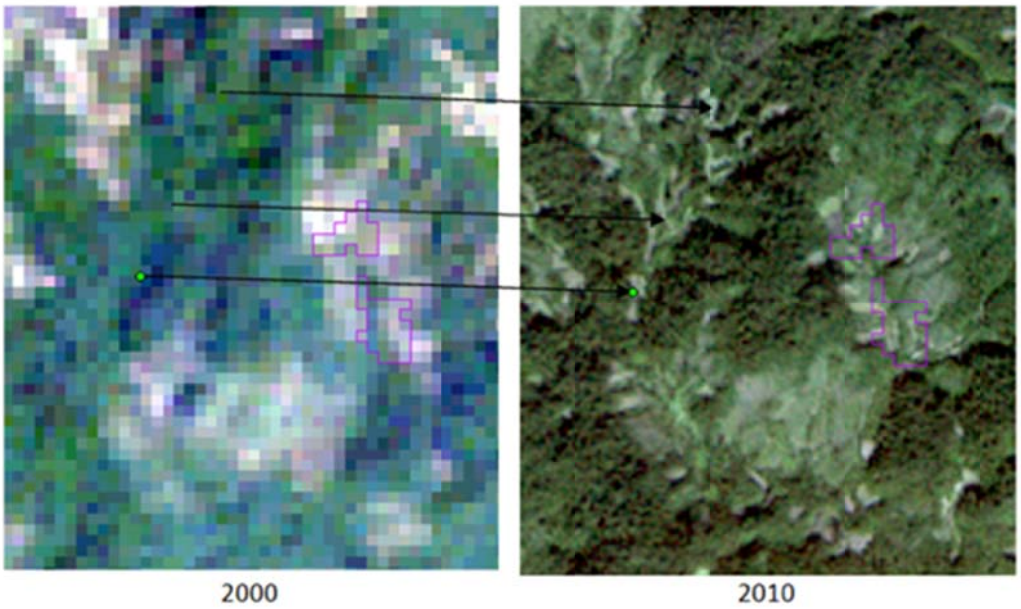


Figure 23: Aruna underestimation of deforestation by location (Cluster 2). Arrows indicate areas of loss not identified by Aruna.

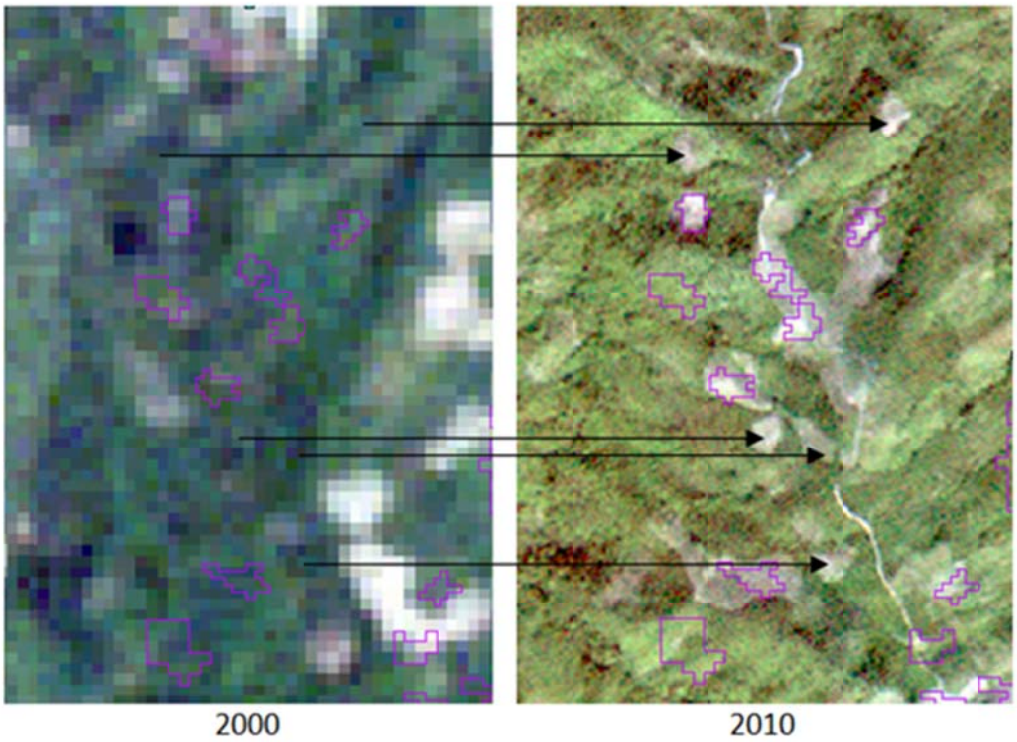


Figure 24: Aruna underestimation of deforestation by location (Cluster 6). Arrows indicate areas of loss not identified by Aruna.

Similar to the Aruna dataset, the WCS dataset was found to over and underestimate forest loss, both in relation to the extent and location of forest loss. As discussed later, the underestimation was considered a more severe issue than the overestimation. Screenshot images of these issues are provided below in Figure 25 through Figure 31.

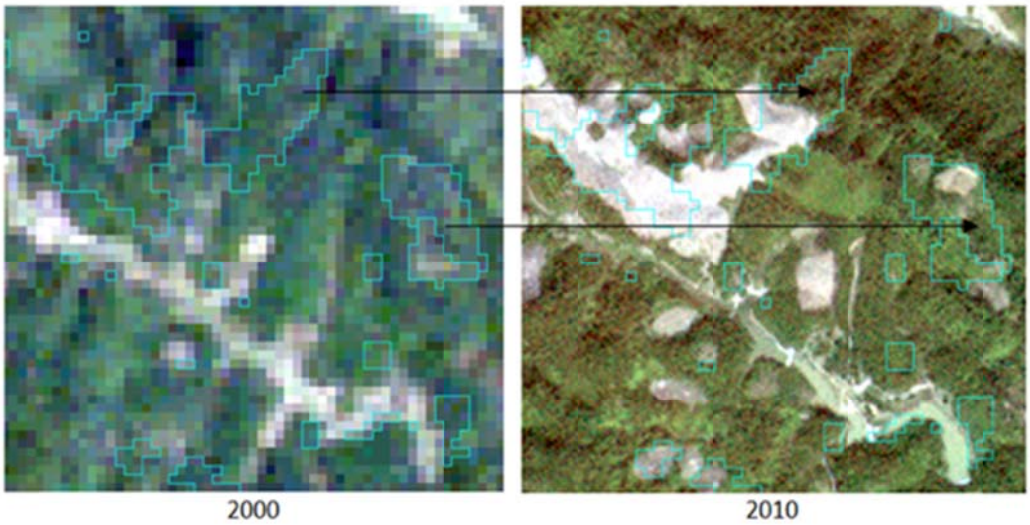


Figure 25: WCS overestimation of deforestation by extent (Cluster 1). Arrows indicate polygons that encompass an area larger than the actual deforestation event.

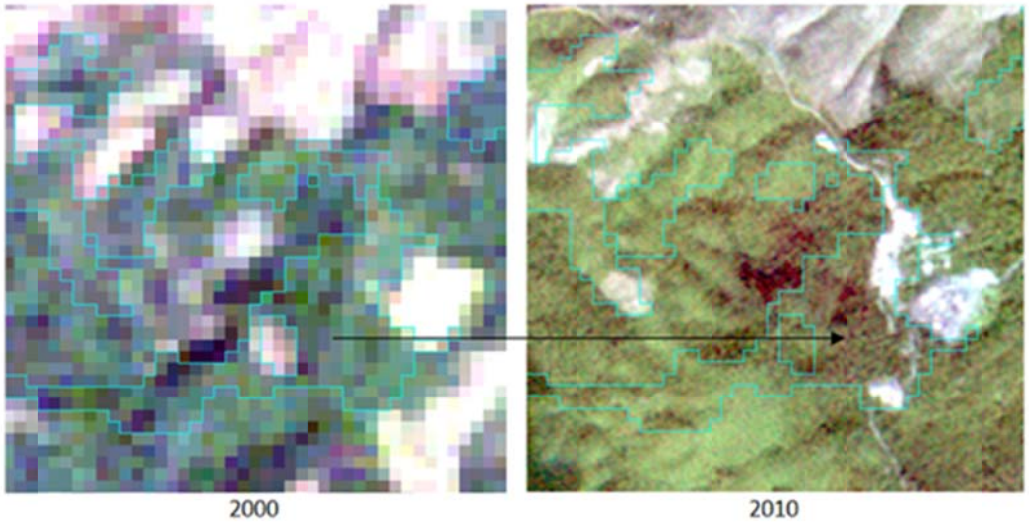


Figure 26: WCS overestimation of deforestation by extent (Cluster 6). Arrows indicate polygons that encompass an area larger than the actual deforestation event.

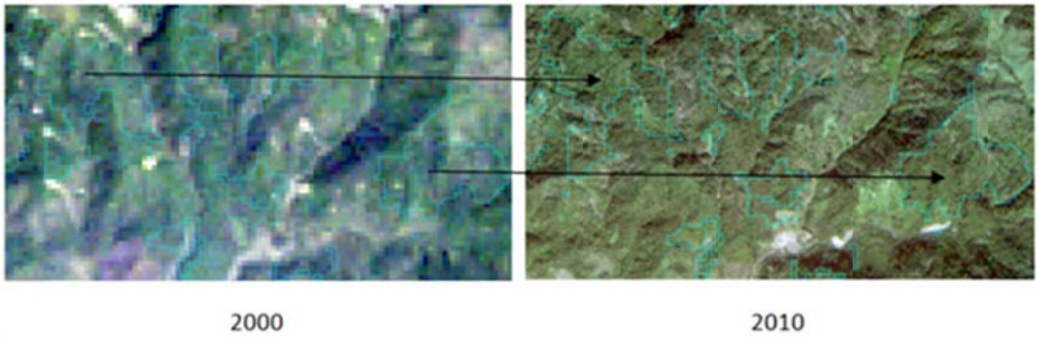


Figure 27: WCS overestimation of deforestation by location (Cluster 2). Arrows indicate areas identified as loss when none occurred.

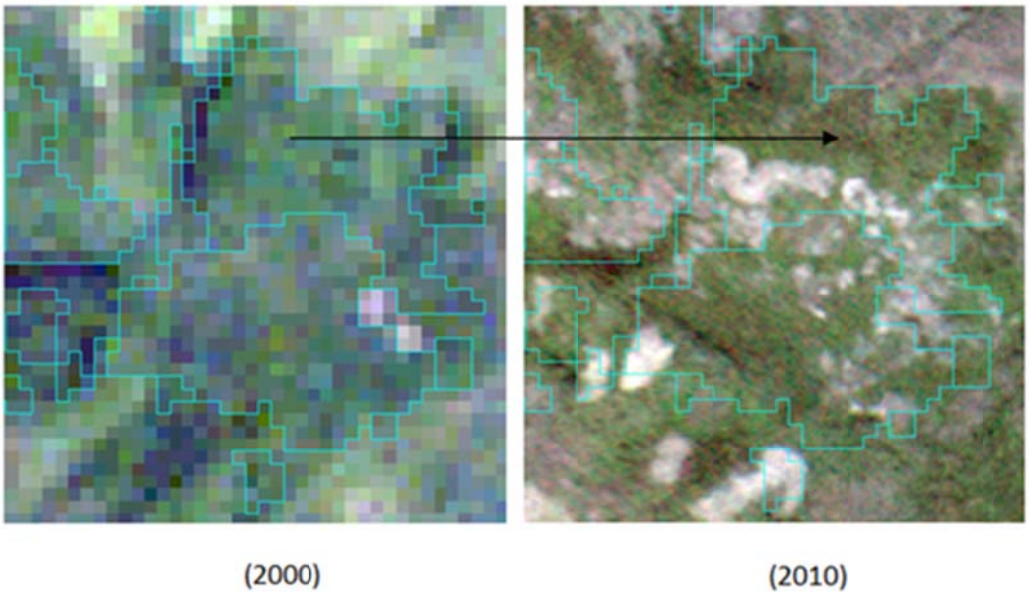


Figure 28: WCS overestimation of deforestation by location (Cluster 4). Arrows indicate areas identified as loss when none occurred.

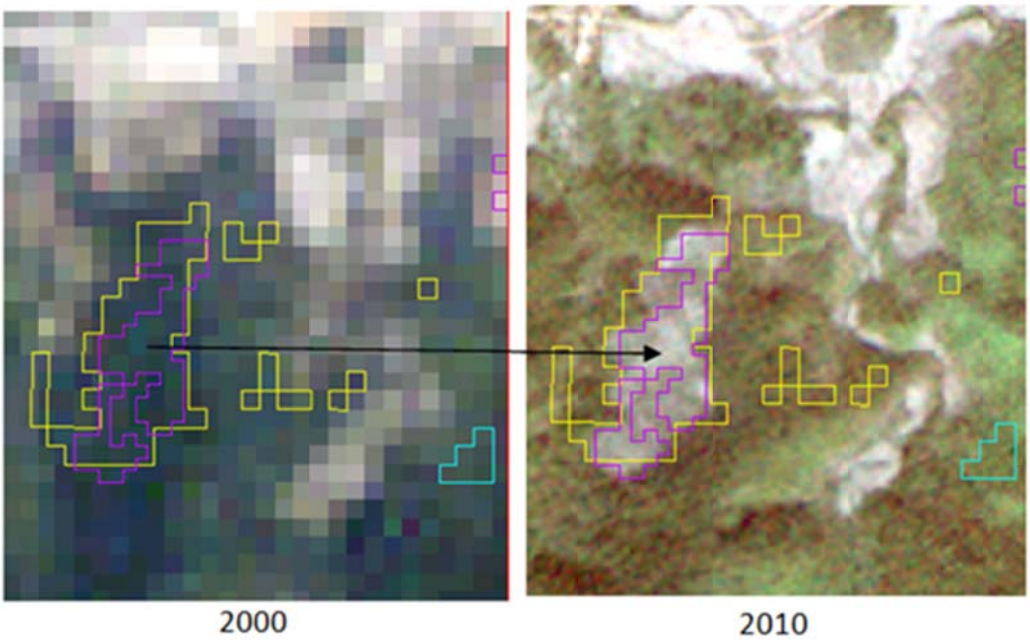


Figure 29: WCS underestimation of deforestation by location (Cluster 1). Arrows indicate areas correctly identified as loss by Hansen (yellow) and Aruna (magenta), but not by WCS (cyan).

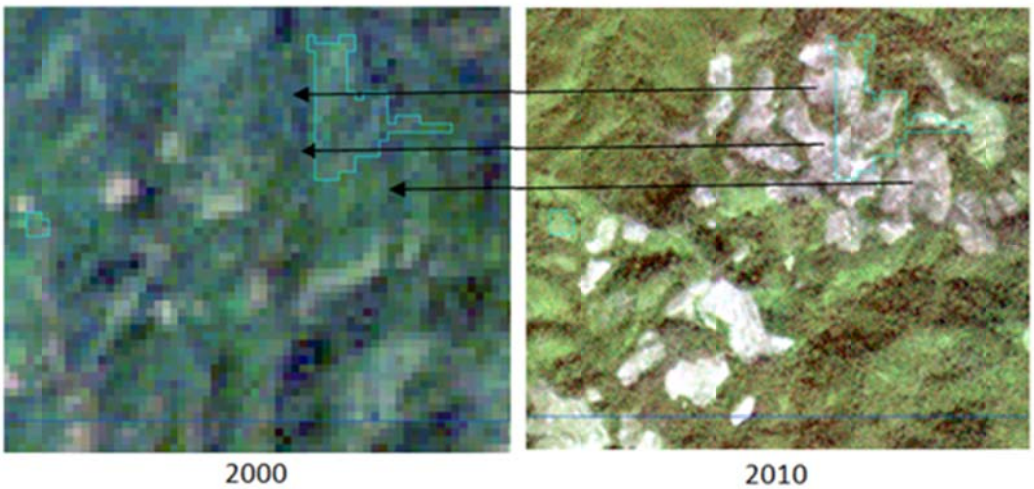


Figure 30: WCS underestimation of deforestation by extent (Cluster 1). Arrows indicate polygons of loss smaller than the actual loss event.

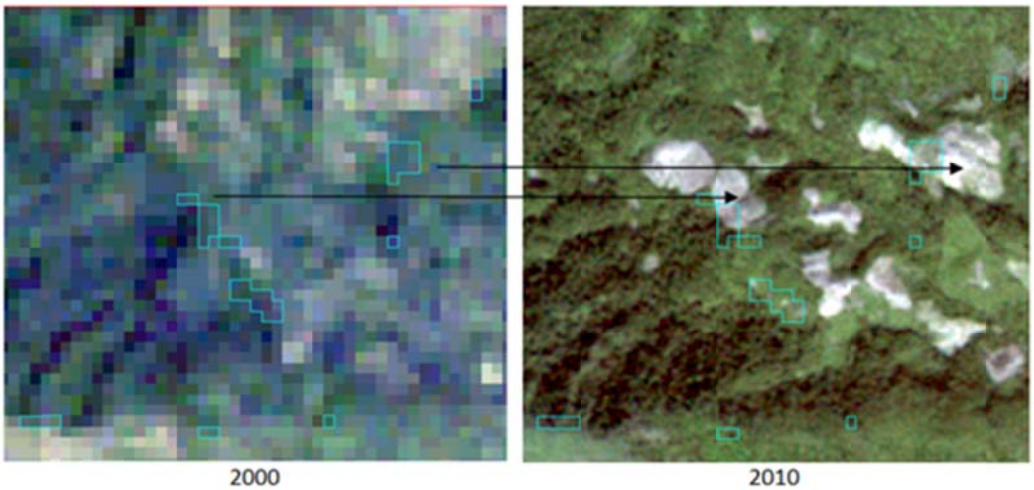


Figure 31: WCS underestimation of deforestation by extent (Cluster 2). Arrows indicate polygons of loss smaller than the actual loss event.

4.1.1 CONCLUSION ON MOST APPROPRIATE CHANGE DETECTION DATASET

Provided below in Table 7 is a summary of the symptomatic issues outlined above and an assessment of the severity of the problem, when considered across the entire target landscape, with regards to accurately representing forest loss dynamics.

Table 7: Assessment of severity of symptomatic issues on dataset's ability to capture accurate forest loss dynamics

Dataset	Problem	Reason	Severity
Hansen	Overestimation	By extent	Low
		By location	High
	Underestimation	By location	High
		By extent	Low
Aruna	Underestimation	By extent	Medium
		By location	Low
	Overestimation	By location	Low-Medium
WCS	Overestimation	By extent	Low
		By location	Low
	Underestimation	By location	High
		By extent	Medium-High

Based on the review of the symptomatic issues across the entire district, the Hansen and WCS datasets were considered to be less accurate than Aruna. The WCS dataset tended to underestimate forest loss too much while the Hansen dataset exhibited inacuuracies both in over and underestimating loss. The Aruna dataset was the more accurate both in terms of identifying the correct extent of forest loss as well as the locations.

The total amount of loss for the three datasets for the same eleven-year period of analysis is provided in Table 8. The Aruna dataset estimates the most amount of deforestation at 30,280 ha, followed by Hansen at 29,322 ha and lastly WCS at 26,031 ha. These results support the view that the WCS dataset is underestimating the total amount of deforestation compared to the other datasets.

Table 8: Total deforestation per period as calculated by the two datasets

Dataset	Actual Year of Analysis	Deforestation (ha)
Aruna	2000 – 2007	16,736
	2007 – 2011	13,657
	Sum Total	**30,393**
Hansen	2000 – 2007	16,922
	2007 – 2011	12,400
	Sum Total	**29,322**
WCS	2000 – 2004	9,226
	2004 – 2007	8,480
	2007 - 2011	8,325
	Sum Total	**26,031**

Although both the Hansen and WCS datasets have the advantage of also showing forest cover gain, and therefore forest cover changes associated with the swidden cycle, this was not deemed a sufficient reason to select either

of these datasets over Aruna. The Hansen dataset forest gain layer also demonstrated symptomatic problems with the accurate identification of actual reforestation. Many areas classified as forest gain were associated with bare land returning to a higher vegetative state – but not to forest. The WCS dataset on the other hand showed very little forest cover gain throughout the area of analysis and, therefore, does not provide a great deal of additional information over the Aruna dataset.

As a result, the Aruna dataset should be considered the most appropriate to estimate deforestation in the target area. This must be under the strict understanding that the Aruna dataset provides values for gross deforestation only. Net deforestation would be lower since some areas of swidden are likely to return to forest. This trend, however, is currently decreasing as land use intensifies and fallow cycles are shortened (as explained in Section 3). Amounts of actual reforestation are therefore not expected to create a major difference between gross and net deforestation rates.

While the Aruna dataset does contain errors it provides a more realistic and accurate view on the amount of deforestation occurring in the district. For this reason, it is more helpful in terms of supporting the USAID LEAF program and its counterparts to identify deforestation hotspot areas in the target area.

ANNEX 2: REPORTS CONSULTED FOR THE DRIVERS ANALYSIS

DOF (2010) *Forest Carbon Partnership Facility Readiness Preparation Proposal (R-PP), Lao PDR*. Department of Forestry. Ministry of Agriculture and Forestry, Lao PDR.

EIA (2011) Crossroads: The Illicit Timber Trade Between Laos and Vietnam. London, EIA.

Forest Trends (2011) Baseline Study 2, Lao PDR: Overview of Forest Governance, Markets and Trade. Kuala Lumpur, EU FLEGT Facility.

GCDA (2011) *Socioeconomic Assessment and Analysis of Drivers for Deforestation and Forest Degradation in the Landscape of Nam Xam National Biodiversity Conservation Area (NBCA), Houaphan Province.* Report commissioned by SNV Lao PDR.

Halperin, J. and Mortenson, L. (2012) *Forest Degradation in Northern Lao PDR: An Assessment in Monitoring Options and Capacity building Needs in Houaphan Province.* LEAF/USFS report, Draft Version 4.

Inthiratvongsy, S. (2012), *Forest Under Threat - Spatial Analysis for Selected Districts in Lao PDR, Presentation to LEAF Road to Readiness Workshop*. Bangkok: LEAF

LEAF (2014) *Site-Level Assessment Report 1: Progress Toward Site Targets*. Bangkok: LEAF.

Lestrelin G, Trockenbrodt M, Phanvilay K, Thongmanivong S, Vongvisouk T, Pham TT and Castella J-C. (2013). *The context of REDD+ in the Lao People's Democratic Republic: Drivers, agents and institutions*. Occasional Paper 92. Bogor, Indonesia: CIFOR.

Lestrelin G. 2010. Land degradation in the Lao PDR: Discourses and policy. *Land Use Policy* 27(2):424–439

Mekong Maps (2010) *Analysis of land use and forest changes and related driving forces in the Lao PDR.* Vientiane, Lao PDR.

Moore, C., Ferrand, F. and Khiewvongphachan, X. (2012) *Assessment and Conceptualization of a Jurisdictional REDD+ Approach in Houaphan Province, Lao PDR.* CliPAD project report, Vientiane, Lao PDR.

Nhoybhouakong, M., Sengthianthr, V., Khammounheang, K., Clarke, M., Komany, S., and Bouttavong, S. (2012) *Lao Environment Outlook 2012.* Vientiane, MONRE.

SNV Lao PDR (2013) *LEAF Socio-Economic Baseline Survey: Lao PDR*. Bangkok: LEAF.

SNV Lao PDR (2014) *Livelihood Assessment Report.* Bangkok: LEAF.

Viau, J., Keophosay, A., Castella, J.C. (2009) *Impact of maize expansion on traditional rice production systems in Northern Lao PDR. A case study in Xiengkhor district, Huaphan province.* Catch-Up Programme, NAFRI, Vientiane, Laos.