USAID
FROM THE AMERICAN PEOPLE

LEAF
LOWERING EMISSIONS IN ASIA'S FORESTS

REPORT

Accuracy assessment for forest and land use maps

From 1990 to 2010

Lam Dong province, Viet Nam

Ha Noi September, 2013

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, the report details the methodology and results of activities undertaken to verify the accuracy of historical forest and land use maps of Lam Dong from 1990 to 2010.

Authors

Vu Tien Dien, Pham Duc Cuong, Peter Stephen, Tran Van Chau, Alexandre Grais, Silvia Petrova.

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

Contents

List of figures and tables ii

Abbreviations iii

Background 1

Part I: Objective, contents and methods 2

1.1 Objective 2

1.2 Contents 2

1.3 Methods 2

1.3.1 Preparation 2

1.3.2 Establishment of ground truth points 4

1.3.3 Accuracy assessment matrix 6

1.3.4 Accuracy calculation 6

Part II: Performance Result 7

2.1 Map accuracy in 2010 7

2.2 Map accuracy in 2005 11

2.3 Map accuracy in 2000 13

2.4 Map accuracy in 1995 16

2.5 Accuracy assessment in 1990 19

Part III: Conclusion and Recommendations 21

3.1 Conclusion 21

3.2 Challenges 21

List of figures and tables

Figure 1: Position of SPs in Lam Dong 3

Figure 2: Arrangement of measuring plots in SPs 3

Figure 3: Some images of site surveys 6

Figure 4: Location of checked and assessed ground truth points for 2010 forest and land use map 8

Figure 5: Location of checked and assessed ground truth points for 2005 forest and land use map 11

Figure 6: Location of checked and assessed ground truth points for forest and land use map in 2000 14

Figure 7: Location of checked and assessed ground truth points for 1995 forest and land use map 16

Figure 8: Location of checked and assessed ground truth points for 1990 forest and land use map 19

Table 1: Field teams responsible for accuracy assessment of the maps per district 7

Table 2: Matrix of accuracy assessment in 2010 9

Table 3: Matrix of accuracy assessment in 2005 12

Table 4: Matrix of accuracy assessment in 2000 15

Table 5: Matrix of accuracy assessment in 1995 18

Table 6: Matrix of accuracy assessment in 1990 20

Abbreviations

DARD	Department of Agriculture and Rural Development
FIPI	Forest Inventory and Planning Institute
FREC	Forest Resource and Environment Center
GHG	greenhouse gas
GPS	global positioning system
LEAF	Lowering Emissions in Asia's Forests
NGO	non-governmental organization
NRAP	National REDD+ Action Program
PRAP	Provincial REDD+ Action Plan
RDMA	Regional Development Mission for Asia
REDD+	Reducing Emissions from Deforestation and Forest Degradation (including forest degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks)
RL	reference level
SNV	SNV Netherlands Development Organisation
SP	sample plot
SSP	secondary sampling plot
UNFCCC	United Nations Framework Convention for Climate Change
USAID	United States Agency for International Development

Introduction

Over the past decade, various national and international organizations have made significant efforts to work out mechanisms to combat deforestation and reduce emissions of greenhouse gases (GHG) from the forest and land use sectors. They have attempted to quantify different values of forest resources and forest environmental services and propose workable market payment incentive mechanisms so as to effectively manage these valuable resources. Among these efforts, the most prominent initiative is the Reducing emissions from deforestation and forest degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries (REDD+) mechanism. This performance based mechanism is aimed at compensating developing countries for conserving and protecting their forest resources, thereby reducing GHG emissions and increasing GHG removals. REDD+ mechanisms also seek to generate additional social and environmental benefits, or 'multiple-benefits', which include biodiversity conservation, improvement of local livelihoods and gender equity.

The United States Agency for International Development (USAID) funded Program "Lowering Emissions in Asia's Forests" (LEAF) is being implemented by Winrock International in partnership with SNV Netherlands Development Organisation, Climate Focus and The Center for People and Forests (RECOFTC) in six countries: Viet Nam, Laos, Cambodia, Thailand, Malaysia and Papua New Guinea. The purpose of the program is to strengthen the capacity of developing countries in the Asian region to produce meaningful and sustained reductions in GHG emissions from the forestry and land use sectors, thereby allowing these countries to benefit from the emerging international REDD+ program framework.

In Viet Nam, the USAID LEAF program was approved by the Ministry of Agriculture and Rural Development (MARD). USAID LEAF will provide support for the successful implementation of the Vietnam National REDD+ Action Program (NRAP).

The province of Lam Dong has been selected as one of six pilot provinces under the NRAP to pilot REDD+. USAID LEAF is supporting the development of the Lam Dong Provincial REDD+ Action Plan (PRAP).

This report presents the methodology and results undertaken to verify the accuracy of historical land use/ forest cover maps of Lam Dong from 1990 to 2010. Determining the accuracy of these maps is essential in confidently predicting historical forest and land use rates of change and subsequently historical GHG emission and removal levels. The report also outlines challenges in developing these historical maps for Lam Dong from which further efforts could be undertaken to improve their accuracy in the future.

Part I: Objective, contents and methods

1.1 Objective

To verify the accuracy of 1990, 1995, 2000, 2005 and 2010 forest and land use maps for Lam Dong Province.

1.2 Contents

- Preparation
- Establishing ground truth points
- Establishing an accuracy assessment matrix
- Calculating accuracy assessment indices
- Proposing solutions to further improve the quality of the results maps

1.3 Methods

1.3.1 Preparation

Relevant data collection

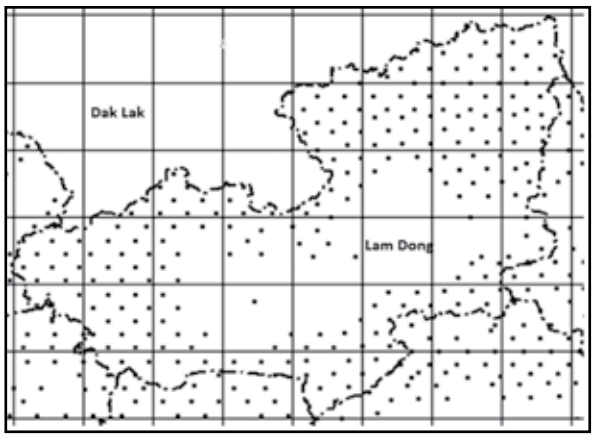
The forest status and land use maps of Lam Dong province in 1990, 1995, 2000, 2005 and 2010 which have been upgraded based on the classification results of satellite images acquired at more or less the same times.

Temporal sample plots (SPs) system conducted between 1990 and 2010 in Lam Dong province.

Sample plots system and measuring plots

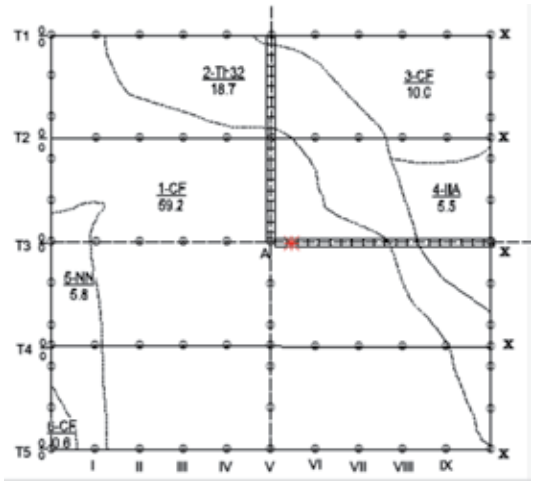
The sample plots were established in national forest change monitoring and assessment programs in the periods 1990 - 1995, 1995 - 2000, 2000 - 2005 and 2005 - 2010. They were systematically designed and spread evenly over the forested area of Lam Dong province, with 8km between each SP.

Figure 1: Position of SPs in Lam Dong



Each sample plot is 100 ha (1km x 1km). Within each SP a system of 40 measuring plots (secondary sampling plots) was designed along two central axis, and numbered from 1 to 20 on the south - north axis and from 21 to 40 in on the east – west axis. The area of each secondary sampling plot (SSP) is 500m^2 (20m x 25m). Within each SSP, the DBH was measured for all trees with a diameter of 6cm or more, and three trees of average height were also measured. The arrangement of the measuring plots in the SPs are shown in Figure 2.

Figure 2: Arrangement of measuring plots in SPs



Tools and equipment

The following tools and equipment were used in the accuracy assessment process:

- MapInfo and ArcGIS software were used to overlay the forest cover and land use maps and the NFI SSP, used for ground truthing. This overlay was used to establish the accuracy assessment matrix for each map.
- GPS units were used to determine the position of a ground truth point for 2010 on the field.
- Digital cameras were used for taking photos of the ground truth plot.

1.3.2 Establishment of ground truth points

Ground truth points were established following different procedures for the maps for the period between 1990 and 2004 and for the map of 2010.

Ground truth points to assess the accuracy of 1990, 1995, 2000 and 2005 maps

The NFI SSPs from 1990, 1995, 2000 and 2005 were used as ground truth points to assess the accuracy of the forest status and land cover maps for these years. The SSPs were surveyed and measured at more or less the same times. The ground truth points were defined as the location of the center of the measuring plot which is evaluated as representative for forest types within the sample plot.

Steps for assessing and choosing the ground truth points based on the results of sample plots:

1. Choose the SPs implemented around (less than one year's difference) 1990, 1995, 2000 and 2005.
2. Determine the coordinates of the SSPs and their forest type.
3. Display the location of the center of the SSPs on the pre-processed satellite image at more or less the same time.
4. Based on the properties of the satellite images at various periods, as well color, texture and structure, check the coordinates and forest type of the measuring plots and choose representative measuring plots for forest types within the sample plot by applying the expertise method (the distance between chosen measuring plots must be 200m or more).

Only some of the SSPs in each sample plot were selected to evaluate the accuracy of forest status maps. The center of the chosen plots was mapped by using MapInfo software in order to create the ground truth point maps for 1990, 1995, 2000 and 2005.

An accuracy matrix was created by recording the land cover category from the ground truth points and reconciling this with the mapped forest status based on the result of satellite images classification for the four time periods, 1990, 1995, 2000 and 2005.

Ground truth points to assess the accuracy of the 2010 map

The ground truth points for assessing the accuracy of the forest status map in 2010 were created using the following steps:

Step 1: Create indoor checking points

The checking points were created randomly by applying MapInfo software based on the following criteria:

- Checking points must be distributed across all forest and land use types across the province.
- Checking points for the forest types should give priority to the areas of protected forest, nature reserves and national parks where there is little change over time.

Step 2: Establish system checking point map (Put checking points on the land cover map of 2010)

MapInfo software was used to create a checking points' layer which was overlaid on the forest status layer in 2010 in order to create the system checking point map (map of checked ground truth points for 2010 forest and land use map). Other base maps (road system map, contour map, water body map etc.) were overlaid on the system checking point map.

Step 3: Field survey

- A field survey for ground truth and accuracy assessment of the forest cover map in 2010 was conducted, which included:
- Identifying the precise positions of the checking points in the field using GPS.
- Using the Biteclic rule to quickly identify the basal area and estimating stock volume of the forest type at the observed points, some other quantitative factors of the observed points such as crown coverage, average height, and dominant species were quickly estimated by using other tools (sunto or blumley).
- Precisely identifying the forest types containing the checking points and recording all field survey results on the field data sheet.

Figure 3: Some images of site surveys


Step 4: Transferring the field data

The field ground truth points were transferred from the field GPS units and displayed on the maps in MapInfo.

1.3.3 Accuracy assessment matrix

ArcGIS software was used to overlay the ground truth points (SSPs for 1990, 1995, 2000 and 2005 and ground points for 2010) on top of the forest and land use status maps. An accuracy assessment was performed using statistical methods and information from the assessment matrix for each year.

1.3.4 Accuracy calculation

The Overall Accuracy (OA) was estimated using the following formula:

$$OA = \frac{\text{Number of corrected points}}{\text{Total of number of points}} \times 100 \quad (1)$$

Calculating Kappa coefficient (K) by using following formula:

$$K = \frac{P_o - P_c}{1 - P_c} \quad (2)$$

K: Having value from 0 ~ 1

K > 0.8: High level of acceptance

K = 0.4 ~ 0.8: Average level of acceptance

K < 0.4: Low level of acceptance

P_0: Overall accuracy

P_c: The random match

(2): *Cohen's Kappa in University of York Department of Health Sciences, Cohen, J. (1968) Weighted kappa: nominal scale agreement with provision for scaled disagreement or partial credit. Psychological Bulletin 70, 213-220.*

Part II: Performance result

2.1 Map accuracy in 2010

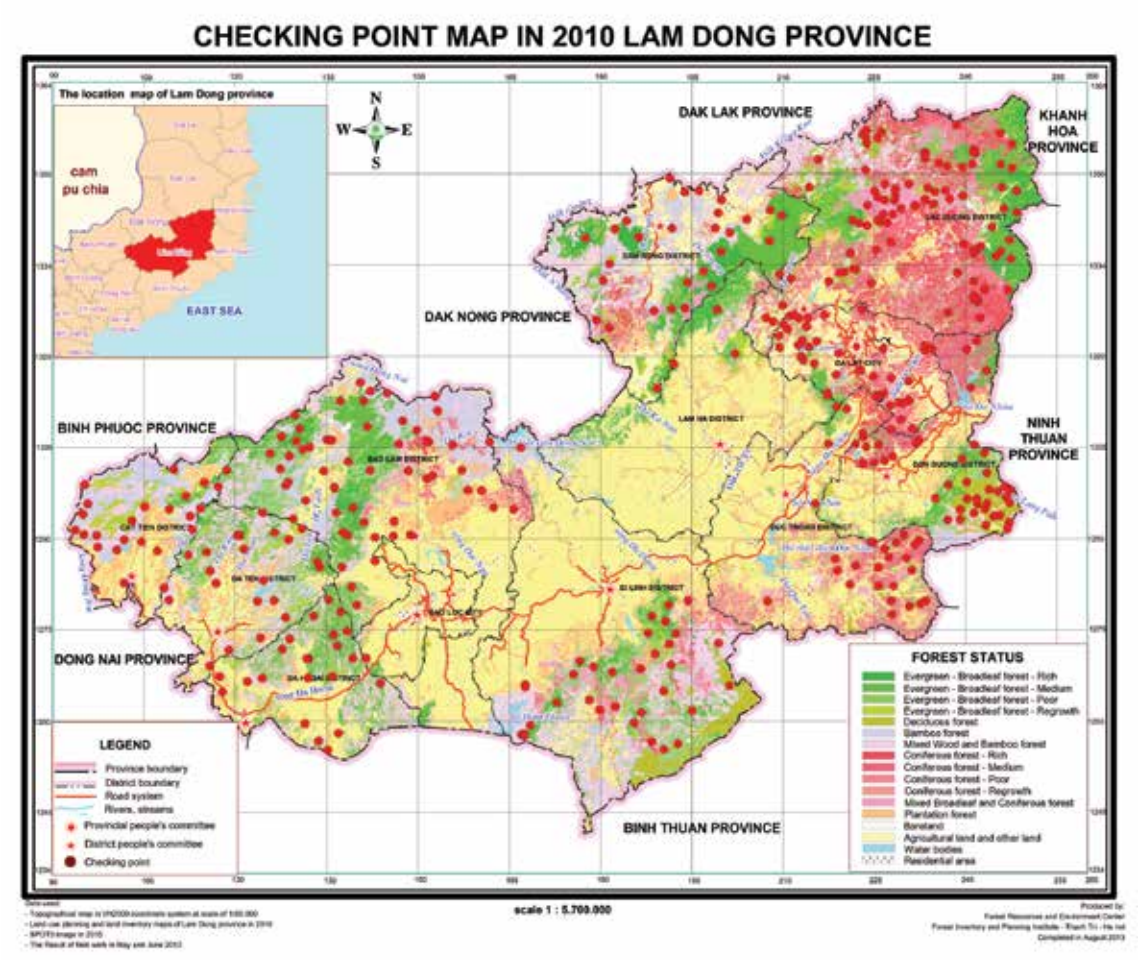
Four field teams were established to check the randomly assigned ground truth points for 2010. Each team consisted of three people: one consultant and two staff of the Agriculture–Forestry Consulting Company of Lam Dong province. Fieldwork was a close cooperation between forest rangers and the technical staff from the State forest companies in the district. All field teams checked the accuracy for selected districts and results were aggregated at the province level. Table 1 provides information on the distribution of the districts per field team.

Table 1: Field teams responsible for accuracy assessment of the maps per district

Field Team	Accuracy assessment of districts
Team 1	Bao Loc, Bao Lam and Di Linh
Team 2	Cat Tien, Da Teh and Da Huoai
Team 3	Lam Ha, Dam Rong and Lac Duong
Team 4	Duc Trong, Don Duong and Da Lat City

A total of 522 points were checked and assessed. The checked and assessed points are displayed in Figure 4.

Figure 4: Location of checked and assessed ground truth points for 2010 forest and land use map



ArcGIS software was used to overlay the result of the checked points with the 2010 map. The results of the calculation and analysis were put into a matrix and are shown in Table 2 (see page 9).

Table 2: Matrix of accuracy assessment in 2010

Checking point	Forest status on the map 2010																	Total	Accuracy
	EBF - Rich	EBF-Medium	EBF-Poor	EBF-Regrowth	Deciduous forest	Bamboo forest	Mixed W-B forest	CF-Rich	CF-Medium	CF-Poor	CF-Regrowth	Mixed B-C forest	P - forest	Bare land	Agricultural	Water	Residential		
EBF - Rich	29	1																30	97%
EBF-Medium	1	28	1															30	93%
EBF-Poor		1	27	2			1											31	87%
EBF-Regrowth			2	26		1	3											32	81%
Deciduous forest					30													30	100%
Bamboo forest			1	1		28	1							1				32	88%
Mixed W-B forest		1	1	2		1	27											32	84%
CF-Rich								29	2									31	94%
CF-Medium								1	27	1		2						31	87%
CF-Poor									1	26	2	2						31	84%
CF-Regrowth										2	25		1	2				30	83%
Mixed B-C forest		1								2	1	26						30	87%
P - forest											1	1	30					32	94%
Bare land					1						1		1	26	1			30	87%
Agricultural														1	29		1	31	94%
Water																30		30	100%
Residential																	29	29	100%
Total of number of points	30	32	32	31	31	30	32	30	30	31	30	31	32	30	30	30	30	522	
Number of corrected points	472																		
Status Accuracy	97%	88%	84%	84%	97%	93%	84%	97%	90%	84%	83%	84%	94%	87%	97%	100%	97%		
Overall Accuracy	90%																		
Kappa coefficient	0.80		50																

Note: EBF - Evergreen - Broadleaf forest, W-B - Wood and Bamboo, CF - Coniferous forest, B-C - Broadleaf and Coniferous, P - Plantation.

The calculation and analysis showed:

- Total checked points: 522
- Total correct points: 472
- Overall accuracy: 90%
- Random suitability Pc: 0.51t
- Kappa coefficient: K = 0.80 (a high acceptable level)t

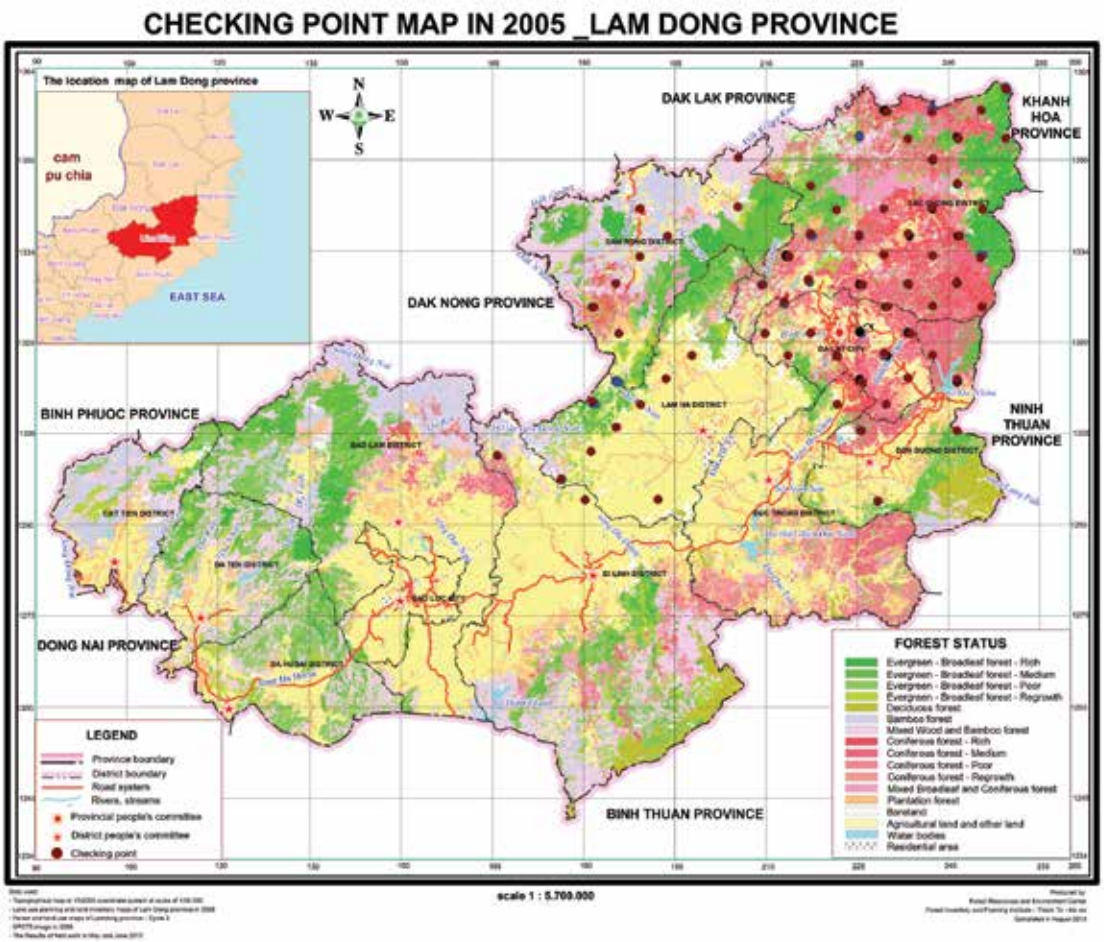
The forest categories with high accuracy were rich evergreen broadleaf forest (97%), medium evergreen broadleaf forest (93%) and rich coniferous forest (93%). These mapped forest types have distinctive color, structure, and composition pattern and are therefore easy to identify through the classification and mapping process.

The forest categories with lower accuracy were regrowth evergreen broadleaf forest (81%), regrowth coniferous forest (83%), poor coniferous forest (84%) and mixed wood and bamboo (84%). Results of the ground truthing showed that identification of the boundary between these forest types on the image as well as in the field is not very clear, so it usually resulted in mixture of the strata during the classification.

2.2 Map accuracy in 2005

During the period 2000 to 2005, sample plots were concentrated in 2002 and 2003 and in the districts in the north of Lam Dong province, such as Lac Duong, Don Duong, Dam Rong, Duc Trong and Lam Ha. Many of the sample plots were found inside one stratum and the number of sample plots selected for assessment of the map in 2005 was limited. As there was no other data available, such as other high resolution satellite imagery or aerial photographs, only SSPs plots were used for assessment of the 2005 map. Based on the above method, the total number of selected points was 300 points, equivalent to 300 SSPs in a total number of 53 sample plots. There were 10 forest classes across the total number of selected points. The strata of the SSPs were mainly coniferous forest, 69 points; rich coniferous forest, 27 points; medium coniferous forest, 34 points; poor coniferous forest, 18 points; and agricultural land, 34 points.

Figure 5: Location of checked and assessed ground truth points for 2005 forest and land use map



Results of the calculation, analysis of the matrix and assessment of the accuracy of the 2005 map are shown in Table 3.

Table 3: Matrix of accuracy assessment in 2005

Sample plots	Forest status on the map 2005										Total	Accuracy
	EBF - Rich	EBF-Medium	EBF-Poor	EBF-Regrowth	CF-Rich	CF-Medium	CF-Poor	P-forest	Bare land	Agricultural		
EBF - Rich	32	2	1								35	91%
EBF-Medium	3	32	3			1					39	82%
EBF-Poor		2	28	2			2				34	82%
EBF-Regrowth		1	3	8			1				13	62%
CF-Rich					24	2					26	92%
CF-Medium					2	28	1				31	90%
CF-Poor					1	3	14	1			19	74%
P-forest	-	-	-	-				31	1	1	33	94%
Bare land			1	1				1	29	5	37	78%
Agricultural	-	-	-	-				1	4	28	33	85%
Total of number of points	35	37	36	11	27	34	18	34	34	34	300	
Number of corrected points	254											
Status Accuracy	91%	86%	78%	73%	89%	82%	78%	91%	85%	82%	85%	
Overall Accuracy	85%											
Kappa coefficient	0.81											

Note: EBF - Evergreen - Broadleaf forest, W-B - Wood and Bamboo, CF - Coniferous forest, B-C - Broadleaf and Coniferous, P - Plantation

The calculation and analysis showed:

- Total checked points: 363
- Total correct points: 254
- Overall accuracy: 84%
- Kappa coefficient: K = 0.80 (high acceptable level)

The forest categories with high accuracy were rich evergreen broadleaved forest (97%), bamboo forest (89%), rich coniferous forest (88%) and medium evergreen broadleaved forest (83%).

The forest categories with lower accuracy were regrowth evergreen broadleaved forest (60%), deciduous forest (74%) and poor evergreen broadleaved forest (76%).

The calculation of the accuracy in 2000 shows that many strata were wrongly identified, such as mixed medium broad-leaved, mixed forest and coniferous forest. Therefore, the process of updating and upgrading the quality of the map should focus on these forest types.

2.3 Map accuracy in 2000

Contrary to 2005, the sample plots in 2000 were located in the south in the districts of Di Linh, Da Huoai and Da Teh. The inventory cycle of 2000 was conducted from 1996 to 2000. Thus 43 sample plots collected in 1999 and 2000 were selected for assessment of map accuracy in 2000 and 363 SSPs out of these 43 sample plots were selected as 363 checked points for assessment of map accuracy in 2000 (see Table 4).

There were 12 forest types on the SSPs, of which rich evergreen broadleaved forest covered 31 points, medium evergreen broadleaved forest was 37 points, poor evergreen broadleaved forest was 33 points, rehabilitation evergreen broadleaved forest was 20 points, deciduous forest was 23 points, coniferous forest was 68 points, mixed wood bamboo forest was 57 points, bamboo forest was 28 points, bare land was 20 points and agricultural land was 39 points. Results of the calculation and analysis in matrices and shown in Table 4.

The calculation and analysis showed that:

- Total checked points: 363
- Total correct points: 254
- Overall accuracy: 84%
- Kappa coefficient: K = 0.80 (high acceptable level)

The forest categories with high accuracy were rich evergreen broadleaved forest (97%), bamboo forest (89%), rich coniferous forest (88%) and medium evergreen broadleaved forest (83%).

The forest categories with lower accuracy were regrowth evergreen broadleaved forest (60%), deciduous forest (74%) and poor evergreen broadleaved forest (76%).

The calculation of the accuracy in 2000 shows that many strata were wrongly identified, such as mixed medium broad-leaved, mixed forest and coniferous forest. Therefore, the process of updating and upgrading the quality of the map should focus on these forest types.

Figure 6: Location of checked and assessed ground truth points for forest and land use map in 2000

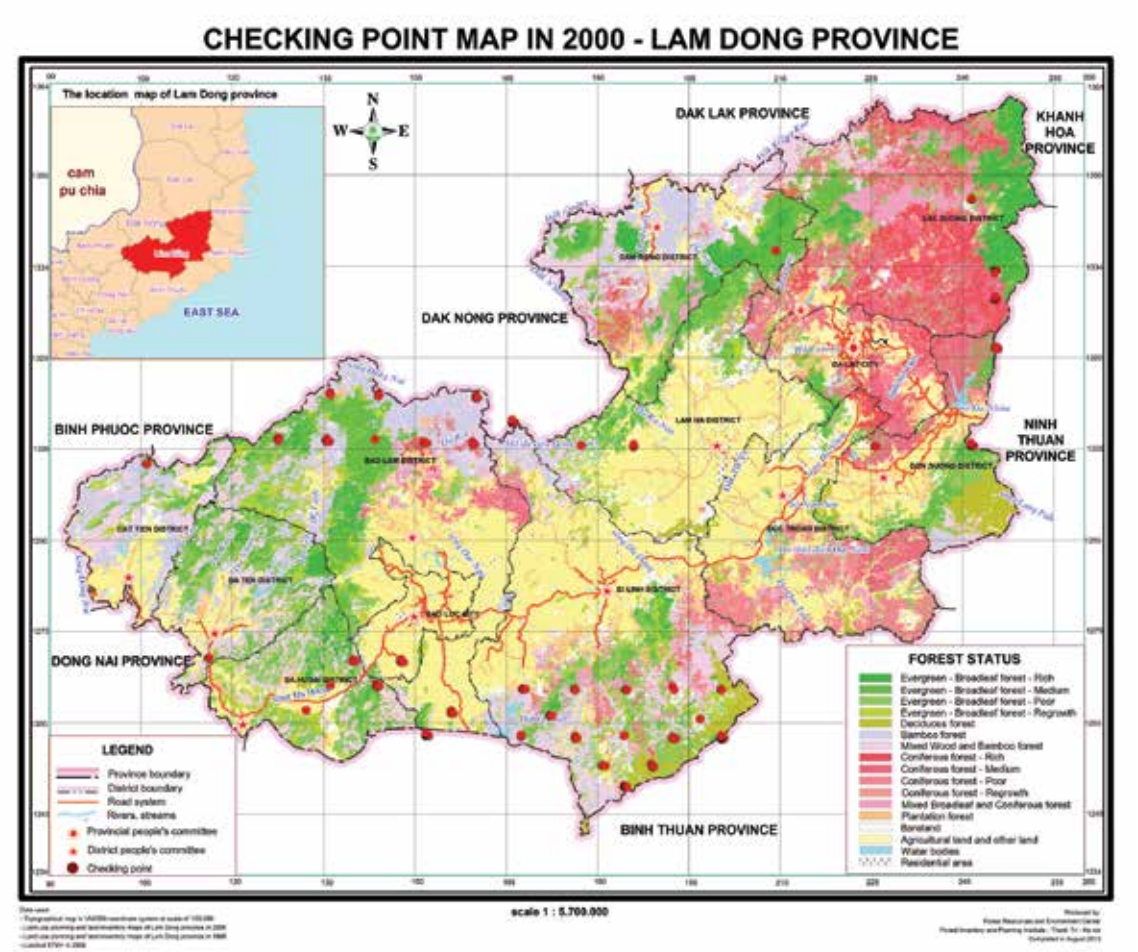


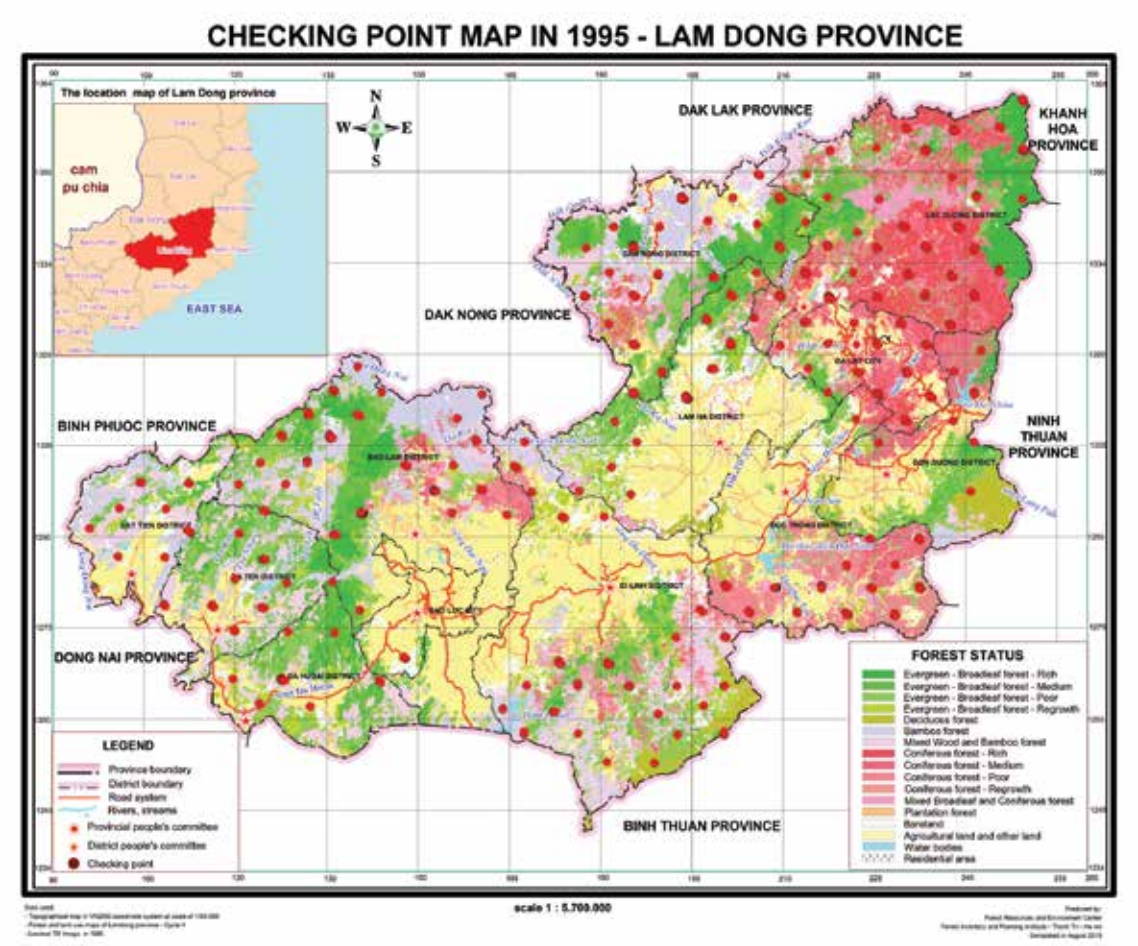
Table 4: Matrix of accuracy assessment in 2000

Sample plots	Forest status map in 2000												Total	Accuracy
	EBF - Rich	EBF-Medium	EBF-Poor	EBF-Regrowth	Deciduous forest	Bamboo forest	Mixed W-B forest	CF-Rich	CF-Medium	CF-Poor	Bare land	Agricultural		
EBF - Rich	30	1											31	97%
EBF-Medium	1	34	1	1			2		1	1			41	83%
EBF-Poor		1	25	3		1				1	1	1	33	76%
EBF-Regrowth		1	3	12		2	2						20	60%
Deciduous forest			1	1	22					1		2	27	81%
Bamboo forest			1			25	2						28	89%
Mixed W-B forest			2	2	1	2	48		1	1			57	84%
CF-Rich								22	2	1			25	88%
CF-Medium							1	2	19	1			23	83%
CF-Poor								1	1	17	1		20	85%
Bare land				1		2					17	2	22	77%
Agricultural						1					1	34	36	94%
Total of number of points	31	37	33	20	23	33	55	25	24	23	20	39	363	
Number of corrected points	305													
Status Accuracy	97%	92%	76%	60%	96%	76%	87%	88%	79%	74%	85%	87%		
Overall Accuracy	84%													
Kappa coefficient	0.80													

2.4 Map accuracy in 1995

In 1995, a number of the sample plots inventoried in 1994, 1995 and 1996 were laid throughout the province. 548 points (SSPs) were selected over a total of 157 sample plots.

Figure 7: Location of checked and assessed ground truth points for 1995 forest and land use map



There were fourteen forest types across the total number of SSPs that were selected as ground truth points for an accuracy assessment of the 1995 forest status map. Overlapping the map of ground truth points with the map of 1995 resulted in an accuracy matrix (Table 5) which shows:

- Total checked points: 548 points
- Total correct points: 460
- Overall accuracy: 84%
- Accuracy with forest: 92%
- Random suitability Pc: 0.38
- Kappa coefficient: 0.74

In 1995, the forest categories with high accuracy were mixed broadleaf and coniferous forest (96%), rich evergreen broadleaf forest (92%), poor evergreen broadleaf forest (94%), rich coniferous forest (86%), bamboo forest (87%), medium evergreen broadleaf forest (83%) and medium coniferous (82%).

The forest categories with lower accuracy were regrowth evergreen broadleaf forest (57%), deciduous forest (76%), forest plantation (76%) and poor coniferous forest (79%).

In 1995, the forest types with the most classification errors were bamboo forest, regrowth evergreen forest and mixed wood bamboo forest.

Table 5: Matrix of accuracy assessment in 1995

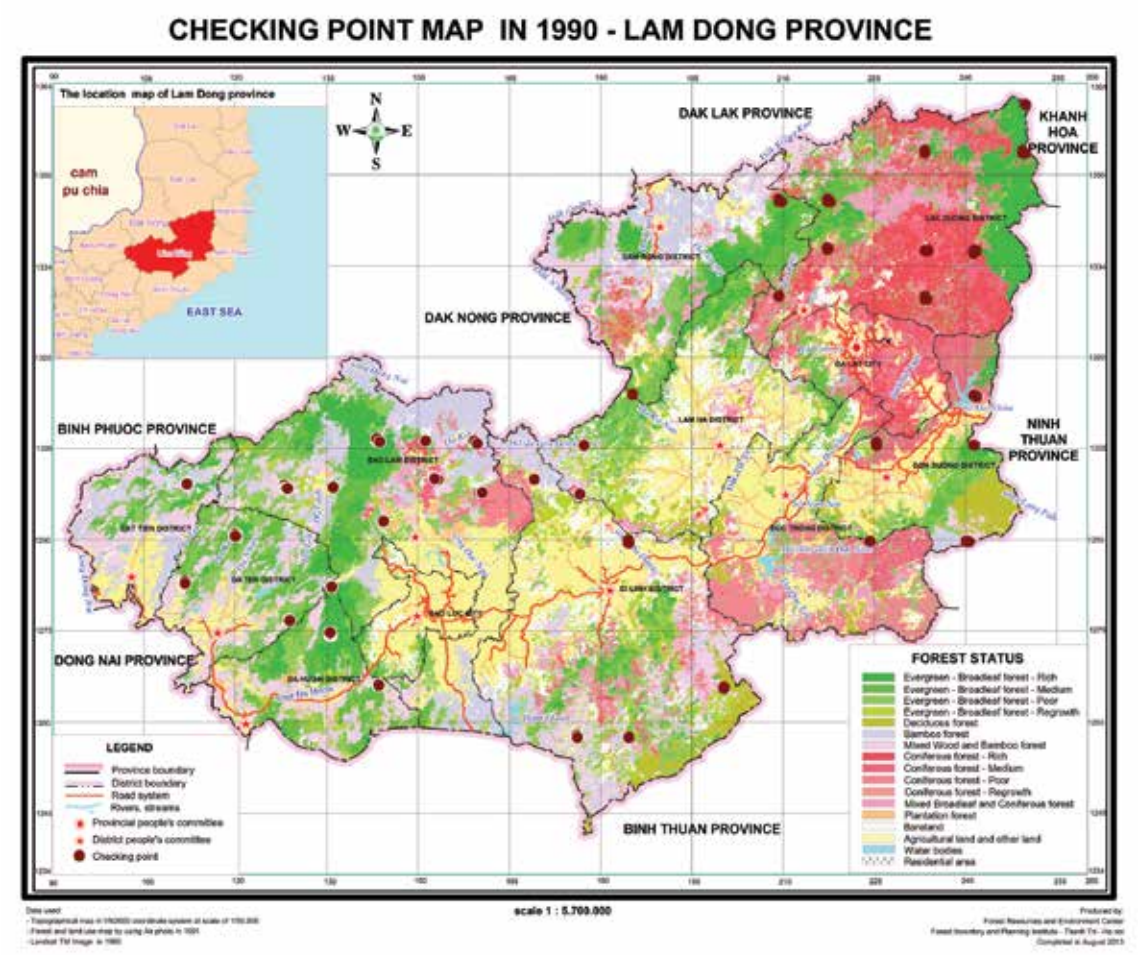
Sample Plots	Forest status on the map in 1995														Total	Accuracy
	EBF - Rich	EBF-Medium	EBF-Poor	EBF-Regrowth	Deciduous forest	Bamboo forest	Mixed W-B forest	CF-Rich	CF-Medium	CF-Poor	Mixed B-C forest	P-forest	Bare land	Agriculture		
EBF - Rich	35	3													38	92
EBF-Medium	8	49	2												59	83
EBF-Poor		1	48		1	1									51	94
EBF-Regrowth		2	2	8						2					14	57
Deciduous forest			2		19					1	3				25	76
Bamboo forest		2	1	1		41	2								47	87
Mixed W-B forest		2	2	2	1	5	19		1	1			1		34	56
CF-Rich								32	2	1	2				37	86
CF-Medium								3	36	3	1	1			44	82
CF-Poor									3	33	2		2	2	42	79
Mixed B-C forest		1				1					46				48	96
P-forest			1									16	3	1	21	76
Bare land							1					1	44	2	48	92
Agriculture												1	5	34	40	85
Total of number of points	43	60	58	11	21	48	22	35	42	41	54	19	55	39	548	
Number of corrected points	460															
Status Accuracy	81%	82%	83%	73%	90%	85%	86%	91%	86%	80%	85%	84%	80%	87%		
Overall Accuracy	84%															
Kappa coefficient	0.74															

Note: EBF - Evergreen - Broadleaf forest, W-B - Wood and Bamboo, CF - Coniferous forest, B-C - Broadleaf and Coniferous, P - Plantation

2.5 Accuracy assessment in 1990

Sample plots from 1991 and 1992 were selected for accuracy assessment of the map in 1990, with a total of 40 sample plots. The total number of checking points was 298 (equivalent to 298 SSPs), of which rich evergreen broadleaf forest was 27 points, medium evergreen broadleaf forest was 35 points, poor evergreen broadleaf forest was 31 points, regrowth evergreen broadleaf forest was 17 points, rich coniferous forest was 31 points, medium coniferous forest was 29 points, mixed broad-leaved forest was 21 points, bare land was 30 points and agricultural land was 23 points. The red points displayed in the Figure 8 are the checking points.

Figure 8: Location of checked and assessed ground truth points for 1990 forest and land use map



Results of the accuracy assessment of forest status maps in 1990 are presented in Table 6 and showed the following:

- Total checked points: 298
- Total correct points: 230
- Overall accuracy: 77%
- Kappa coefficient: K = 0.77

Table 6: Matrix of accuracy assessment in 1990

Sample plots	Forest status on the map in 1990											Total	Acc-uracy
	EBF - Rich	EBF-Medium	EBF-Poor	EBF-Regrowth	CF-Rich	CF-Medium	CF-Poor	Mixed B-C forest	Mixed W-B forest	Bare land	Agri-culture		
EBF - Rich	25	2										27	93%
EBF-Medium	2	30	1	1								34	88%
EBF-Poor		2	22	2					2	2		30	73%
EBF-Regrowth		-	2	10	1	-	-	-	2	2	-	17	59%
CF-Rich	-	-	-	-	27	2	2	1	-	-	-	32	84%
CF-Medium	-	-		-	2	23	2	2	-	1	-	30	77%
CF-Poor	-	-	-	-	1	2	18	-	4	2	-	27	67%
Mixed B-C forest	-	-	1	1		2	2	16	1	-	-	23	70%
Mixed W-B forest	-	1	2	1	-	-	-	2	20	1	-	27	74%
Bare land	-	-	2	1	-	-	1	-	-	19	3	26	73%
Agriculture	-	-	1	1	-	-	-	-	-	3	20	25	80%
Total of number of points	27	35	31	17	31	29	25	21	29	30	23	298	
Number of corrected points	230												
Status Accuracy	93%	86%	71%	59%	87%	79%	72%	76%	69%	63%	87%		
Overall Accuracy	77%												
Kappa coefficient	0.77												

Note: EBF - Evergreen - Broadleaf forest, W-B - Wood and Bamboo, CF - Coniferous forest, B-C - Broadleaf and Coniferou

The forest categories with high accuracy were rich evergreen broadleaf forest (93%), medium evergreen broadleaf forest (88%), rich coniferous forest (84%) and medium coniferous forest (77%).

The forest categories with lower accuracy were regrowth evergreen broadleaf forest (59%), poor coniferous forest (67%), mixed broadleaf and coniferous forest (70%) and poor evergreen broadleaf forest (73%).

In 1990, the forest types with the most classification errors included poor and regrowth evergreen broadleaved forest, mixed wood bamboo forest and mixed broadleaf and coniferous forests.

Part III: Conclusion and Recommendations

3.1 Conclusion

The interpretation and classification of the satellite images, forest mapping and accuracy calculation across the period of 1990 – 2010 found that the overall accuracy of the 2010 map was 90%; for the 2005 map was 85%, for the 2000 map was 84%; for the 1995 map was 84% and for the 1990 map was 77%.

The accuracy was estimated for each land cover type and results showed that rich and medium forest (evergreen broadleaf and coniferous forest) and agricultural land had high accuracy, of over 90%, for all years. For the land cover classes such as mixed wood bamboo forest and poor and regrowth forest (evergreen broadleaf and coniferous forest) the accuracy was lower due to confusion between the forest types. The accuracy of the poor evergreen broadleaf forest ranged from 75% to 84%, for mixed wood bamboo forest from 75% to 85 % and for regrowth evergreen broadleaf forest from 70% to 80%.

3.2 Challenges

In the period 1990 - 2000, both quality and quantity of dataset (sample plots) of these inventory cycles was limited by three factors: (1) The sample plots were not collected in the same year (collected in a 5 year period) (2) The application of GPS was also not used for conducting the field trip that resulted in the bias of center points of SPs location (3) The forest classification systems over the forest inventory periods was changed that led to errors resulted of conversion of forest types from old system to new system. All of the limitations mentioned above led to the limitations of dataset (sample plots) from 1990 to 2010 for all the forest strata.

There were limitations of data input, archive as well as analysis. This dataset may have been mistakenly adjusted during data input possibly impacting on the results of the accuracy assessment of the maps from1990 - 2005.

For the period 1990 - 2000, no high resolution satellite images or aerial photography was available to also assess accuracy of the forest and land use maps. Also during this period, the inventory group only used hard copy maps so that it was very difficult to identify the center point of the sample plots during the field work, impacting on the results of the assessment of accuracy of the map.

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