Ministry of Agriculture and Rural Development
VIETNAM

Forest Carbon Partnership Facility (FCPF)

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Emission Reductions Program Document (ER-PD)

Annex 13: Activity Data Report

ER Program

Name and Country: Vietnam

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Acronyms and Abbreviations

AD	Activity data
AE	Allometric Equation
AF	Afforestation
AGB	Above Ground Biomass
BCEF	Biomass Conversion and Expansion Factors
BEF	Biomass Expansion Factor
BGB	Below Ground Biomass
BUR	Biannual Updated Report
CF	Carbon Fraction
DARD	Dept. of Agriculture and Rural Development (at the Province)
DBH	Diameter at Breast Height
DF	Deforestation
EBF-M	Evergreen Broadleaf Forests, Medium
EBF-P	Evergreen Broadleaf Forests, Poor
EBF-R	Evergreen Broadleaf Forests, Rich
EF	Emission Factor
ER_PIN	Emission Reduction Program Idea Note
ER-P	Emission Reduction Program (area)
ERPA	Emission Reduction Payment Agreement
FAO	Food and Agriculture Organization
FCM	Forest cover map
FD	Forest degradation
FE	Forest enhancement
FIPI	Forest Inventory and Planning Institute
FORMIS	Forest Resource Monitoring System
FPCF	Forest Carbon Fund Facility
FPD	Forest Protection Department
FREC	Forest Resources and Environment Centre
FREL	Forest Reference Emission Level
FRL	Forest Reference Level
GHG	Green house gases
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
JICA	Japan International Cooperation Agency
LULUCF	Land use, Land Use Change and Forestry
MARD	Ministry of Agriculture and Rural Development
Mha	Millions hectare
MONRE	Ministry of Natural Resources and Environment
Mt CO_2e	Million tonnes carbon dioxide equivalent
NCC	North Central Coast
NDVI	Normalized difference vegetation index
NFI	National Forest Inventory
NFIMAP	National Forest Inventory, Monitoring and Assessment Program

NFIS	National Forest Inventory and Statistics
PPMU	Provincial Program Management Unit
PSU	Primary Sample Unit
QA/QC	Quality Assurance/Quality Control
REDD+	Reducing Emission from Deforestation, forest Degradation, forest carbon conservation and enhancement and sustainable management of forests
RF	Removal Factors
R/S	Root to shoot ratio
SCC	South Central Coastal
SD	Standard deviation
SF	Stable forest
SNF	Stable non-forest
SSP	Secondary sample plot
STDEV	Standard deviation
tC	Tonne of carbon
TTHue	Thua Thien Hue (province in the NCC))
UNFCCC	United Nations Framework Convention on Climate Change
VAFS	Vietnam Academy of Forest Sciences
VFU	Vietnam Forest University
VNFOREST	Vietnam Forest Administration
VRO	Vietnam REDD+ Office
WD	Wood Density

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1 OBJECTIVES AND TASKS

1.1 Objectives and tasks

The objectives of this work are to: 1) review and upgrade the historical forest cover maps for 2000, 2005 and 2010; and 2) generate forest and land use change maps and matrices to serve the development of a forest reference level for the North Central Coastal (NCC) region of Vietnam.

To achieve the mentioned objectives, the following tasks were undertaken: 1) Review and update historical forest cover maps for 2000, 2005 and 2010 for each province, aggregate them to regional maps for the NCC; 2) Develop the forest and land use change maps and matrices for the periods 2000-2005 and 2005-2010; and 3) Assess the accuracy of the forest cover map.

2 METHODOLOGY

Historical forest cover maps have been reviewed and improved through a number of technical and financial assistance projects funded by international development partners including Finland, Japan, and UNREDD, and also through a follow up project under MARD. Limitations of the existing maps included that 1) they have not been standardized due to the difference of applied methods; 2) the classification system and coordinate system is different with different formats (hardcopy and softcopies); and 3) they have differences in forest definition, in terms of canopy cover (30% canopy cover was applied before 2004 and 10% after the 2004, this change was according to Forest Protection and Development Law 2004). The process of improving original historical forest cover maps is presented below:

The following maps were used:

- The map in 2000: the hard copy map of the second National forest inventory and statistic (NFIS) program for the period 1998-2000 and digital map of National forest inventory, monitoring and assessment program (NFIMAP) cycle 2 for the period of 1996 – 2000;
- The map in 2005: a digital map of National forest inventory, monitoring and assessment program (NFIMAP) cycle 3 for the period 2001 – 2005; and
- The map in 2010: a digital map of National forest inventory, monitoring and assessment program cycle 4 for the period 2006 – 2010.

Nordeco Project[1]

The main activities of this project was the digitization of the hard copy maps of the NFIS for the period of 1998-2000 and standardizing of digital output map and the mapping of NFIMAP cycles 3 and 4; including: classification system, coordination, and structure of attributes. However, there were some limitations such as the satellite images of 2000, 2005, and 2010, which were less used to supplement and update the maps accordingly. The content that needed to be updated included: polygon boundaries, names of forest type and logical forest change over time.

[1] Project "Technical Assistance in the Development of the National REDD Programme of Vietnam" funded by Finland

JICA project[2]

This study was aimed at the enhancement of the quality of the maps produced by the Nordeco project, including: Landsat images covering the periods 2000, 2005 and 2010 were used for enhancing the quality of the maps by applying visual interpretation methods, including: polygon boundaries, names of forest type and misclassification of forest changes over time. The main limitation of this mapping was that the results were subjective and depended on the knowledge and experience of the interpreters, hence the quality of the enhanced map is uneven.

National FREL/FRL establishment:

Under the work for the establishment of the national FREL/ FRL continued efforts focused on enhancement of the quality of maps produced by JICA project has continued, including: the result of an "Object based" classification method applied for Landsat images to upgrade the quality of maps produced by the JICA project, including: polygon boundaries, names of forest type and correcting of large areas having misclassification of forest changes over time. Sample plots implemented more or less the same year as the maps have also been used for correcting the name of the forest type of the polygon containing that plot, if the forest type is different. The limitation is that only regional forest maps were produced and no consultation was conducted to produce forest cover maps for each province in North Central Coast (NCC) region.

2.1 Time interval

The time period to calculate the activity data (AD) serving for emission/removal estimation for the NCC region is determined to be 5 years (2000, 2005 and 2010) and is based on the following criteria:

1) To date, the forest cover maps at the regional level of Vietnam have been standardized, and quality has been upgraded through several projects with set intervals of 5 years (2000, 2005 and 2010), which also is the time period of implementation of NFIMAP cycle.

2) The period of 5 years for a cycle is chosen to ensure that monitoring and evaluation of forest changes in Vietnam is in line with the plantation forest cycle where the planted trees are mostly fast growing species with a cycle of 6 - 7 years. Therefore, if the period of time to assess forest changes is longer than the cycle of forest plantation, (e.g. 10 years) that will lead to inaccuracies, as many newly areas that are planted at the beginning of the cycle would have been harvested at the end of the cycle.

3) For the past decades, the forest cover in Vietnam have been rapidly fluctuating as a result of the effects of regeneration and deforestation such as conversion of forest use purposes, shifting cultivation etc. Therefore, the time period of 10 years for evaluating forest changes would not fully reflect the changes of the forest.

4) Currently, the NFIS program for the period from 2013 to 2016 has been implemented, of which, to date only Ha Tinh province has been completed, the five remaining provinces in NCC region are still on-going, consequently the forest cover map for the NCC region in 2015 is not yet completed. Therefore, the forest cover map for 2010 is the latest map of the region and so is used for this program.

Consequently, the input forest cover maps for AD calculation serving for the construction of the FREL/FRL were taken from the outcomes of the Project "National forest reference level"

[2] Project "Potential Forests and Land Related to "Climate Change and Forests" in The Socialist Republic of Vietnam

as based on the level of enhancement of the quality of forest cover maps described above, including the forest cover maps of 2000, 2005 and 2010.

2.2 Land uses and forest stratification

This work applies to the forest and land use classification system used in the forest cover maps improved by the JICA Project. This classification system is based on Circular No. 34/2009/TT-BNN. The original forest cover maps for the year 2000 produced by the NFIMAP used in the classification system that was based on Decision 84 while the map for the year 2010 used a classification system that is based on Circular No. 34. With the support from the JICA Project, these maps have been harmonized to a classification system that is based on Circular No. 34.

Table 2.1 Forest and land use classification system for national scale

Type	Forest and land use type	Forest/non-forest
1	Evergreen broadleaves forest - rich	Forest
2	Evergreen broadleaves forest - medium	Forest
3	Evergreen broadleaves forest - poor	Forest
4	Evergreen broadleaves forest - regrowth	Forest
6	Bamboo forest	Forest
7	Mixed woody - bamboo	Forest
10	Mangroves forest	Forest
11	Limestone forest	Forest
12	Plantations	Forest
13	Limestone without forest	Non-forest
14	Bared land	Non-forest
15	Water bodies	Non-forest
16	Residence	Non-forest
17	Other land	Non-forest

Based on the result of the average timber stock volume calculation for the forest types in the NCC region in the report on national reference level establishment conducted by Forest Inventory and Planning Institute (FIPI), the forest type numbers 3, 4 and 7 have more or less the same value of stock volume, however, it is quite difficult to distinguish among those classes when using Landsat data for image interpretation. As a result, it is suggested that those types should be combined in to one forest type to reduce uncertainty during the forest and land use mapping/updating. The harmonized classification system in the NCC is shown in Table 2.2.

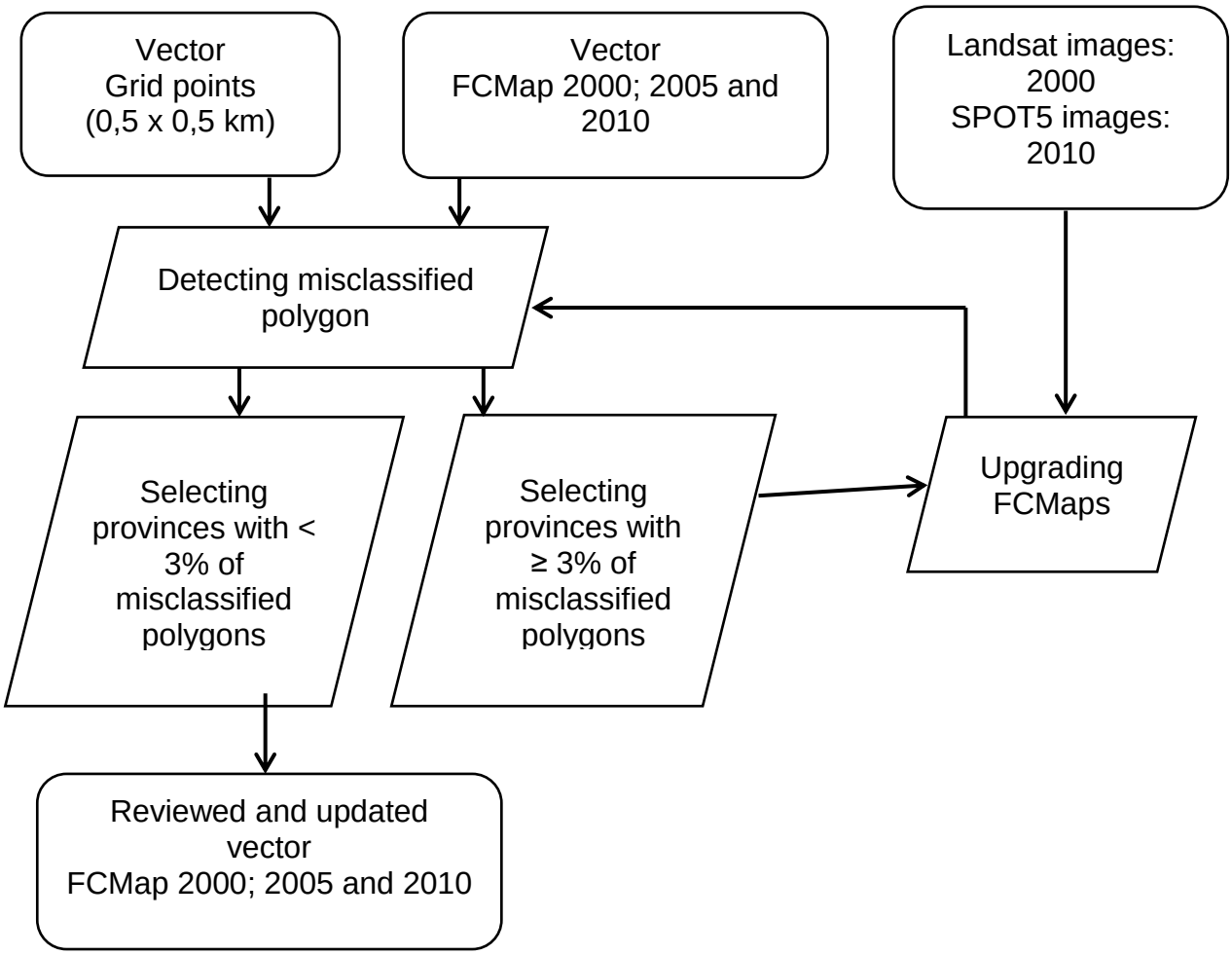
Table 2.2 Forest and land use classification system for the NCC

Type	Forest and land use type	Forest/non-forest
1	Evergreen broadleaves forest - rich	Forest
2	Evergreen broadleaves forest - medium	Forest
3	Evergreen broadleaves forest - poor	Forest
4	Other Forest	Forest
5	Plantations	Forest
6	Non-forest land	Non-Forest

2.3 Review and upgrade forest cover maps

The review and upgrade process is shown in the Figure 2.1.

Figure 2.1 Method of review and upgrade forest cover maps



There are three existing forest cover maps for the years 2000, 2005 and 2010. Therefore, the review process examines changes of different forest classes and non-forest area among different periods. Misclassification of forest and land use changes are detected to find problems of interpretation of those maps for further upgrade/re-interpretation. The determination of misclassification of changes relied on the following factors:

- The regulation of forest changes: it takes a certain time to change the forest type during the growing and development of forest. According to FIPI (2010), in the Vietnam, the average growth rate of forest stands is about 1.5 - 2% per year, consequently, for a timber volume growth of 100 m^3, it needs a period of 25 - 30 years. Thus, over a period of 10 years, the forest state that has a timber stock volume of less than 100 m^3/ha cannot develop into a rich forest in that period; or a non-forest state (as in 0 timber stock volume) cannot develop to be a forest state having timber stock volume over 100 m^3/ha.

Misclassification of changes during examined periods are discussed and decided by Vietnamese forestry experts as presented in Table 2.3 below:

Table 2.3 Misclassification of changes of forest states during period 2000 – 2005 and 2005 – 2010

Map year X+5	Map year X	Problem-ID
1	3, 4, 5, 6	P2.1
2	4, 5, 6	P2.2

To upgrade the forest and land use map for 2000, 2005 and 2010, the overlaid maps of the two periods are opened on satellite imagery of the same period to test the large polygons having inconsistent changes to correct the forest status name so as to make it appropriate to the rules allowing changes. During the processing and testing, updating and enhancement of forest and land use maps for 2000, 2005 and 2010, the collected reference maps and survey of the permanent sample plots, conducted more or less the same time, were converted to the same projection system to improve map quality using expert interpretation experiences.

2.4 Generating forest and land use change maps and matrices

Forest and land use change maps were generated using the intersect tool of ArcGIS by opening the two maps of the beginning and ending years and applying the Analysis Tools\ Overlay\ Intersect tool. This process has been applied for period 2000 – 2005 and 2005 - 2010 over six provinces. The provincial forest and land use change maps are then aggregated to generate the NCC forest and land use change maps.

To generate the forest and land use change matrices, calculations of the area for each polygon in the forest and land use change maps was done using ArcGIS. The attributes of the forest and land use change maps were exported to EXCEL file and using the Pivot Table to generate the forest and land use change matrices.

Based on the forest and land use change map, deforestation, forest degradation, forest enhancement and afforestation can be determined by using the selection tool in ARC/GIS, it can be seen in Table 2.4.

Table 2.4 Forest change in the period of 5 year

Year X	Year X+5					
	1	2	3	4	5	6
1						
2						
3						
4						
5						
6						

Forest degradation
Deforestation
Forest quality enhancement
Afforestation
Unchanged

Forest degradation: all forest type changes from higher timber stock volume to lower timber stock volume.

Table 2.5 Forest degradation during a 5 year period

Map year X	Map year X+5	Change-ID
1	2, 3, 4, 5	FD1
2	3, 4, 5	FD2
3	4, 5	FD3
4	5	FD4

Deforestation: All changes from forest to non-forested type

Table 2.6 Deforestation during a 5 year period

Map year X	Map year X+5	Change-ID
1	6	D1
2	6	D2
3	6	D3
4	6	D4
5	6	D5

Forest Enhancement: all forest type changes from lower timber stock volume to higher timber stock volume

Table 2.7 Forest enhancement during a 5 year period

Map year X	Map year X+5	Change-ID
2	1	FE1
3	2	FE2
4	3	FE3
5	3, 4	FE4

Afforestation: all changes from non-forested to forest type

Table 2.8 Afforestation during period of 5 year

Map year X	Map year X+5	Change-ID
6	3	A1
6	4	A2
6	5	A3

2.5 Accuracy assessment

The accuracy assessment of the forest cover maps for 2000, 2005 and 2010 are made on the basis of existing data at more or less the same year, and based on the following:

- Satellite images with high spatial resolution;
- Aerial photographs; and
- Ground truth points: sample plots etc.

However, in the project area, there were no high resolution satellite images or aerial photos available for 2000, 2005 and 2010, thus the accuracy assessment cannot be achieved by applying the above remote sensing and aerial photo methods.

The ground truth points system using the sample plots were implemented at various times in 2000, 2005 and 2010 (during the NFIMAP cycles 2, 3 and 4) and have been fully utilized in the improvement of the quality of the forest cover maps in the project "National FREL/FRL

construction", thus they cannot continue to be used in the assessment of the accuracy of those maps.

Consequently, the accuracy assessment will be conducted using the following steps:

Step 1. Create forest change maps for the period 2000 – 2005 and 2005 - 2010

- By overlaying the forest cover maps in 2 points of time, the forest change map is created with 23 possible changes, seven misclassification (illogical change) and six stable forest and land use types;

- Based on the Tables 1.5,1.6,1.7,and 1.8 the forest change maps for two points of time will be revised and combined as a group of change to create the final forest change map with 6 main change categories as follows:

Table 2.9 Combination of forest changes

Code	Category	Description
FD	Forest degradation (FD1, FD2, FD3, FD4)	All forest type changes from higher timber stock volume to lower timber stock volume.
DF	Deforestation (D1, D2, D3, D4, D5)	All changes from forest to non-forested type
FE	Forest Enhancement (FE1, FE2, FE3, FE4)	All forest type changes from lower timber stock volume to higher timber stock volume
AF	Afforestation (A1, A2, A3)	All changes from non-forested to forest type
SF	Stable forest	No change in forest type
SNF	Stable non-forest	No change in non-forest type

The vector maps of the forest change for the period 2000-2005 and 2005-2010 will be rasterized with the pixel size of 30*30m to create the raster maps of forest change for these two periods.

Step 2. Sampling design

- Determine sample size:
    - Calculate the areas of each change category on the final forest change maps;
    - The number of sample points required per change category is determined by three main parameters: 1) the level of precision required of the estimates, 2) the proportion of each mapped category in the map and 3) the expert-estimated, conservative map accuracy of each category.
    - If the total number of sample points of any change category is less than 30, then it will be given as 30 in order to be satisfied minimum sample size for that category. The sample points of other change categories will then be recalculated.

- Allocate sample points for each category of change
    - Based on the total number of determined sample points, the map of sample points will be stratified randomly created for each forest change category by applying ARC/GIS software. Sample points are separated by at least 400 m.

Step 3. Assess every sample point on Landsat images of “year X” and “year X+5”

Landsat images covering NCC region for 2000, 2005 and 2010 will be downloaded from the Webpage: http://earthexplorer.usgs.gov/ . The details are shown in Table 2.10.

Table 2.10 Metadata of Landsat images

Path/Row	Information	2000	2005	2010
125_48	LANDSAT_SCENE_ID	"LE71250482000311SGS00"	"LT51250482005140BKT00"	"LT51250482010186BKT01"
	DATE_ACQUIRED	06/11/2000	20/05/2005	05/07/2010
	CLOUD_COVER	0	0	0
125_49	LANDSAT_SCENE_ID	"LE71250492000311SGS00"	"LT51250492005124BKT01"	"LT51250492010042BKT00"
	DATE_ACQUIRED	06/11/2000	04/05/2005	11/02/2010
	CLOUD_COVER =	7	7	0
126_47	LANDSAT_SCENE_ID	"LE71260472000158SGS00"	"LT51260472005195BKT00"	"LT51260472009238BJC00"
	DATE_ACQUIRED	06/06/2000	14/07/2005	26/08/2009
	CLOUD_COVER =	2	1	1,63
126_48	LANDSAT_SCENE_ID	"LT51260482000310BKT00"	"LT51260482005275BKT00"	"LT51260482009238BKT00"
	DATE_ACQUIRED	05/11/2000	02/10/2005	26/08/2009
	CLOUD_COVER =	0	7	2
127_46	LANDSAT_SCENE_ID	"LE71270462000261SGS00"	"LT51270462004344BKT01"	"LT51270462010040BKT00"
	DATE_ACQUIRED	17/09/2000	09/12/2004	09/02/2010
	CLOUD_COVER	0	1	0
	LANDSAT_SCENE_ID		"LT51270462005314BJC00"	
	DATE_ACQUIRED		10/11/2005	
	CLOUD_COVER		10	
127_47	LANDSAT_SCENE_ID	"LE71270472000261SGS00"	"LT51270472005026BKT01"	"LT51270472010056BKT00"
	DATE_ACQUIRED	17/09/2000	26/01/2005	25/02/2010
	CLOUD_COVER	0	8	0
	LANDSAT_SCENE_ID		"LT51270472005314BKT01"	
	DATE_ACQUIRED		10/11/2005	
	CLOUD_COVER		16	
128_46	LANDSAT_SCENE_ID	"LE71280462000300SGS00"	"LT51280462005065BKT02"	"LT51280462010111BKT01"
	DATE_ACQUIRED	26/10/2000	06/03/2005	21/04/2010
	CLOUD_COVER	9	8	2
128_47	LANDSAT_SCENE_ID	"LT51280472005113BKT00"	"LT51280472005065BKT01"	"LT51280472010303BKT00"
	DATE_ACQUIRED	23/04/2005	06/03/2005	30/10/2010
	CLOUD_COVER	0	0	2

- Overlay the evaluation sample points on the Landsat images in 2000, 2005 and 2010;
- At each of the evaluation sample points, the forest changes were independently evaluated by three experts in the field of remote sensing and forest change monitoring and assessment by applying visual interpretation method.

Step 4. Summarize the results and create errors matrix.

- The independent evaluated results of three experts will be combined as the consensus reference sample points which will be used to create the errors matrix.

Step 5. Accuracy calculating by applying Olofsson's method[3]

3 RESULTS AND DISCUSSION

3.1 Review and update forest cover maps

The numbers of misclassification change points for each province are provided in the Tables 3.1 and 3.2 below:

Table 3.1: Result of misclassification change assessment for the period of 2000 – 2005 (updated)

Province	Misclassification change		Misclassification points detected	Total points	% of total points
	P2.1	P2.2			
Thanh Hoa	5	8	13	44,199	0.03%
Nghe An	11	25	36	65,742	0.05%
Ha Tinh	1	1	2	23,797	0.01%
Quang Binh	14	26	40	31,956	0.13%
Quang Tri	5	9	14	18,895	0.07%
Thua Thien Hue	8	13	21	19,573	0.11%
Total	**44**	**82**	**126**	**204,162**	**0.06%**

Table 3.2 Result of misclassification change assessment in the period of 2005 – 2010 (updated)

Province	Misclassification change		Misclassification points detected	Total points	% of total points
	P2.1	P2.2			
Thanh Hoa	8	11	19	44,199	0.04%
Nghe An	13	7	20	65,742	0.03%
Ha Tinh		1	1	23,797	0.00%
Quang Binh	3	28	31	31,956	0.10%
Quang Tri	8	18	26	18,895	0.14%
Thua Thien Hue	19	20	39	19,573	0.20%
Total	**51**	**85**	**136**	**204,162**	**0.07%**

The result of misclassification of change assessment revealed that the percentage of points having misclassification of change for all provinces in NNC region satisfied the requirement of accurate level (less than 3%). Consequently, no further forest cover maps enhancement is needed for this program.

[3] Good practices for estimating area and assessing accuracy of land change

3.2 Forest cover maps

Forest cover maps are finalized for all provinces and then combined for the NCC region for 2000, 2005 and 2010 are provided in the following figures:

Figure 3.1: Forest cover map of NCC in 2000

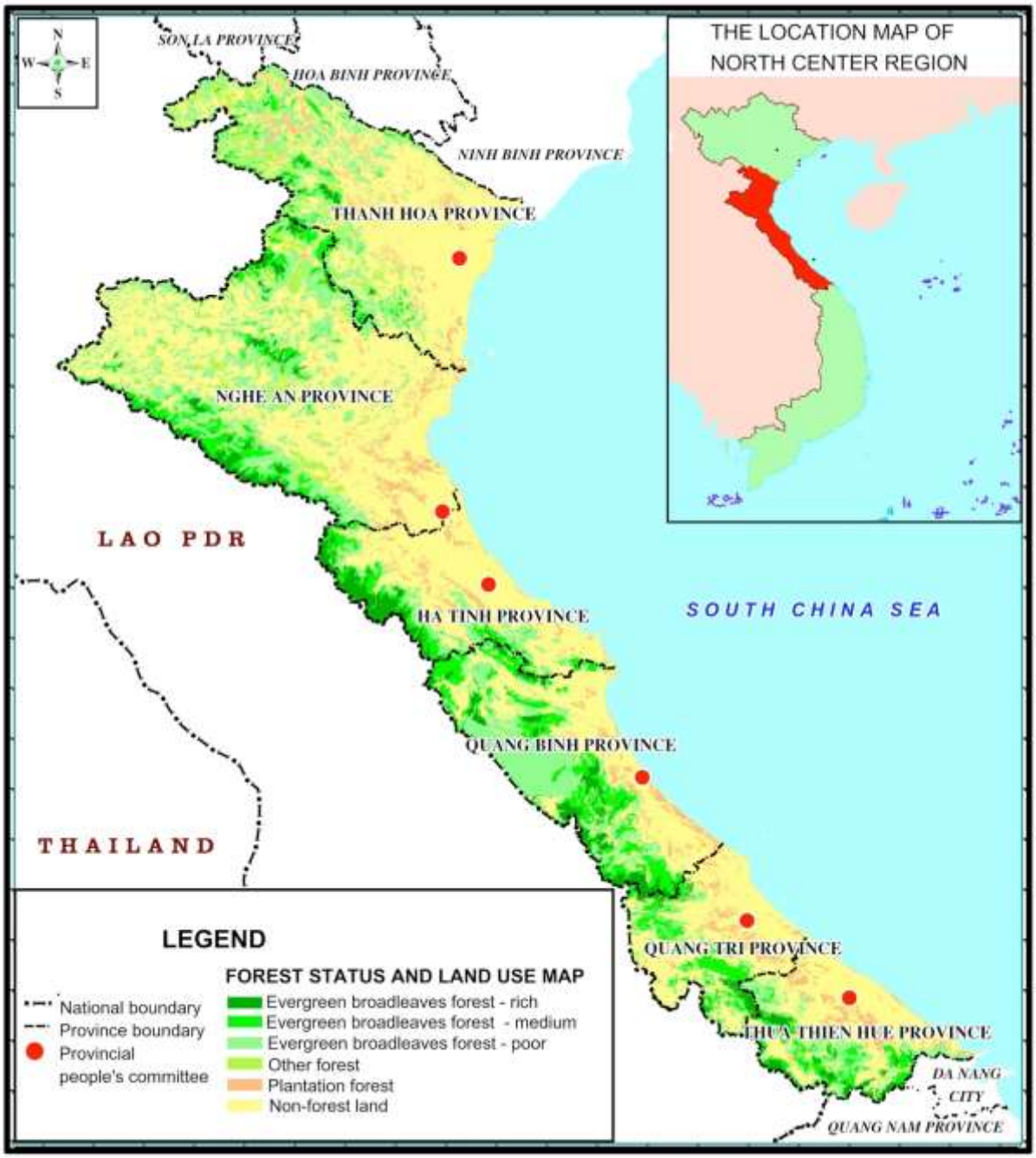


Figure 3.3: Forest cover map of NCC in 2005

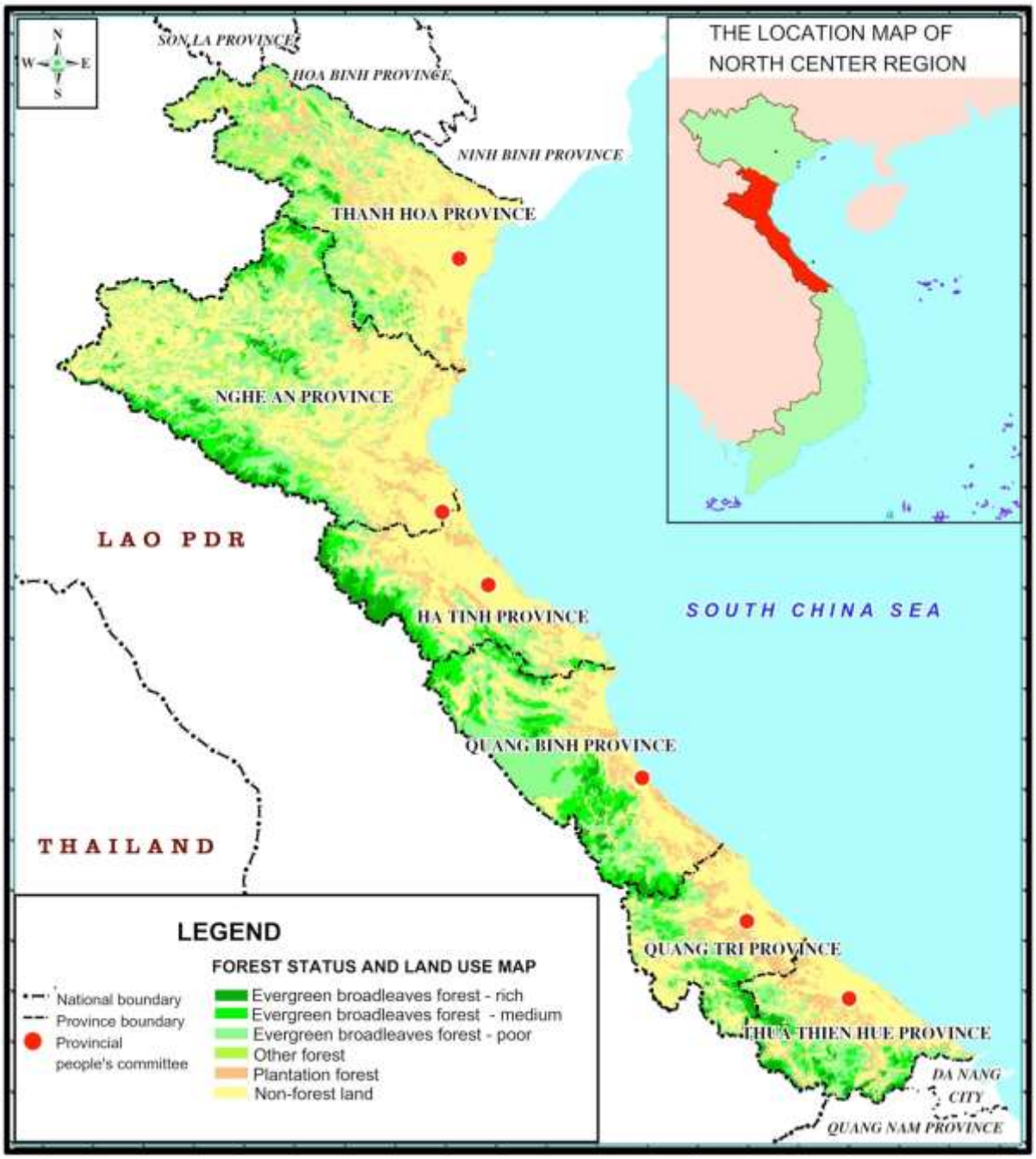
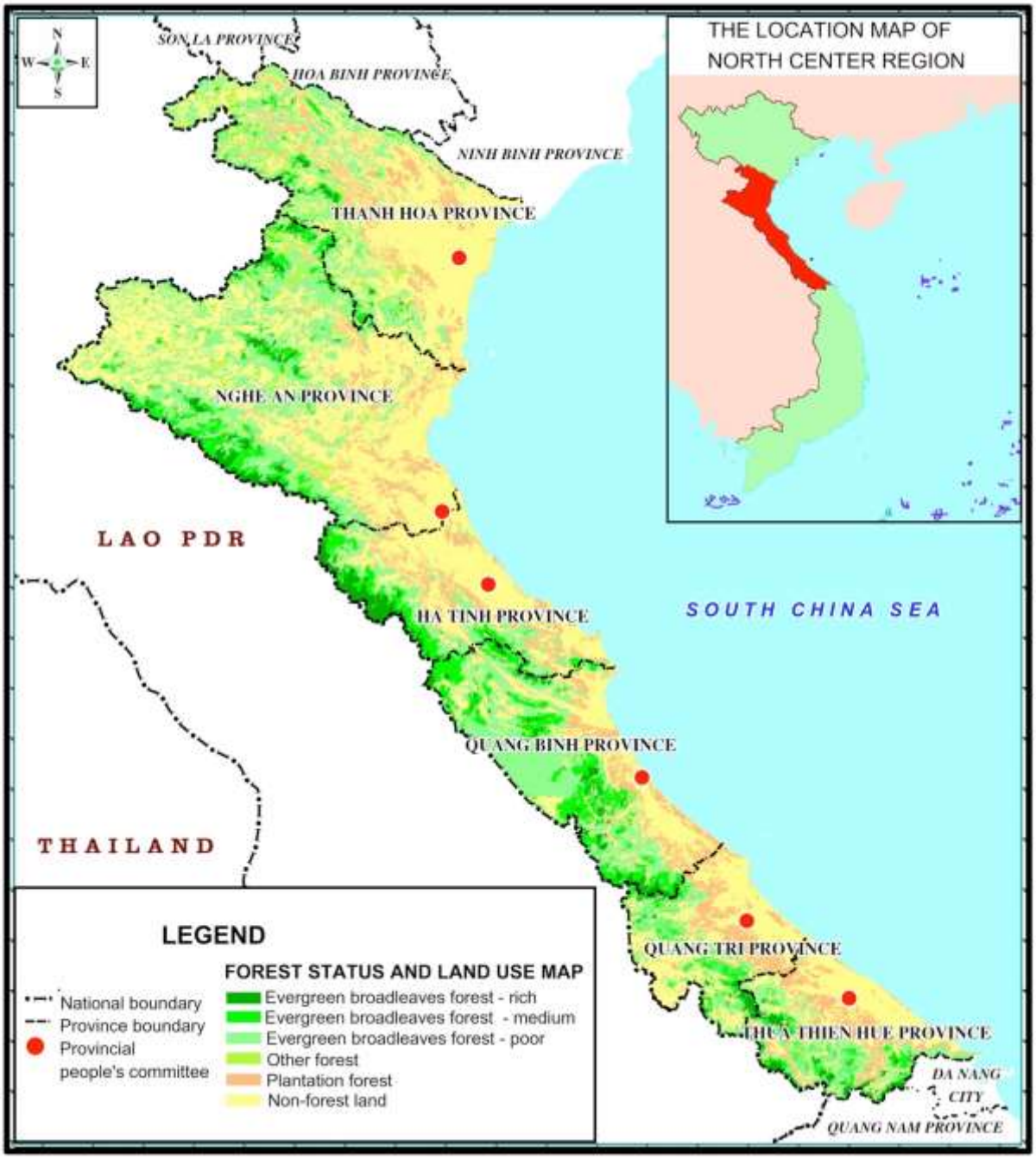


Figure 3.3: Forest cover map of NCC in 2010



3.3 Forest cover changes maps

Forest cover change maps are prepared for two time periods, 2000-2005 and 2005 – 2010. The forest cover change maps are also prepared for every province and whole region.

Figure 3.4: Forest cover change map of NCC for the period of 2000 – 2005

Figure 3.5: Forest cover change map of NCC for the period of 2005 – 2010

3.4 Forest and land use area

The result of forest and land use area calculation for each point of time is shown in the Table 3.4 as follow:

Table 3.3: Area of forest and land use (ha) in the NCC

No	Land uses	2000	2005	2010
1	***Forest land***	***2,319,065***	***2,496,603***	***2.771,531***
1.1	Evergreen broadleaves forest - rich	282,046	233,922	226,626
1.2	Evergreen broadleaves forest - medium	512,245	497,567	452,900
1.3	Evergreen broadleaves forest - poor	1,053,217	1,160,297	1,315,598
1.4	Other Forest	160,146	149,910	138,755
1.5	Plantations	311,411	454,907	637,651
2	***Non-forest land***	***2,825,443***	***2,647,905***	***2,372,977***
Total		**5,144,508**	**5,144,508**	**5,144,508**

The above results show that the total area of forest land in the NCC region tends to increase in the period of 2000 – 2010 with a total increased area of 452,466 ha, or an average of 45,247 ha per year, equivalent to about 2% per year.

Plantation forests have fairly rapid growth rate of 32,624 ha/year, equivalent of 10.81% per year. This result reflects the efforts of the Government of Vietnam through the 661 Program - 5 million hectares of afforestation during this period. Thus, during the process of FRELs/FRLs construction, it is needed to take account of the outputs from the implementation of forestry projects and/or programs before implementing REDD+, which includes the 661 Program. According to the final report on the 661 Program of the government[4], this program meets the requirements of "high transparency" of information. Therefore, the construction FRELs/FRLs will include the success rate of 661 Program in forest development activities, contributing to reduction of emissions, and increase in the removal capacity of the forest.

Natural forests tend to increase slightly, only about 0.6% per year. However, each forest type has a different rate of increase (or decrease), of these, only evergreen forest - poor is likely to increase, at more than 2%. The forest types that have higher volumes such as evergreen forest - rich and medium, tends to decrease, an equivalent of 2.4% and 1.3% per year respectively. It shows that the forest degradation is still occur quite common in the NCC region in the period 2000 - 2010.

3.5 Land cover changes

Land use change for the period of 2000 – 2005 is extracted from forest cover change maps for this period (see Table 3.4 and Table 3.5).

[4] Executive Summary The project report on "5 million hectares afforestation" and forest planning, protection and development in period 2011-2020

Table 3.4: Forest change matrix (ha) in the period of 2000 – 2005

2000	2005						Total
	1	2	3	4	5	6	
1	223,087	48,684	8,267	158	18	1,831	**282,046**
2	9,708	420,723	69,415	952	301	11,146	**512,245**
3	669	25,837	918,657	9,104	3,301	95,649	**1.053,217**
4	37	198	14,056	118,194	1,683	25,978	**160,146**
5		15	224	244	267,731	43,197	**311,411**
6	421	2.110	149,677	21,258	181,874	2,470,102	**2,825,443**
Total	**233,922**	**497,567**	**1,160,297**	**149,910**	**454,907**	**2,647,905**	**5,144,508**

Legend:

- Forest degradation
- Deforestation
- Forest quality enhancement
- Afforestation
- Unchanged

Table 3.5: Area of main forest change (ha) in the period of 2000 – 2005

Province	Forest degradation	Deforestation	Forest Enhancement	Afforestation
1. Thanh Hoa	17,420	45,206	8,373	75,305
2. Nghe An	15,267	49,573	25,158	85,664
3. Ha Tinh	19,191	19,170	3,230	47,127
4. Quang Binh	48,699	15,822	2,697	37,106
5. Quang Tri	25,870	20,182	5,769	55,426
6. Thua Thien Hue	15,434	27,849	4,843	52,180
Total region	**141,882**	**177,802**	**50,068**	**352,809**

A review of the period 2005 - 2010, shows that the total area of degradation forest as well as the deforestation in the NCC region in this period are both larger. Meanwhile, the total area of forest enhancement and afforestation are less. This shows that the development of forest at a later period is better than the previous one. This can be explained through the results of the 661 Program. The initial period was from 2000 to 2005, and was then followed by a 5-year end phase of the program, thus, the forests formed and developed in the late phase of the program were better than the previous one.

For forest degradation, in the period 2000 - 2005, Quang Binh province has the largest area, accounting for nearly 34.3%, followed by Quang Tri with over 18.2% of total area degraded forest. The other provinces do not have a big difference on this kind of forest change, accounting for 10-13% of total area of degraded forest for each province.

The area of deforestation has mostly occurred in Nghe An and Thanh Hoa provinces, and accounts for approximately 27% of the total area. The provinces of Ha Tinh, Quang Tri and Thua Thien Hue have an area of relatively uniform deforestation. Quang Binh has the lowest, accounting for approximately 9% of the total forests lost in this region.

During this period, Nghe An province has the largest area of forest enhancement, accounting for over 50% of the total area. Followed by Thanh Hoa, with over 16%. Quang Tri and Thua

Thien Hue provinces are almost the same, at about 11%. Quang Binh and Ha Tinh have the lowest, only about 6.4% of the total area of forest enhancement.

The area of regeneration, restoration of natural forests and new planted forests in Nghe An and Thanh Hoa province occupies the largest proportion in the region, corresponding to 24% and 21%. Ha Tinh, Quang Tri and Thua Thien Hue province represents between 11-15% of the total area of afforestation.

Based on the forest cover change maps prepared, land use change matrix is developed for a period of 2005 – 2010 (see Tables 3.7 and 3.8).

Table 3.6: Forest and land use change matrix (ha) in the period of 2005 – 2010

2005	2010						Total
	1	2	3	4	5	6	
1	202,274	17,593	12,454	212	413	973	**233,919**
2	23,324	392,902	69,766	1,686	1,869	8,016	**497,563**
3	849	40,339	1,026,186	16,120	9,423	67,380	**1,160,296**
4	31	98	25,767	98,949	1,408	23,659	**149,911**
5	12	22	945	46	429,754	24,120	**454,899**
6	137	1,945	180,481	21,742	194,785	2,248,830	**2,647,919**
Total	**226,626**	**452,900**	**1,315,598**	**138,755**	**637,651**	**2,372,977**	**5,144,508**

Legend:

Forest degradation
Deforestation
Forest quality enhancement
Afforestation
Unchanged

Table 3.7: Area of main forest change (ha) in the period of 2005 – 2010

Province	Forest degradation	Deforestation	Forest enhancement	Afforestation
1. Thanh Hoa	23,924	50,284	24,287	85,666
2. Nghe An	34,420	19,727	28,650	109,169
3. Ha Tinh	5,811	4,859	1,953	50,352
4. Quang Binh	31,419	10,504	13,872	57,136
5. Quang Tri	17,058	19,460	10,973	42,894
6. Thua Thien Hue	18,312	19,314	10,685	51,791
Total region	**130,944**	**124,147**	**90,420**	**397,008**

The above results (Table 3.8) show that, for the period of 2005 – 2010, the total area of degraded forest in the NCC region is 130,944 hectares. In that, Nghe An province is the largest with an area of 34,420 ha, accounting for 26.3%, followed by Quang Binh province – 31,419 ha, accounting for 24% of the total area of degraded forest in the region. Thanh Hoa, Quang Tri, and Thua Thien Hue provinces have quite a similar area of degraded forest with a total area of 59,294 ha, accounting for 45% of the total area of degraded forest in the region. Ha Tinh province has the lowest degraded forests area, with 5,811 hectares, equivalent to 4.4% of the total area of degraded forest in the region.

The total forest area increasing in quality over this period is 90,420 ha. That is lower than the total area of degraded forest in the NCC region. Of which, Nghe An province has largest area of forest enhancement – 28,650 ha, equivalent to 31.7% and Thanh Hoa province is the second with 24,287 ha, accounting for 26.9% of total area of forest enhancement in the regional. Ha Tinh is a province having the lowest forest enhancement area, accounting for only 2.16%.

The total area of deforestation for the period 2005 - 2010 in the NCC region is 124,147 ha, of which Thanh Hoa province, accounted for over 40.5% of the total deforestation area in the region. Nghe An, Quang Tri and Thua Thien Hue provinces have more or less the same area of deforestation, with nearly 16% for each province. The lowest is Ha Tinh, this area accounts for nearly 4% of the total area in the region.

Among the major changes of forest, the area of afforestation which is increasing in this period is the largest at 397,008 ha, more than three times compared to the deforestation area. This result reflects the efforts to achieve the success of the afforestation and reforestation regeneration by Government of Vietnam during this period. Among them, Nghe An is the most successful province, with 109,169 ha of new forest cover, accounting for nearly 27%, followed by Thanh Hoa province with 85,666 ha, equivalent to 21% of the total afforestation area in the region. The difference in area of afforestation is negligible for the remaining provinces, accounting for 11-15% of total area for each province.

4 ACCURACY ASSESSMENT

4.1 Determine sample size

The result of determined sample size is shown in the Tables 3.9 and 3.10.

Table 4.1: Sample size for each forest change category in the period of 2000 – 2005

Change category	**SF**	**SNF**	**AF**	**DF**	**FE**	**FD**	**Total**
Accuracy of class	0.95	0.95	0.9	0.9	0.85	0.85	
Area in pixels	21,646,638	27,442,835	3,919,713	1,975,384	556,260	1,576,310	57,117,140
Wi (Mapped Proportion)	0.38	0.48	0.07	0.03	0.01	0.03	1.00
Si (Standard Deviation)	0.22	0.22	0.30	0.30	0.36	0.36	
Wi*Si	0.08	0.10	0.02	0.01	0.00	0.01	0.23
SE overall accuracy							**0.01**
Total Number of Samples							**536**

	Sample size per stratum						Total
Equal	89	89	89	89	89	89	536
Proportional	203	258	37	19	5	15	536
Allocation of points	**182**	**231**	**33**	**30**	**30**	**30**	**536**

The final result of the determined sample size for each forest change category in the period of 2000 – 2005 showing that the total sample size is 536 points, where as the sample size for DF, FE and FD categories will be given 30 points because the calculated result for these 3

category is less than 30 points. The sample sizes for SF, SNF and AF are allocated as 182, 231 and 33 respectively.

Table 4.2: Sample size for each forest change category in the period of 2005 – 2010

Change category	**SF**	**SNF**	**AF**	**DF**	**FE**	**FD**	Total
Accuracy of class	0.95	0.95	0.9	0.9	0.85	0.85	
Area in pixels	23,887,229	24,984,498	4,410,754	1,379,279	1,004,567	1,454,784	57,121,110
Wi (Mapped Proportion)	0.42	0.44	0.08	0.02	0.02	0.03	1.00
Si (Standard Deviation)	0.22	0.22	0.30	0.30	0.36	0.36	
Wi*Si	0.09	0.10	0.02	0.01	0.01	0.01	0.23
SE overall accuracy							**0.01**
Total Number of Samples							**538**

	Sample size per stratum						Total
Equal	90	90	90	90	90	90	539
Proportional	226	236	42	13	9	14	539
Allocation of points	**201**	**210**	**37**	**30**	**30**	**30**	**538**

The final result of the determined sample size for each forest change category in the period of 2005 – 2010 showing that the total sample size is 539 points, where as the sample size for DF, FE and FD categories will be given 30 points because the calculated result for these 3 category is less than 30 points. The sample sizes for SF, SNF and AF are allocated as 201, 210 and 37 correspondently.

Figure 3.6 Reference sample points map of NCC for the period of 2000 – 2005

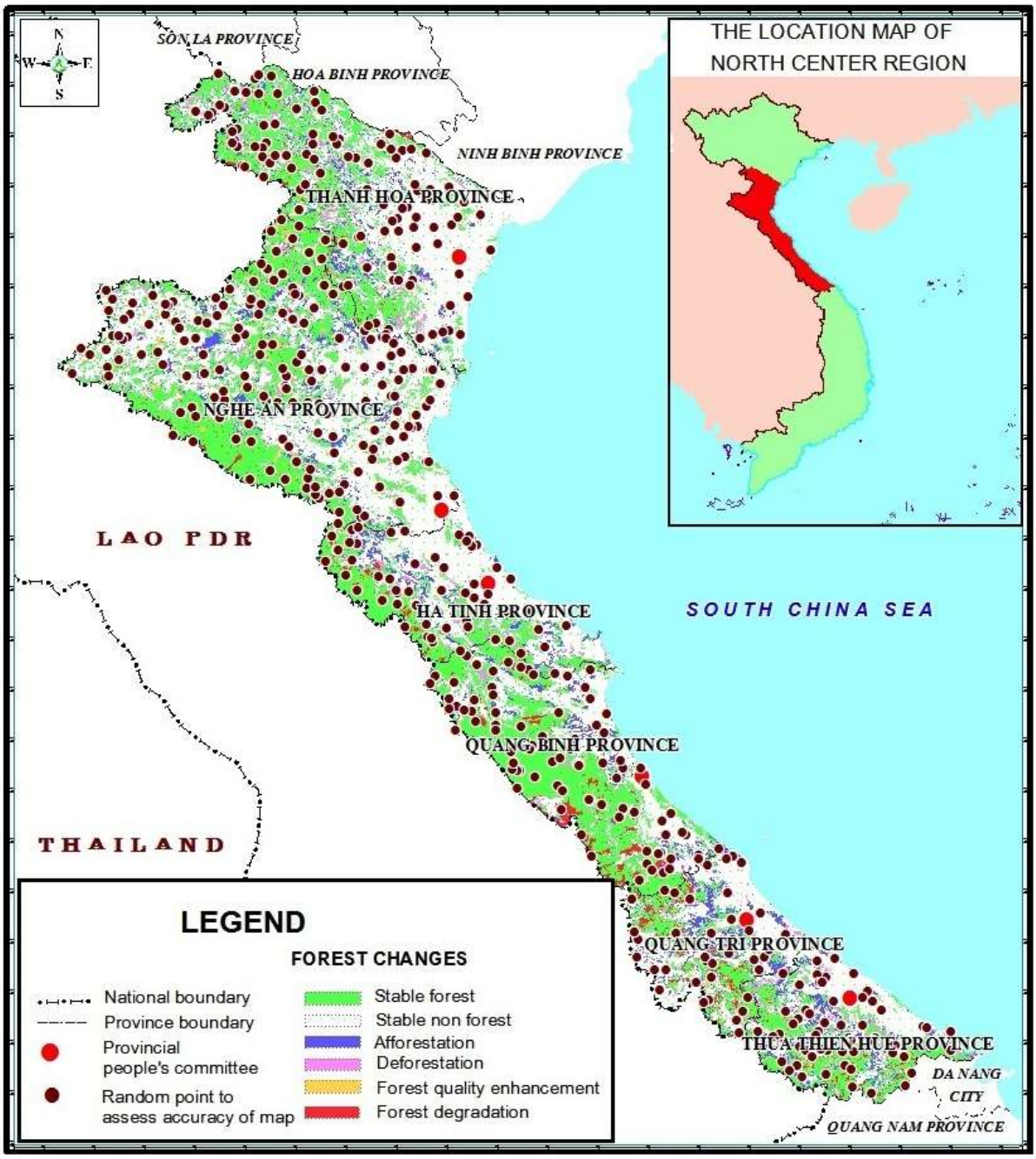
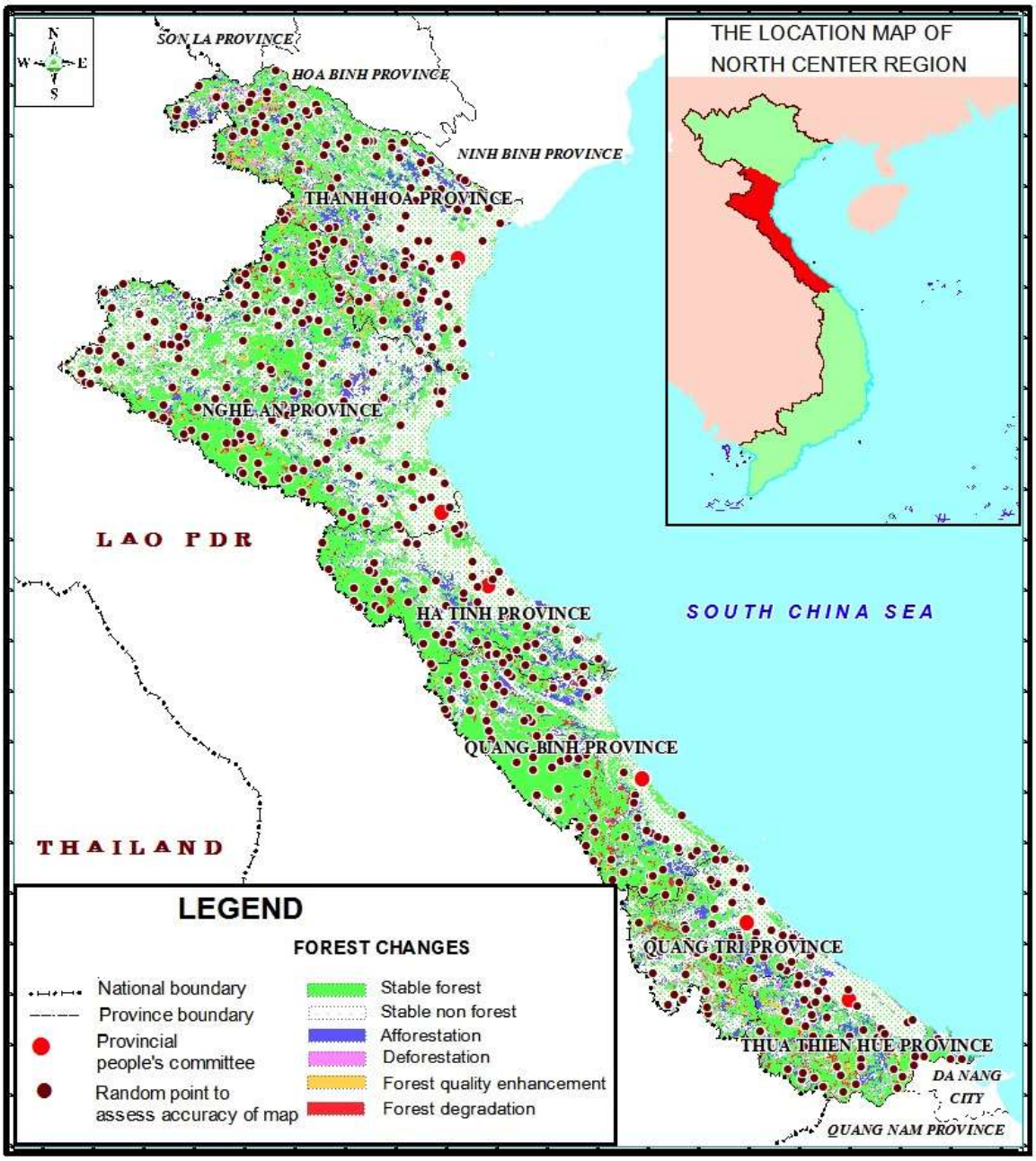


Figure 3.7: Reference sample points map of NCC for the period of 2005 – 2010



4.2 Errors matrix

Table 4.3: Errors matrix of forest change in the period of 2000 – 2005

Forest change category		Change Category from Forest change map						Row Totals
		1	2	3	4	5	6	
		SF	SNF	AF	DF	FE	FD	
1	SF	170	13		1		2	186
2	SNF	2	212					214
3	AF		3	31				34
4	DF	4		2	29	1		36
5	FE	4	1			27		32
6	FD	2	2			2	28	34
Column Totals		**182**	**231**	**33**	**30**	**30**	**30**	**536**

Table 4.4: Errors matrix of forest change in the period of 2005 – 2010

Forest change category		Change Category from Forest change map						Row Totals
		1	2	3	4	5	6	
		SF	SNF	AF	DF	FE	FD	
1	SF	193	9	1			2	**205**
2	SNF	5	201	2	1			**209**
3	AF			34				**34**
4	DF	3			27	1		**31**
5	FE					29		**29**
6	FD				2		28	**30**
Column Totals		**201**	**210**	**37**	**30**	**30**	**30**	**538**

4.3 Accuracy assessment results

Table 4.5: Accuracy assessment for forest change in the period of 2000 – 2005

Map Class	Reference Class					
	SF	SNF	AF	DF	FE	FD
SF	0.3464	0.0265	0.0000	0.0020	0.0000	0.0041
SNF	0.0045	0.4760	0.0000	0.0000	0.0000	0.0000
AF	0.0000	0.0061	0.0626	0.0000	0.0000	0.0000
DF	0.0038	0.0000	0.0019	0.0279	0.0010	0.0000
FE	0.0012	0.0003	0.0000	0.0000	0.0082	0.0000
FD	0.0016	0.0016	0.0000	0.0000	0.0016	0.0227
Cond Ref Class Proportion	0.3576	0.5104	0.0645	0.0299	0.0108	0.0268
SE	0.00872	0.00856	0.00364	0.00308	0.00161	0.00341
95% CI	0.01744	0.01713	0.00729	0.00617	0.00323	0.00682
Adjusted area est (ha)	1,838,234	2,624,236	331,557	153,705	55,530	137,794
95% CI	89.674	88.065	37.462	31.699	16.592	35.039
User accuracy	0.914	0.991	0.912	0.806	0.844	0.824
Producer accuracy	0.969	0.932	0.970	0.932	0.761	0.848
Overall accuracy	**0.944**					

Table 4.6: Accuracy assessment for forest change in the period of 2005 – 2010

Map Class	Reference Class					
	SF	**SNF**	**AF**	**DF**	**FE**	**FD**
SF	0.3937	0.0184	0.0020	0.0000	0.0000	0.0041
SNF	0.0105	0.4207	0.0042	0.0021	0.0000	0.0000
AF	0.0000	0.0000	0.0772	0.0000	0.0000	0.0000
DF	0.0023	0.0000	0.0000	0.0210	0.0008	0.0000
FE	0.0000	0.0000	0.0000	0.0000	0.0176	0.0000
FD	0.0000	0.0000	0.0000	0.0017	0.0000	0.0238
Cond Ref Class Proportion	0.4065	0.4390	0.0834	0.0248	0.0184	0.0279
SE	0.008392	0.008357	0.003589	0.002821	0.000779	0.003110
95% CI	0.016783	0.016714	0.007177	0.005641	0.001558	0.006220
Adjusted area est (ha)	2,090,022	2,257,144	429,016	127,618	94,425	143,191
95% CI	86.290	85.935	36.902	29.004	8.009	31.982
User accuracy	0.941	0.962	1.000	0.871	1.000	0.933
Producer accuracy	0.969	0.958	0.925	0.847	0.958	0.854
Overall accuracy	**0.954**					

5 CONCLUSIONS AND RECOMMENDATIONS

For this assignment, the input forest cover maps for activity data calculation serving for FREL/FRL construction were taken from the outcomes of the Project “National forest reference level”.

The misclassification of change assessment revealed that the percentage of points having misclassification of change for all provinces in the NNC region satisfied the accuracy level requirement of less than 3%. Consequently, no further forest cover maps enhancement is needed for this program.

The accuracy assessment was made for the forest change maps in period of 2000-2005 and 2005-2010 by using Landsat images revealed that the overall accuracy is 94.4% and 95.4% respectively. However, the system of satellite imagery with a higher resolution or aerial photos taken in 2000, 2005 and 2010 is still needed to assess the accuracy of forest change maps through periods in a full and exact way.

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Appendix 1: Area of forest and land use (ha) in 2000 for NCC

No	Type	Thanh Hoa	Nghe An	Ha Tinh	Quang Binh	Quang Tri	TT. Hue	Total
1	Forest land	451,935	716,641	242,864	502,383	175,688	229,554	2,319,065
1.1	*Natural forest*	*378,749*	*641,866*	*200,197*	*463,423*	*141,756*	*181,662*	*2,007,654*
1.1.1	Evergreen broadleaves forest - rich	15,436	68,828	62,761	76,081	20,500	38,439	282,046
1.1.2	Evergreen broadleaves forest - medium	49,188	121,696	57,472	155,799	71,820	56,270	512,245
1.1.3	Evergreen broadleaves forest - poor	239,572	366,831	79,048	231,378	49,435	86,953	1,053,217
1.1.4	Other Forest	74,553	84,511	916,31	166,25			160,146
1.2	*Plantation forest*	*73,186*	*74,775*	*42,667*	*38,960*	*33,932*	*47,892*	*311,411*
2	Non-forest land	661,015	932,357	356,854	303,154	298,295	273,768	2,825,443
Total		**1,112,950**	**1,648,998**	**599,719**	**805,537**	**473,983**	**503,322**	**5,144,508**

Appendix 2: Area of forest and land use (ha) in 2005 for NCC

No	Type	Thanh Hoa	Nghe An	Ha Tinh	Quang Binh	Quang Tri	TT. Hue	Total
1	Forest land	482,197	753,248	270,910	524,569	211,515	254,165	2.496.603
1.1	*Natural forest*	*372,908*	*669,349*	*199,924*	*464,484*	*148,497*	*186,534*	*2.041.696*
1.1.1	Evergreen broadleaves forest - rich	12,949	66,508	52,633	50,410	15,329	36,093	233.922
1.1.2	Evergreen broadleaves forest - medium	46,738	129,039	60,525	157,718	56,503	47,043	497.567
1.1.3	Evergreen broadleaves forest - poor	240,892	397,281	85,870	256,191	76,665	103,398	1.160.297
1.1.4	Other Forest	72,328	76,520	895,67	166,25	0	0	149.910
1.2	*Plantation forest*	*109,289*	*83,899*	*70,986*	*60,084*	*63,018*	*67,631*	*454.907*
2	Non-forest land	630,753	895,750	328,809	280,969	262,468	249,157	2.647.905
Total		**1,112,950**	**1,648,998**	**599,719**	**805,537**	**473,983**	**352,880**	**5,144,508**

Appendix 3: Area of forest and land use (ha) in 2010 for NCC

No	Type	Thanh Hoa	Nghe An	Ha Tinh	Quang Binh	Quang Tri	TT. Hue	Total
1	Forest land	517,797	842,967	316,440	571,672	235,446	287,210	2.771.531
1.1	*Natural forest*	*379,247*	*716,834*	*216,678*	*481,867*	*149,028*	*190,225*	*2.133.879*
1.1.1	Evergreen broadleaves forest - rich	14,046	66,729	51,838	44,450	16,251	33,313	226.626
1.1.2	Evergreen broadleaves forest - medium	37,733	116,538	58,536	150,903	46,519	42,670	452.900
1.1.3	Evergreen broadleaves forest - poor	265,696	457,965	105,089	286,348	86,259	114,242	1.315.598
1.1.4	Other Forest	61,772	75,602	1214,67	166,25	0	0	138.755
1.2	*Plantation forest*	*138,550*	*126,133*	*99,762*	*89,805*	*86,418*	*96,985*	*637.651*
2	Non-forest land	595,153	806,031	283,279	233,866	238,537	216,112	2.372.977
Total		**1,112,950**	**1,648,998**	**599,719**	**805,537**	**473,983**	**503,322**	**5,144,508**

Appendix 4: Forest change matrix 2000 – 2005 (ha) Thanh Hoa province

2000	2005						Total
	1	2	3	4	5	6	
1	12,097	2,486	713	60	0	80	15,436
2	764	40,874	6,082	470	60	938	49,188
3	74	3,136	202,095	5,753	1,184	27,330	239,572
4	8	87	4,250	54,991	611	14,606	74,553
5	0	0	20	203	70,711	2,252	73,186
6	7	156	27,731	10,851	36,723	585,547	661,015
Total	**12,949**	**46,738**	**240,892**	**72,328**	**109,289**	**630,753**	**1,112,950**

Appendix 5: Forest change matrix 2000 – 2005 (ha) Nghe An province

2000	2005						Total
	1	2	3	4	5	6	
1	63,842	3,139	1,608	99	0	141	68,828
2	2,389	112,473	4,990	482	1	1,361	121,696
3	206	12,842	318,521	3,331	547	31,385	366,831
4	29	111	9,797	62,366	1,071	11,137	84,511
5	0	0	91	39	69,095	5,549	74,775
6	41	475	62,274	10,204	13,186	846,177	932,357
Total	**66,508**	**129,039**	**397,281**	**76,520**	**83,899**	**895,750**	**1,648,998**

Appendix 6: Forest change matrix 2000 – 2005 (ha) Ha Tinh province

2000	2005						Total
	1	2	3	4	5	6	
1	51,314	10,715	425	0	14	293	62,761
2	1,255	47,765	7,052	0	114	1,286	57,472
3	59	1,962	64,853	20	851	11,303	79,048
4	0	0	9	671	0	235	916
5	0	0	1	2	36,611	6,053	42,667
6	5	83	13,529	203	33,395	309,639	356,854
Total	**52,633**	**60,525**	**85,870**	**896**	**70,986**	**328,809**	**599,719**

Appendix 7: Forest change matrix 2000 – 2005 (ha) Quang Binh province

2000	2005						Total
	1	2	3	4	5	6	
1	48,085	26,586	1,086	0	0	324	76,081
2	1,975	129,815	20,750	0	21	3,238	155,799
3	81	670	221,016	0	257	9,354	231,378
4	0	0	0	166	0	0	166
5	0	14	52	0	35,987	2,907	38,960
6	269	633	13,287	0	23,819	265,146	303,154
Total	**50,410**	**157,718**	**256,191**	**166**	**60,084**	**280,969**	**805,537**

Appendix 8: Forest change matrix 2000 – 2005 (ha) Quang Tri province

2000	2005					Total
	1	2	3	5	6	
1	13,743	3,844	2,582	4	327	20,500
2	1,432	47,840	19,213	105	3,231	71,820
3	97	4,293	38,714	123	6,209	49,435
5	0	0	44	23,473	10,415	33,932
6	57	526	16,112	39,314	242,286	298,295
Total	**15,329**	**56,503**	**76,665**	**63,018**	**262,468**	**473,983**

Appendix 9: Forest change matrix 2000 – 2005 (ha) T.T Hue province

2000	2005					Total
	1	2	3	5	6	
1	34,007	1,913	1,854	0	666	38,439
2	1,893	41,956	11,328	0	1,092	56,270
3	152	2,935	73,458	339	10,069	86,953
5	0	2	15	31,854	16,021	47,892
6	41	238	16,743	35,437	221,308	273,768
Total	**36,093**	**47,043**	**103,398**	**67,631**	**249,157**	**503,322**

Appendix 10: Forest change matrix 2005 – 2010 (ha) Thanh Hoa province

2005	2010						Total
	1	2	3	4	5	6	
1	9,543	2,079	1,162	79	0	86	12,949
2	4,374	30,608	8,674	956	133	1,993	46,739
3	106	4,765	197,673	9,577	521	28,251	240,894
4	11	66	14,727	38,331	742	18,450	72,328
5	0	3	385	36	107,356	1,504	109,283
6	11	211	43,075	12,793	29,798	544,869	630,757
Total	**14,046**	**37,733**	**265,696**	**61,772**	**138,550**	**595,153**	**1,112,950**

Appendix 11: Forest change matrix 2005 – 2010 (ha) Nghe An province

2005	2010						Total
	1	2	3	4	5	6	
1	59,011	3,518	3,766	134	0	77	66,506
2	7,497	102,665	17,299	724	130	724	129,039
3	166	10,079	365,536	6,423	1,761	13,315	397,281
4	20	31	11,025	59,858	665	4,922	76,521
5	0	0	38	10	83,162	689	83,899
6	34	245	60,301	8,454	40,414	786,304	895,751
Total	**66,729**	**116,538**	**457,965**	**75,602**	**126,133**	**806,031**	**1,648,998**

Appendix 12: Forest change matrix 2005 – 2010 (ha) Ha Tinh province

2005	2010						Total
	1	2	3	4	5	6	
1	50,478	1,505	640	0	0	10	52,633
2	1,338	56,481	2,432	6	35	232	60,524
3	19	515	82,840	120	1,073	1,303	85,869
4	0	0	14	593	1	287	896
5	0	0	86	0	67,873	3,026	70,986
6	4	35	19,077	495	30,780	278,420	328,811
Total	**51,838**	**58,536**	**105,089**	**1,215**	**99,762**	**283,279**	**599,719**

Appendix 13: Forest change matrix 2005 – 2010 (ha) Quang Binh province

2005	2010						Total
	1	2	3	4	5	6	
1	39,647	5,908	4,026	0	380	448	50,409
2	4,717	135,379	14,455	0	1,309	1,856	157,716
3	70	9,153	235,891	0	5,341	5,733	256,188
4	0	0	0	166	0	0	166
5	0	1	2	0	57,613	2,467	60,083
6	17	461	31,974	0	25,162	223,362	280,975
Total	**44,450**	**150,903**	**286,348**	**166**	**89,805**	**233,866**	**805,537**

Appendix 14: Forest change matrix 2005 – 2010 (ha) Quang Tri province

2005	2010					Total
	1	2	3	5	6	
1	12,435	1,791	923	2	179	15,329
2	3,720	37,018	13,629	154	1,982	56,503
3	78	7,233	59,366	559	9,432	76,667
5	0	1	20	55,129	7,868	63,017
6	18	477	12,320	30,574	219,077	262,467
Total	**16,251**	**46,519**	**86,259**	**86,418**	**238,537**	**473,983**

Appendix 15: Forest change matrix 2005 – 2010 (ha) T. T Hue province

2005	2010					Total
	1	2	3	5	6	
1	31,160	2,792	1,936	31	174	36,093
2	1,678	30,751	13,278	108	1,227	47,042
3	410	8,593	84,880	168	9,346	103,398
5	12	18	414	58,621	8,567	67,631
6	53	516	13,734	38,057	196,798	249,158
Total	**33,313**	**42,670**	**114,242**	**96,985**	**216,112**	**503,322**