<u>Appendix-6</u>

Analysis of Satellite Image

to demonstrate Land Eligibility

Appendix-6   Analysis of Satellite Image to demonstrate Land Eligibility

In order to evaluate the eligibility of AR-CDM project, it is necessary to identify "forested" and "non-forest" area at the end of 1989 in the project sites. Areas which are defined as "forested" in Vietnam should fulfill following condition.

- A single minimum tree height is more than 3 meters

- A single minimum tree crown cover is more than 30 percent

- A single minimum land area is more than 0.5 hectare

According to decision by UNFCCC, in the event that a land-use map of the area around 1989 is not available, a satellite image shall be used to prove land eligibility. In the Study, classification maps showing "forested" and "non-forest" were prepared using satellite images around 1989.

The contents of the report are as follows;

1. Overview of flow to evaluate "forest" and "non-forest"

2. Methods for specification and classification of data

3. Result of classification

4. Evaluation of "forest" area at the end of 1989

5. Summary and conclusion

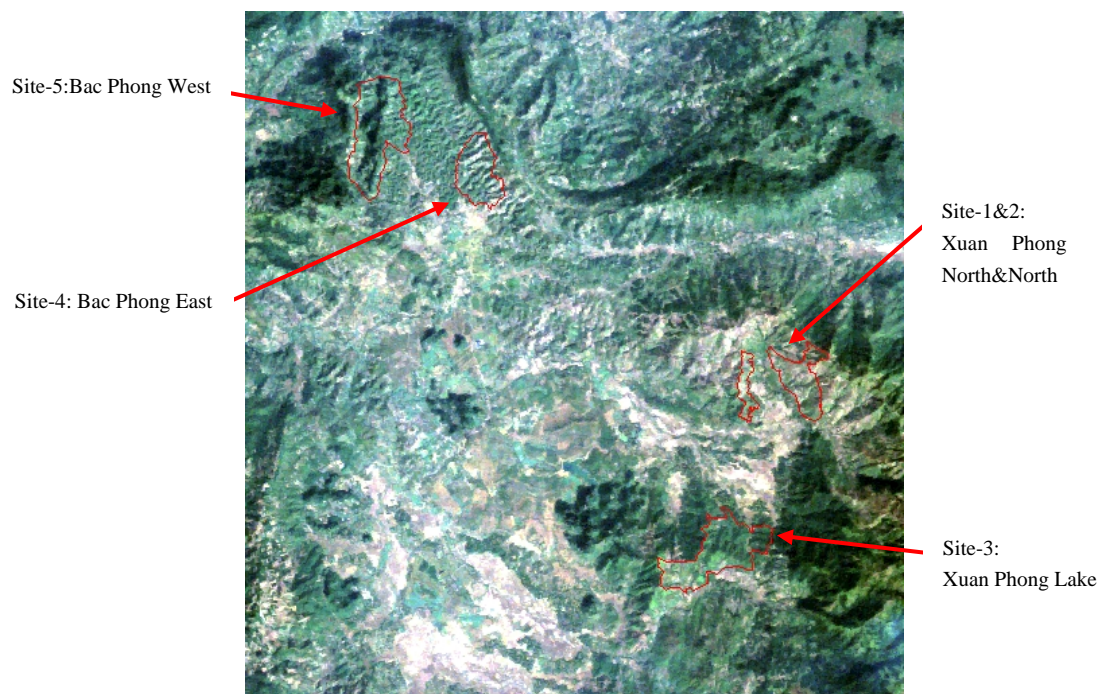Location of the study areas are shown in the following image;

Figure A6-1   Location of the study areas (Landsat/TM5, November 30, 1989)

1 Overview of flow to evaluate "forest" and "non-forest" areas

In the Study, satellite images, taken with the Landsat/TM5 sensor, in 2007, 1993, 1989, and 1987, were used to evaluate "forest" area at the end of 1989 to maximize the accuracy of the analysis. Maps of land classifications in the study areas of each year were prepared following supervised classification (MLE: Maximum likelihood estimation) utilizing the results of preliminary aerial photo analysis and field survey. The flow showing method of the study is shown in Figure 2.
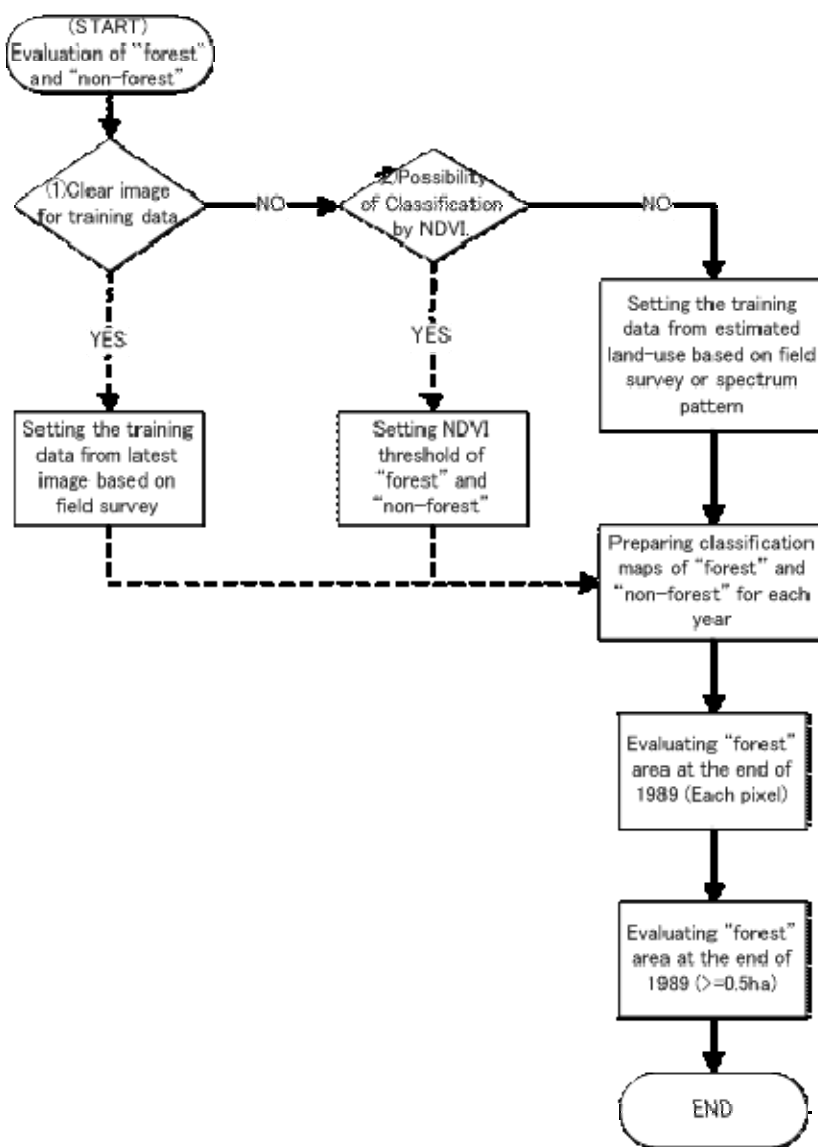

Figure A6-2   Flow of the study

- The latest satellite image taken in 2007 did not provide good training data for classification because most areas were covered with thin clouds which have an influence on spectrum patterns in the image.

- As a result of preliminary aerial photo analysis and field survey, it was proved that forest (e.g. regeneration forest) and shrub could not be distinguished appropriately by the classification using Normalized Difference Vegetation Index (NDVI).

Thus, a map showing "forest" and "non-forest" areas in each year should be prepared utilizing training data in each year. The validity of the training data in each year was confirmed by comparison with typical spectrum patterns, etc.

2   Data Specification and Classification Method

The satellite images used for the analysis are shown in Table **A6-**1.

Table A6-1 Satellite images used for the analysis

Sensor	Spatial resolution	Observation period
Landsat/TM5	25m	February 1, 2007
		December 27, 1993
		November 30, 1989
		January 9, 1987

For preparation of maps showing forest and non-forest areas in each year, supervised classification (MLE: Maximum likelihood estimation) was adopted. Supervised classification is a common method in classification of land use in satellite images.

The categories of classification were as follows;

- Regeneration forest
- Shrub
- Grassland
- Bare land (including cultivated land and fallow land)
- Paddy field (wetland and dry land)
- Water body

"Plantation areas" were not included in the above categories because the spectrum pattern in each generation stage of plantation were all different and it was difficult to identify a characteristic spectrum pattern for "Plantation area".

Sampling plots for the training data were selected via consideration of the existing map, spectrum pattern of the satellite image and results of field surveys in January and September 2007. Selected sampling plots for training data of forest, grassland and bare land are shown in Figure 3. Spectrum patterns of each vegetation category in the Study and typical spectrum patterns are shown in Figure 4. Pictures of each vegetation category are shown in Figure 5. In addition, typical spectrum patterns[1] and their features are described in Table A6-2.

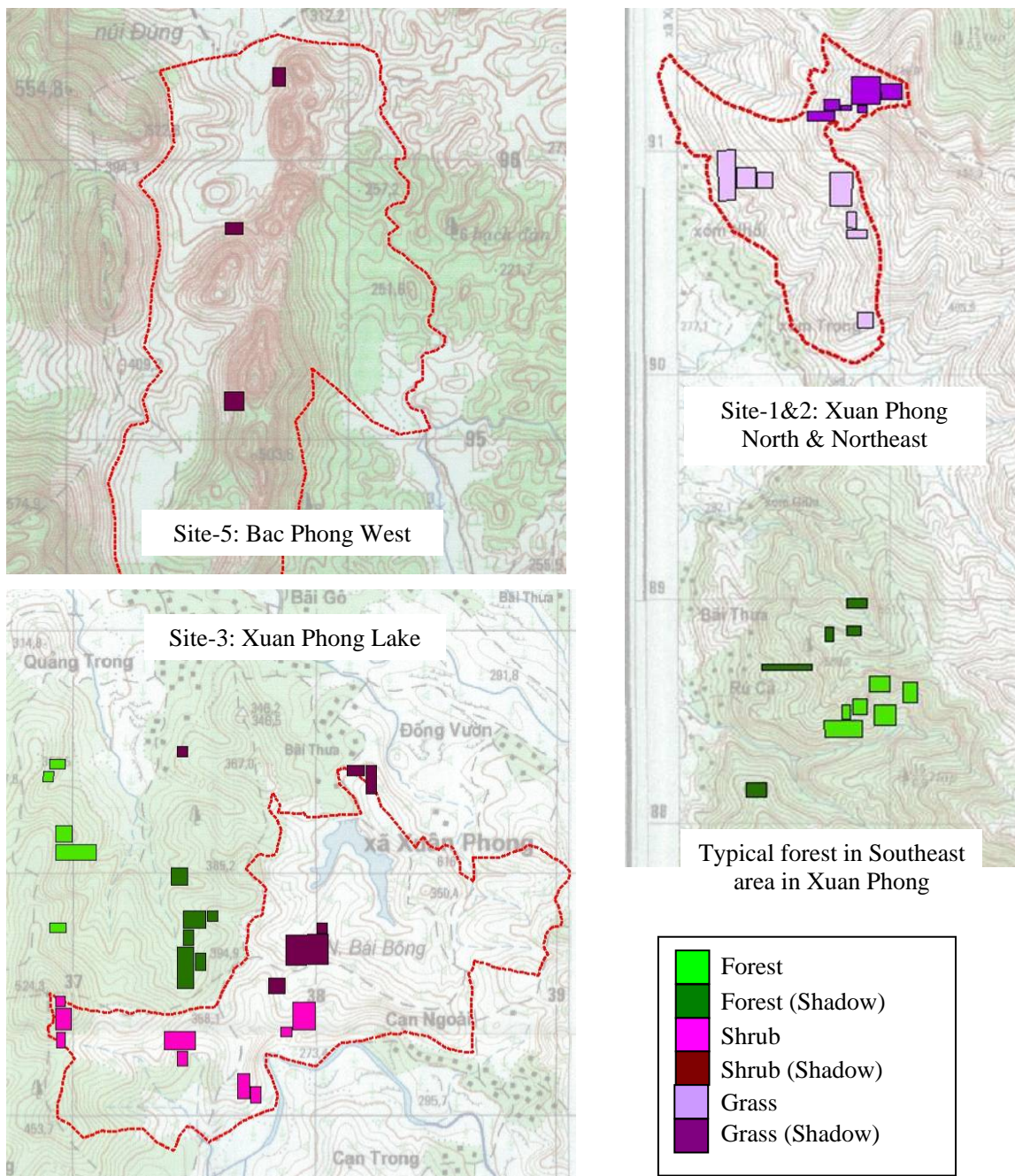[1] Masato KATOH (2004). *Forest Remote Sensing*. Japan Forestry Investigation Committee.

Figure A6-3   Location map of sampling plots for training data in the study areas
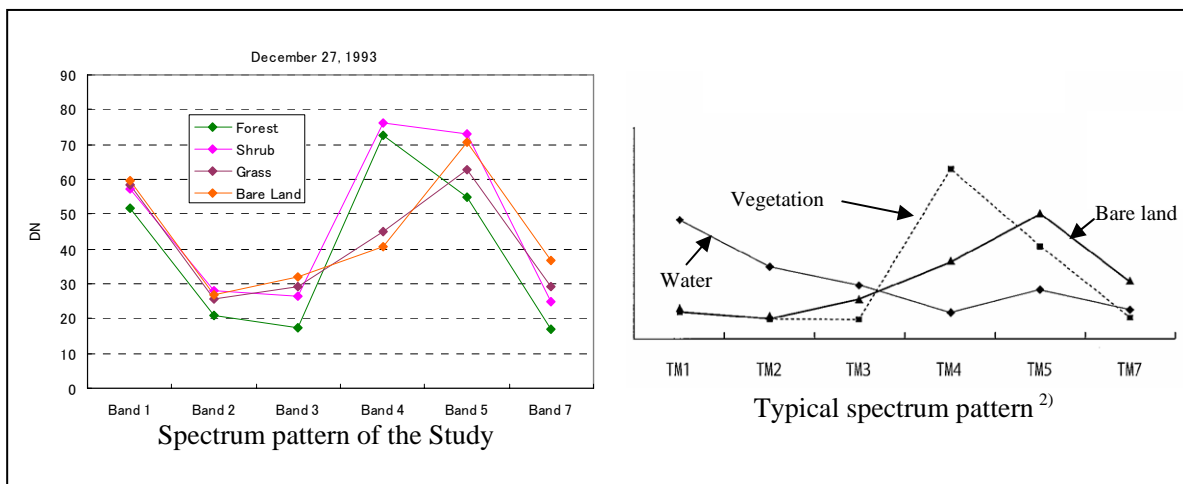
December 27, 1993

- Forest
- Shrub
- Grass
- Bare Land

Spectrum pattern of the Study

Vegetation

Water

Bare land

Typical spectrum pattern [2]

Figure A6-4   Spectrum patterns in each classification category.

Shrub (Mixed area of Shrub/Grass)
(Sep. 2007)

Forest (Regeneration forest)
(Sep. 2007)

Grassland
(Jan. 2007)
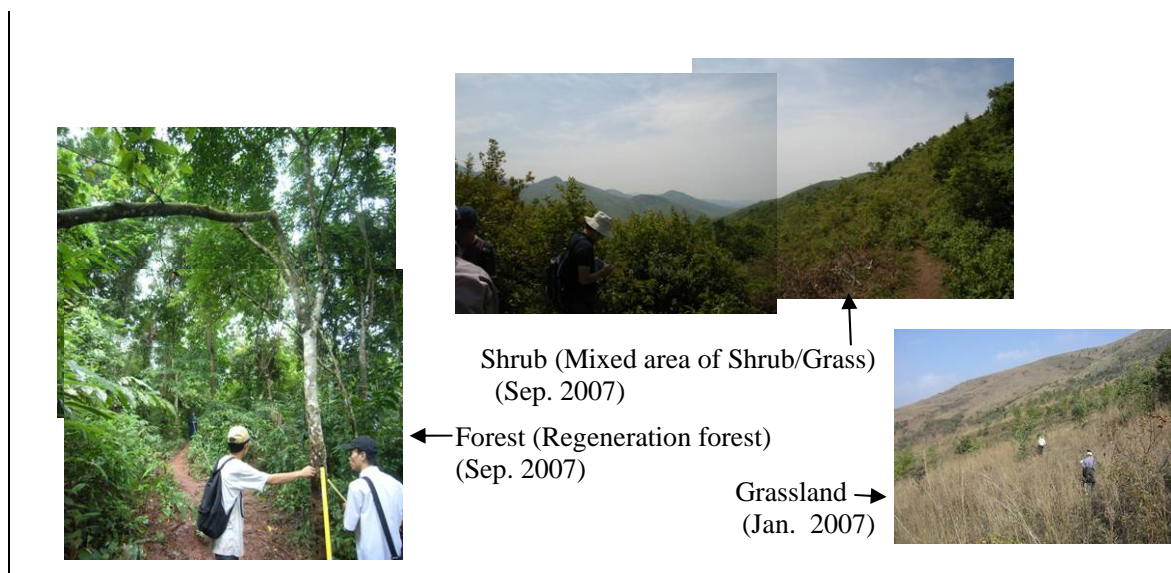
Figure A6-5   Pictures of each classification category in the Study areas

---

[2]   Masato KATOH (2004). *Forest Remote Sensing*. Japan Forestry Investigation Committee.

Table A6-2   Summary of spectrum patterns for each classification category

Vegetation category	Spectrum feature		Correlation
	Landsat/TM5 (Dec. 1993)	General spectrum pattern	
Forest (Vegetation)	Band4 > Band1,Band2, Band3,Band5, Band7	TM4 > TM1,TM2, TM3,TM5, TM7	High
Bare land	Band3 < Band4 < Band5	TM3 < TM4 <TM5	High
Grass	Band3 < Band4 < Band5 (Similar to Bare land)	-	-
Shrub	Band4 DN is equivalent to forest. Band3 and Band5 DN are higher than forest.	-	-

*DN: Digital Number

- Spectrum pattern in Study and typical spectrum patterns of forest and bare land nearly correspond. Therefore, it was valid to use these spectrum patterns as training data.

- As for grass land, spectrum patterns were similar to bare land because of the low activity of grass in dry season.

- As for shrub, Band 4 showed a high activity which was the same as in forest. On the other hand, Band 3 & 5 also showed high activity unlike forests.

- In general, Band 3 is a spectral band that corresponds to red light in a human eye. For the forest and water body is low DN in the satellite image. On the other hand, residential and bare land shows a high DN. Therefore, it might be that spectrum pattern feature of shrub areas (mixture of shrub and grass) are similar to those of residential areas or bare land as shown in Figure **A6-**3.

- In general, Band5 is utilized to estimate the moisture content of soil and plants and to distinguish between clouds and snow. According to spectrum pattern, bare land shows a high DN of Band 5, and forest with a low DN. From the viewpoint of DN for Band3 and Band5, shrub is more similar to the bare land rather than the forest. Therefore, it might be proved that the training data of shrub areas was appropriate for this classification.

The training data in the shadowed area on the slope was prepared for classification of forest, shrub and grassland because spectrum patterns in the sunny area differ from those in the shadowed area. The patterns of the shadow area are shown in Figure A6-6. The DNs of the forest, shrub and grass in the shadow area are lower than that for the sunny area for Band4 and Band5.
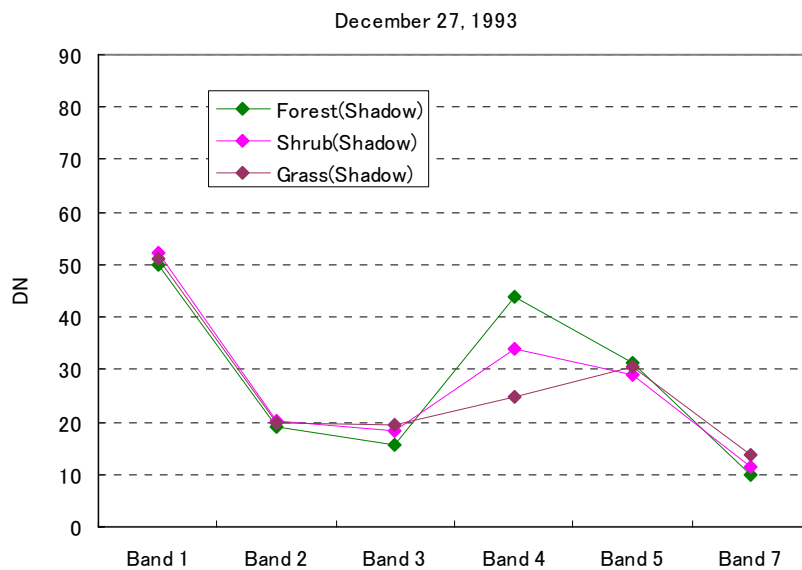
December 27, 1993

Figure A6-6   Spectrum patterns at the shadow area (Forest, Shrub, Grass)

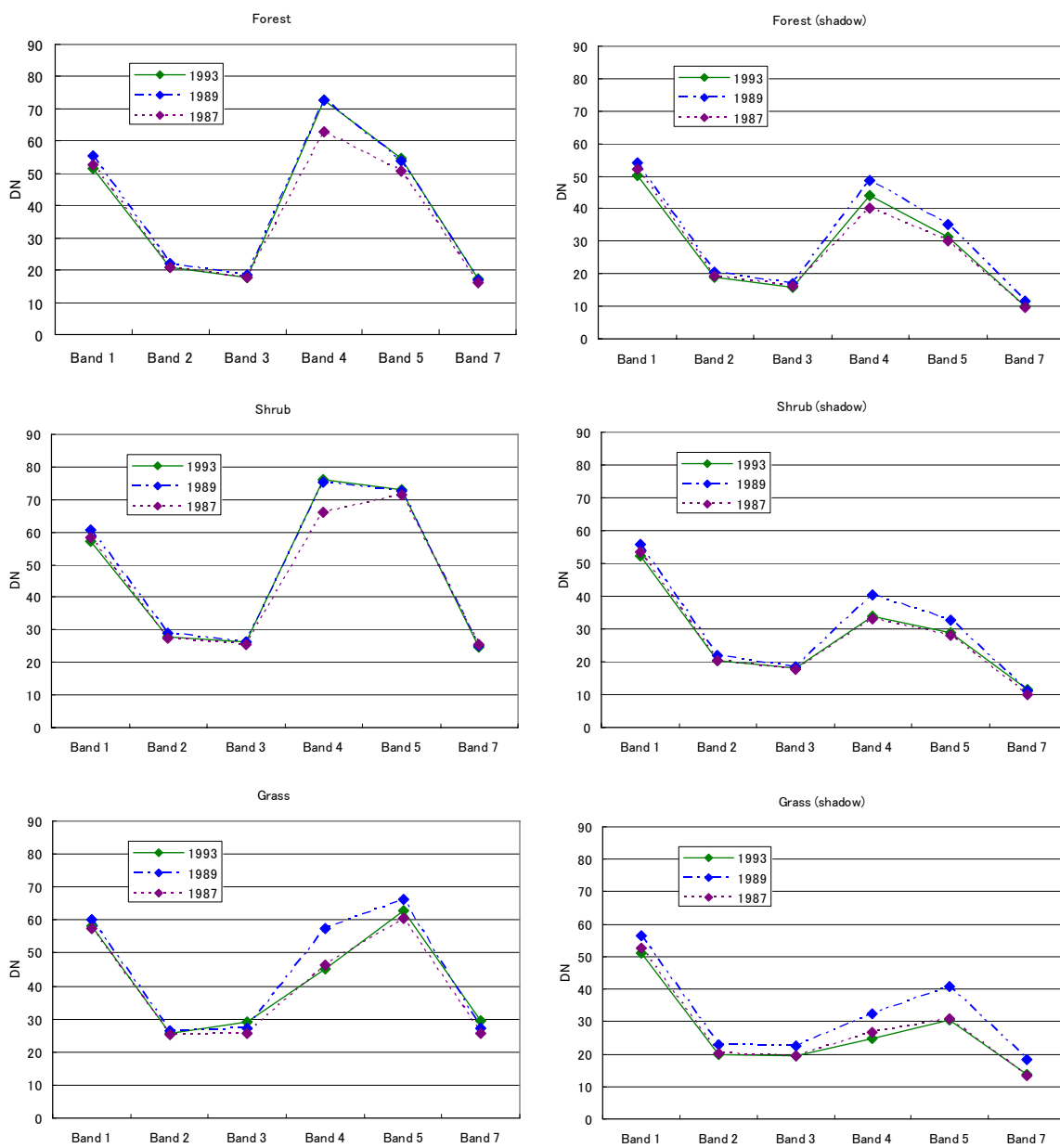The spectral patterns in the sunny and shadow areas, in 1993, 1989, and 1987 are shown in **A6-**7.

Figure A6-7 Spectrum patterns in the sunny and shadow areas (Forest, Shrub and Grass)

3   Results of Classification

3.1   Results of classification of training area

Satellite images from four years (2007, 1993, 1989, and 1987) were classified using training data. At first, in order to check the accuracy of the training data, the accuracy of each classification category was calculated as follows. The accuracy of each classification was calculated as a percentage ratio of the number of pixels classified correctly per total number of pixels in the training area as following formula.

$$Pi = \frac{Mi}{Ni} \times 100$$

i   : Classification category

Pi   : Division accuracy for category

Mi   : Number of pixels those are classified correctly for category

Ni   : Total number of pixels for category

Table A6-3   Division accuracy

| Classification Category	Number of pixels in the training area	Division accuracy (Pi)			
		2007	1993	1989	1987
Forest	122	98%	99%	97%	99%
Forest (Shadow)	99	99%	98%	97%	97%
Shrub	81	100%	100%	99%	95%
Shrub (Shadow)	89	91%	88%	96%	89%
Grass	99	91%	100%	91%	93%
Grass (Shadow)	57	95%	96%	91%	89%
Bare Land	28	100%	100%	100%	100%
Paddy (Dry)	129	100%	100%	98%	100%
Paddy (Wet)	92	100%	100%	96%	100%
Waterbody	56	100%	100%	98%	100%

3.2   Result of Classification in the Project Sites

The classification maps of "forest" and "non-forest" areas in the project sites are shown in Figure **A6-11**. The correspondence of "forest" and "non-forest" areas and classification categories are shown in Table **A6-4**.
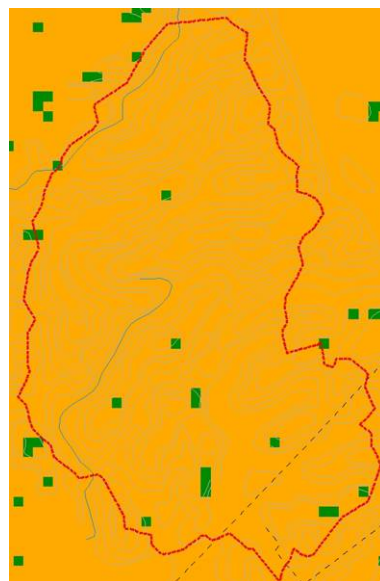
Table A6-4   Correspondence of classification category

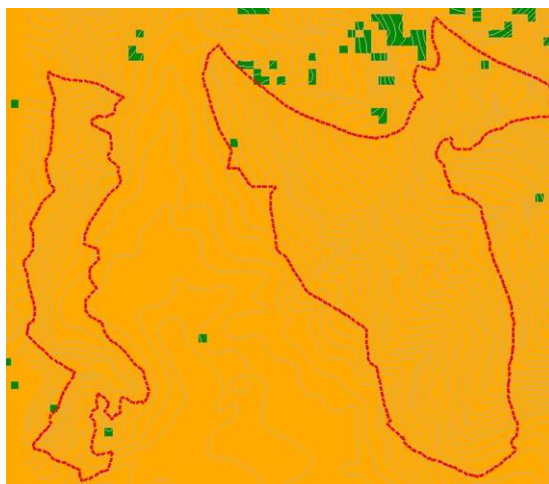|	Classification category	Color in Fig.8-11
Forest	Forest, Forest (Shadow)	Green
Non forest	Shrub, Shrub (Shadow), Grass, Grass (Shadow),	Orange

Site-5:
Bac Phong
West area
(2007)
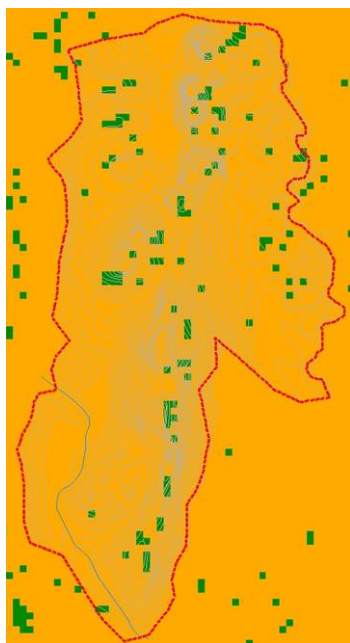
Site-4:
Bac Phong
East area
(2007)

Site-1&2:
Xuan Phong North
and Northeast area
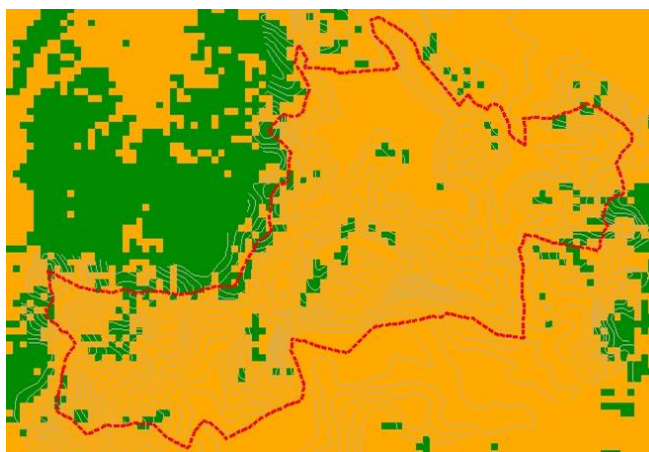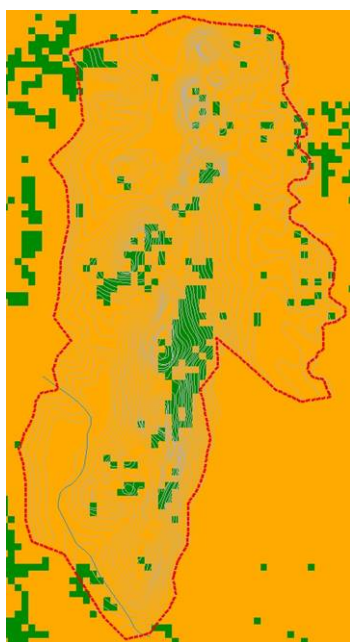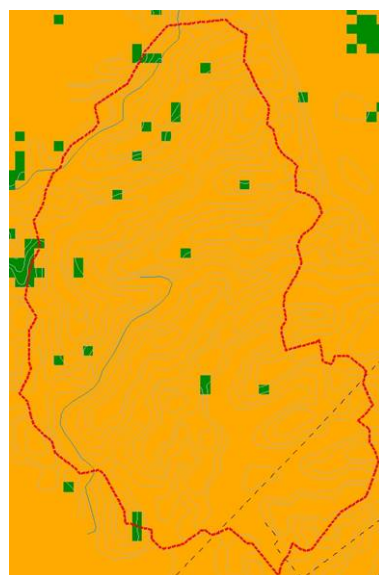(2007)

Site-3:
Xuan Phong
Lake area
(2007)

Figure A6-8   Classification maps of the forest and non-forest areas (2007)
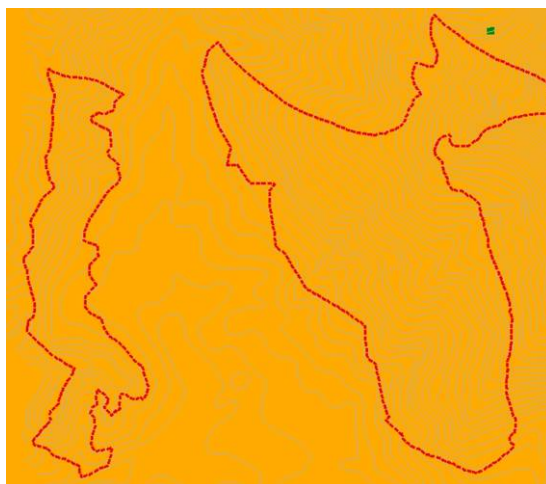
Site-5:
Bac Phong
West area
(1993)

Site-4:
Bac Phong
East area
(1993)

Site-1&2:
Xuan Phong North
and Northeast area
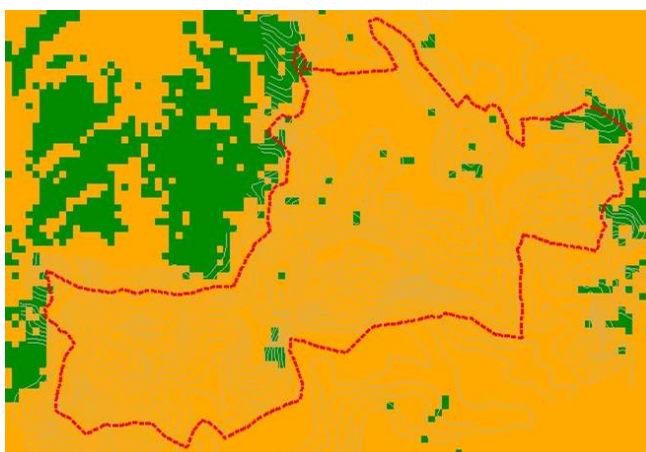(1993)

Site-3:
Xuan Phong
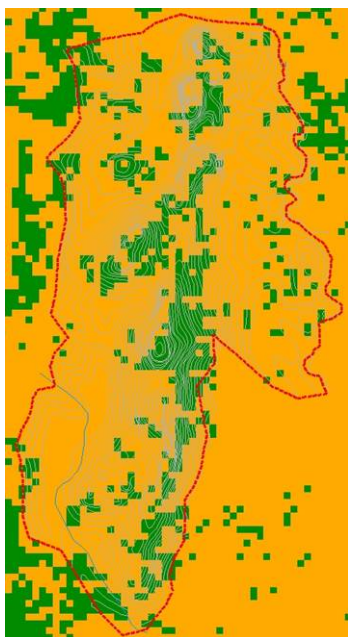Lake area
(1993)

Figure A6-9   Classification maps of the forest and the non-forest areas (1993)

Site-5:
Bac Phong
West area
(1989)

Site-4:
Bac Phong
East area
(1989)

Site-1&2:
Xuan Phong North
and Northeast area
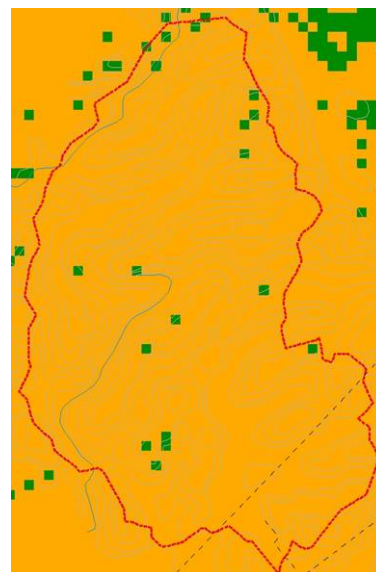(1989)

Site-3:
Xuan Phong
Lake area
(1989)

Figure A6-10   Classification maps of the forest and the non-forest areas (1989)
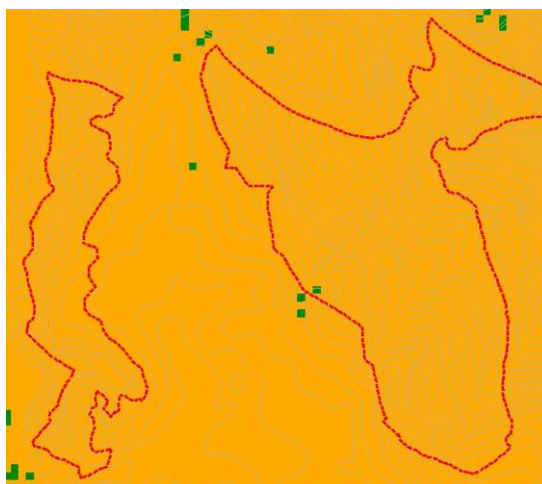
Site-5:
Bac Phong
West area
(1987)

Site-4:
Bac Phong
East area
(1987)

Site-1&2:
Xuan Phong North
and Northeast area
(1987)
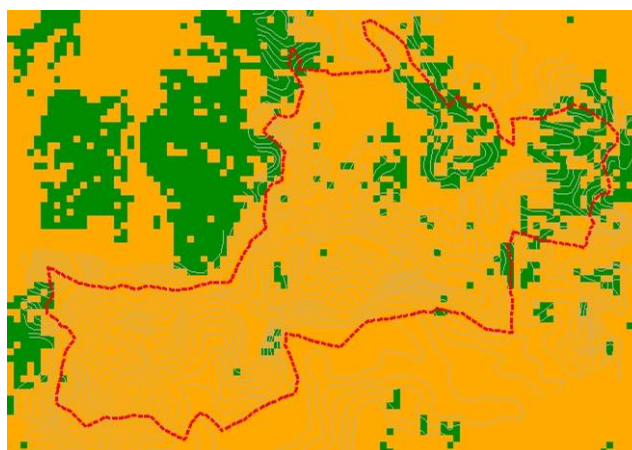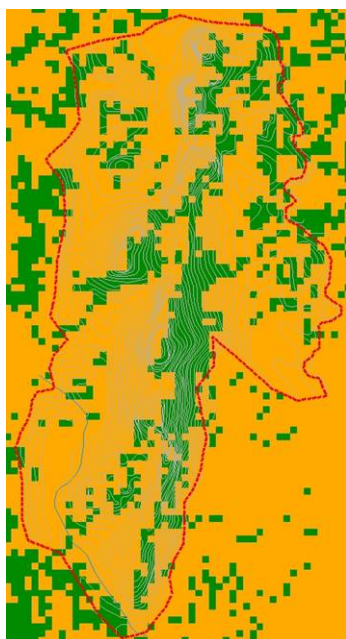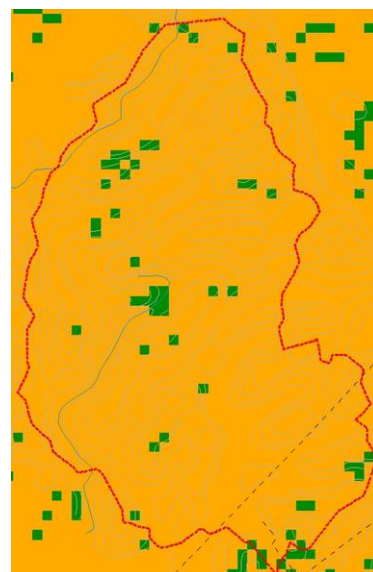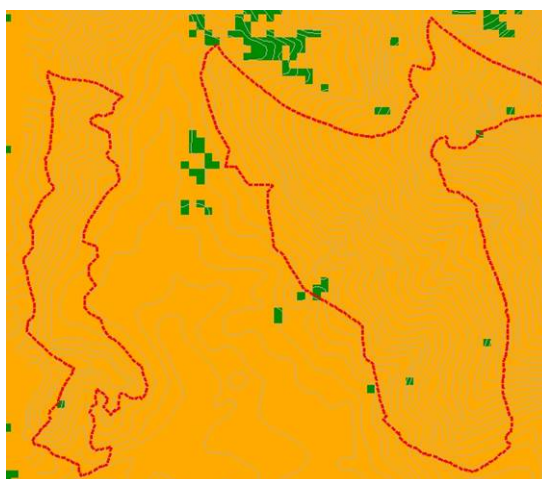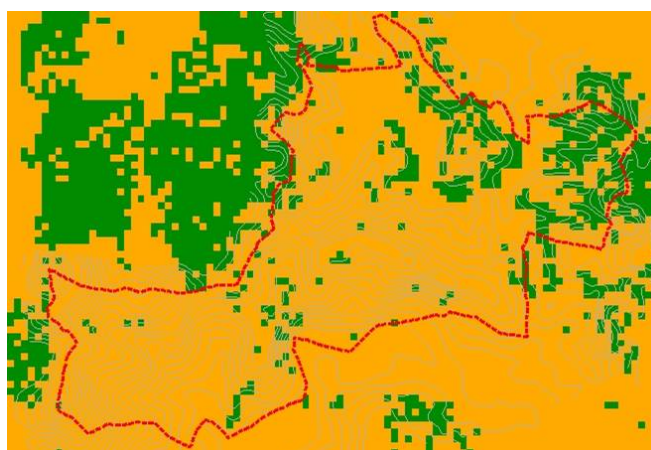

Site-3:
Xuan Phong
Lake area
(1987)

Figure A6-11   Classification maps of the forest and the non-forest areas (1987)

3.3 Comparison of Classification Results and Actual Land Covering Situation

Site-1&2: Xuan Phong North and Northeast areas

Few areas in the site were classified as "forested" area.

Site-3: Xuan Phong Lake area

As a result of the field survey, areas classified as "forested" in satellite images were naturally regenerated forest and thick shrub. The regeneration forest is distributed in the northwest area of the site. As a confirmation of aerial photographs taken in 2004 and 1971, trees existed densely at those areas. In addition, it is difficult to confirm actual shrub areas in the satellite image because of dense clouds in the images. According to the classification results for 2007, areas near the northwest boundary areas of the site were classified as "forest". As a result of a field survey in September 2007, it was revealed that there were regenerated forests and shrub of less than 3 m in height.

Site-4: Bac Phong East area

As a result of field surveys of areas classified as "forest", there may have been Lau Lach (a kind of gramineous grass) in the past. According to interviews with local people, these land cover situation had not changed significantly and there was Lau Lach at the sites classified as "forest" on the classification map in the past.

The field survey reveals that there is a possibility that Lau Lach grew in the past. It must be noted that Lau Lach may have been distributed in the area classified into the forest on the maps for 1987, 1989, and 1993.

Site-5: Bac Phong West area

As a result of the field survey of areas classified as "forest", there were lime stone hills with shrub and Lau Lach. According to interview with local peoples, these land cover situations had not changed significantly and it should be considered when evaluating forest at this site.

Steep hills with shrub (Sep. 2007)   Lau Lach (Jan. 2007)

Figure A6-12   Photographs of land covering situation in Site-5 (Bac Phong West area)

Thick shrub (less than 3m height) area No.1 (Sep. 2007)

Thick shrub (less than 3m height) area No.2 (Sep. 2007)

Figure A6-13   Photographs of land covering situation (Shrub less than 3m height)

The features of each area identified as forest and methods for confirmation were shown in Table A6-5.

Table A6-5   Summary of features classified to the forest

Land covering	Location	Grounds
Regenerated forest	Northwest direction of Xuan Phong Lake	Investigation (2007) Aerial photo (2004, 1970)
Thick shrub (less than 3m height)	On the boundary of project site (Xuan Phong Lake)	Investigation (2007)
Bedrock of limestone in which the shrub grows thick	Bac Phong West	Investigation (2007) Local commune (Past 10 years)
Lau Lach	Bac Phong West	Investigation (2007) Local commune (Past 10 years)
Sugar cane	Out of the project sites	Investigation (2007)

4   Evaluation of "forest" areas at the end of 1989

4.1   Evaluation of "Forest" and "Non-forest" areas for each pixel on satellite image
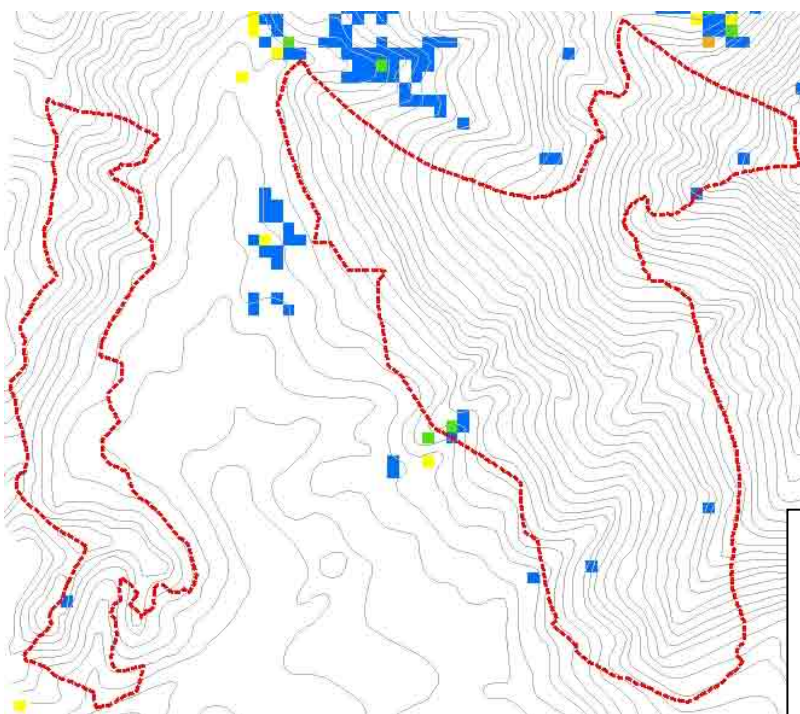
Classification results for each year were summarized in Table A6-6. According to the classification results for each satellite image, the classification standards at the end of 1989 were concluded in the right row in Table A6-6. The satellite images were evaluated and identified each pixel into as "forest" and "non-forest" at the end of 1989 using the classification standard at the end of 1989

Table A6-6   Evaluation standard for the land use at the end of 1989

No.	Classification results for each satellite image			Classification Standard (End of 1989)
	1987	1989	1993	
1	Forest	Forest	Forest	**Forest**
2	Forest	Forest	Non forest	**Forest**
3	Non forest	Forest	Forest	**Forest**
4	Non forest	Forest	Non forest	**Forest**
5	Forest	Non forest	Forest	**Non forest**
6	Forest	Non forest	Non forest	**Non forest**
7	Non forest	Non forest	Forest	**Non forest**
8	Non forest	Non forest	Non forest	**Non forest**

The evaluated results are shown in Figure **A6-14 and 15**.
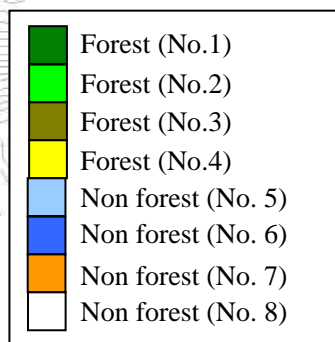
Site-1&2: Xuan Phong North and Northeast area

■ (dark green)	Forest (No.1)
■ (green)	Forest (No.2)
■ (olive)	Forest (No.3)
■ (yellow)	Forest (No.4)
■ (light blue)	Non forest (No. 5)
■ (blue)	Non forest (No. 6)
■ (orange)	Non forest (No. 7)
□ (white)	Non forest (No. 8)

Site-3: Xuan Phong Lake area
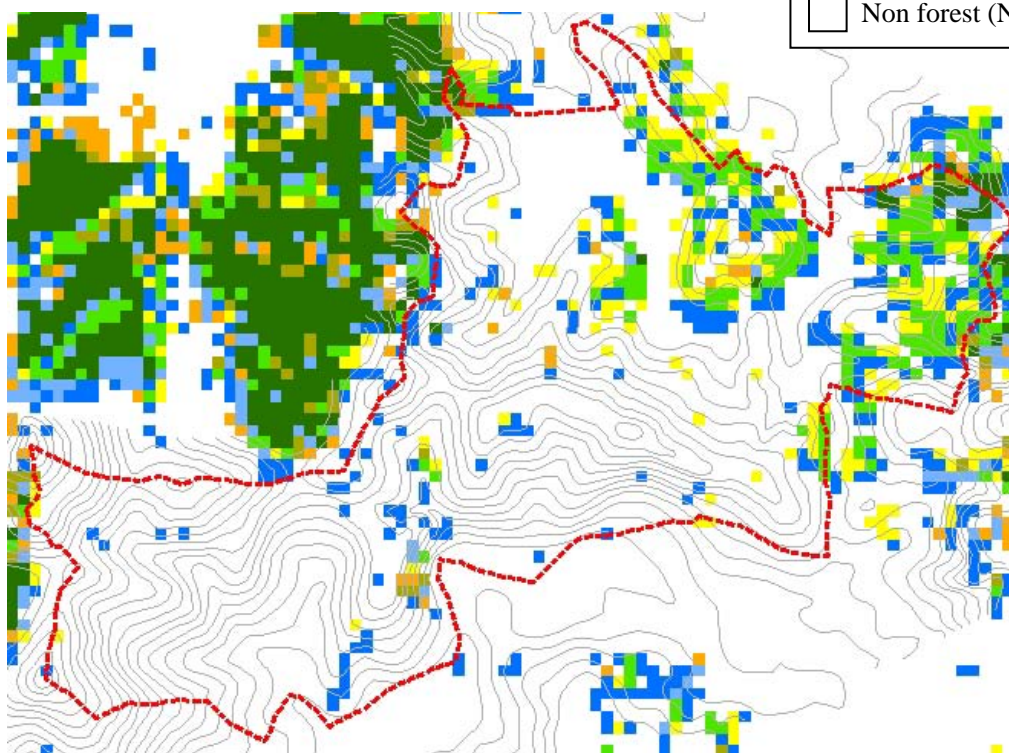
Figure A6-14   Evaluation results of "forest" and "non-forest"   (Xuan Phong)

Site-5: Bac Phong West area   Site-4: Bac Phong East area

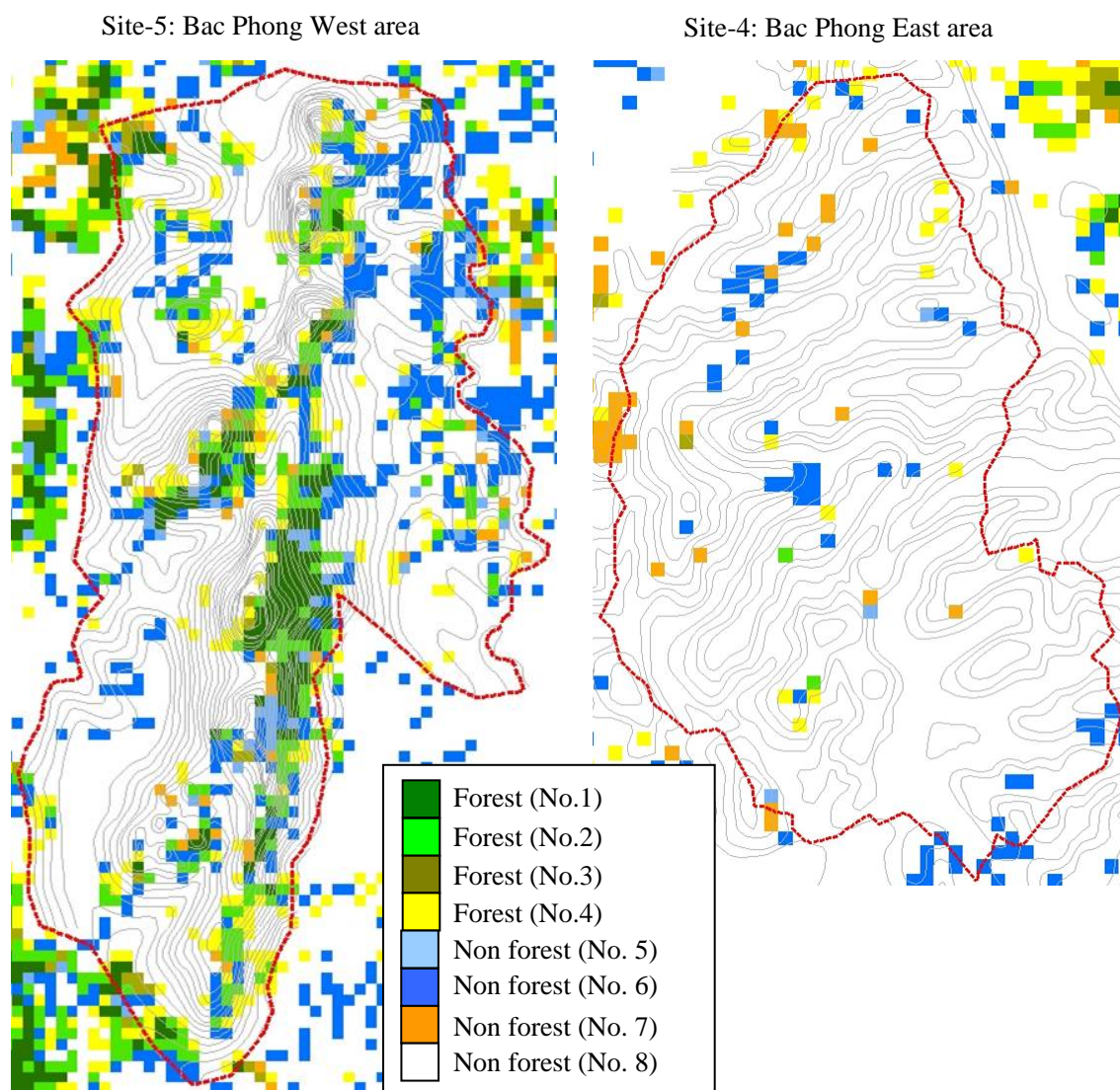| | Forest (No.1) |
	Forest (No.2)
	Forest (No.3)
	Forest (No.4)
	Non forest (No. 5)
	Non forest (No. 6)
	Non forest (No. 7)
	Non forest (No. 8)

Figure A6-15 Evaluation results of "forest" and "non-forest" in Bac Phong commune

4.2   Evaluation of "Forest" and "Non-forest" Area in the Project sites

The definition of "forest" area in Vietnam is that a single forested area is more than 0.5 hectares. If the forested area is less than 0.5 hectares (that is, the adjoining less than eight pixels), it will not interpreted as "forested". Forest areas fulfilling the definition of "forest" in Vietnam are shown in Figure **A6-**16 and 17. The results of each site are summarized as below;

Site-1&2: Xuan Phong North and Northeast areas

There were no areas of "forest" in the sites.

Site-3: Xuan Phong Lake area

There were 9 areas of "forest" in the sites. Those were mainly distributed in the northeast side of the project site. It must be noted that thick shrub less than 3m in height may also be evaluated as

"forest" at this site, as shown in Table A6-5. With regard to the part evaluated as "forest", it may be desirable to check the land covering situation at the end of 1989 using other methods.

Site-4 Bac Phong East

There were no areas of "forest" in the sites.

Site-5: Bac Phong West area

There were 14 areas of "forest" in the sites. The most were on limestone hills. At this site, the Lau Lach (a kind of gramineae grass) and limestone hills with shrub may also be evaluated as "forested" at this site, as shown in Table A6-5. With regard to the part evaluated as the forested, it may be desirable to check the land covering situation at the end of 1989 using other methods.

Site-1&2
Xuan Phong North and
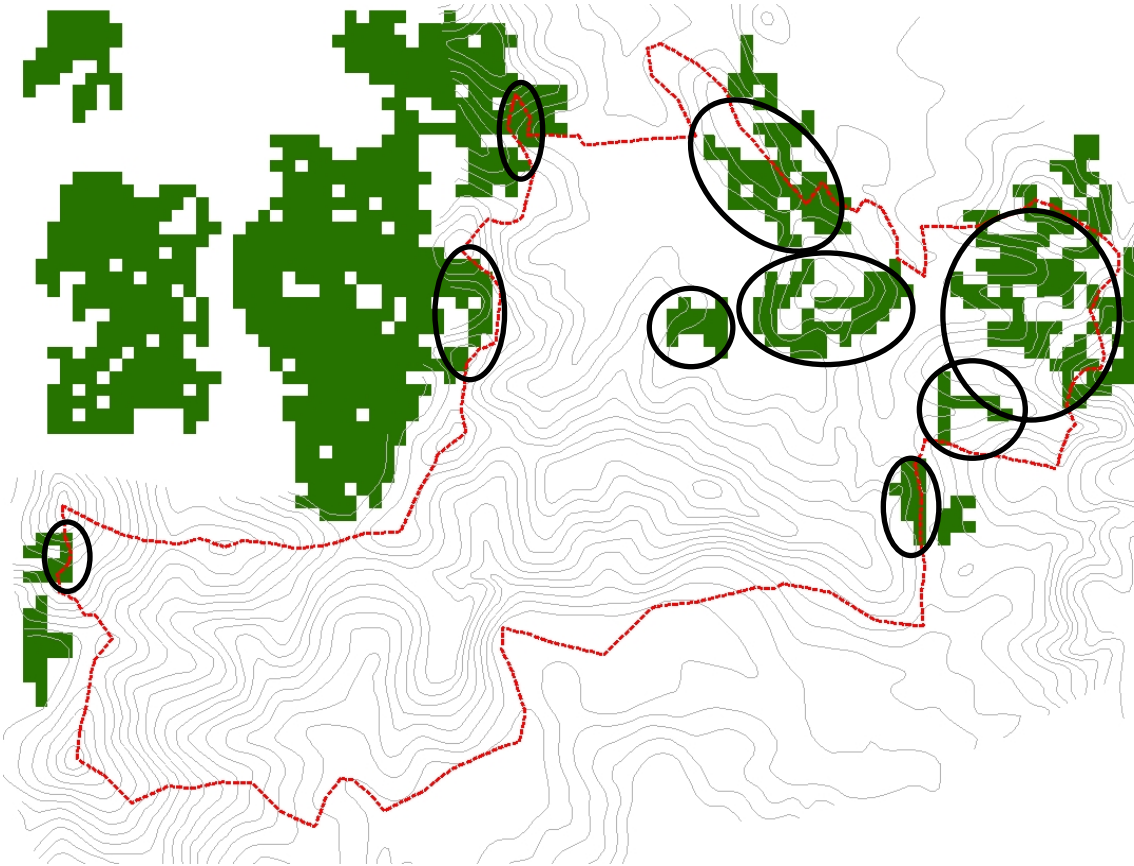Northeast areas
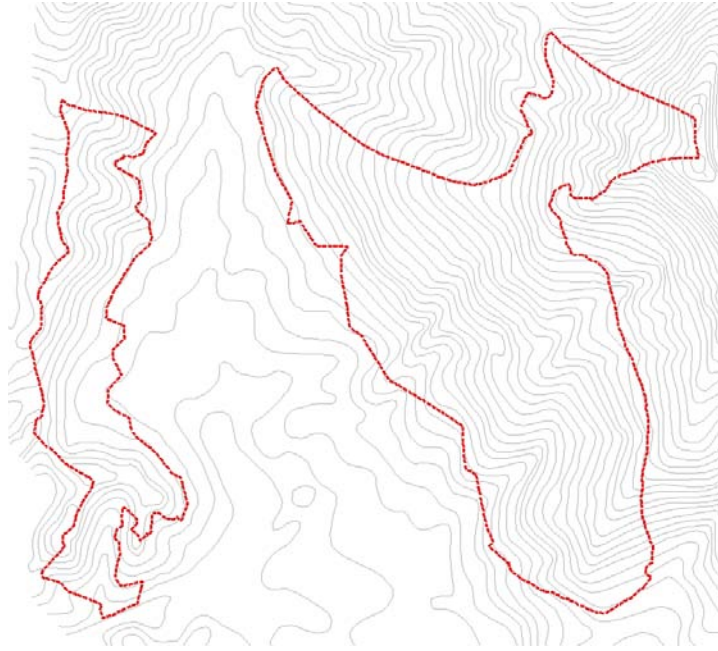
Site-3 Xuan Phong Lake area

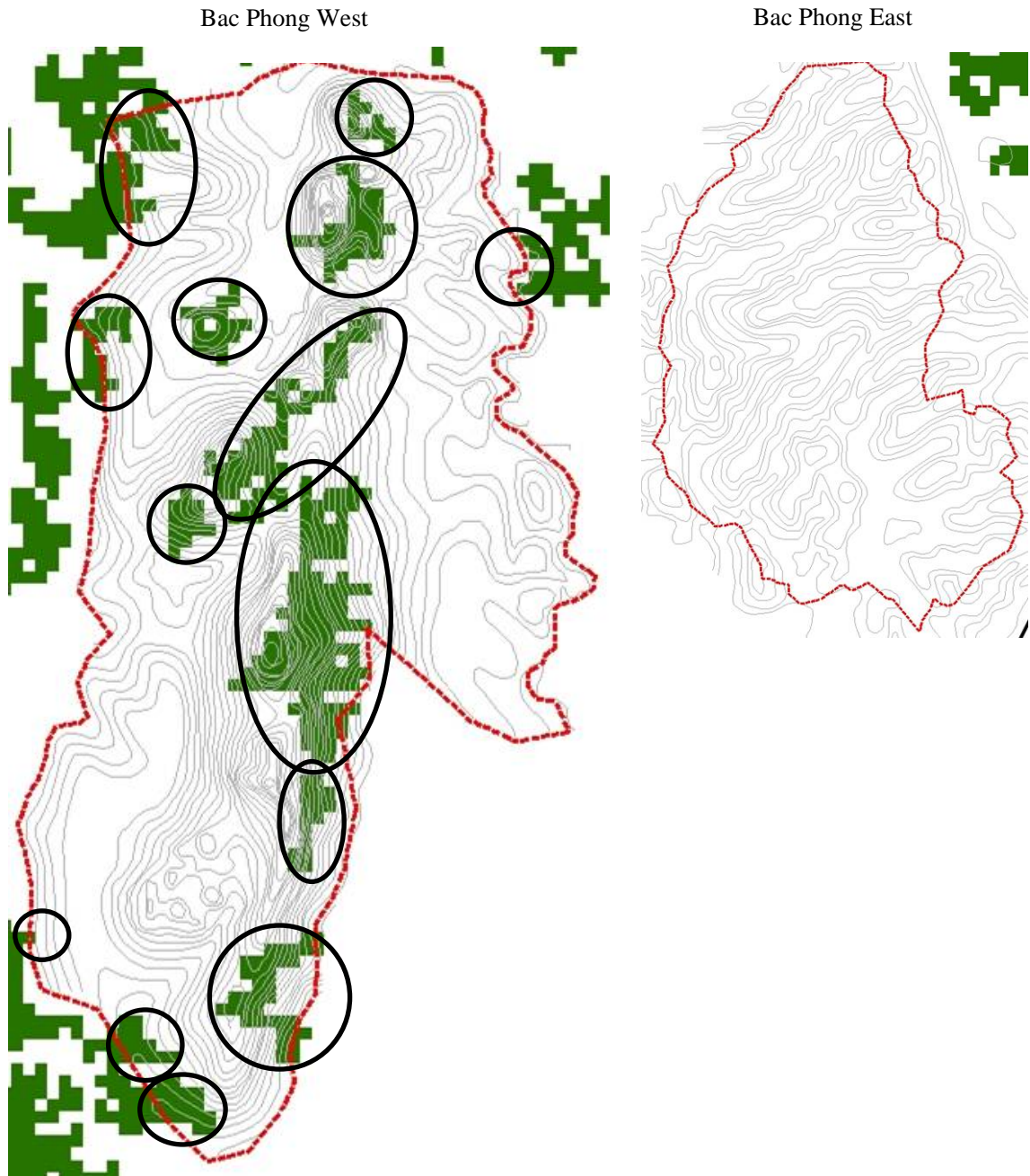**Figure A6-16　"Forest" areas at the end of 1989 in Xuan Phong commune**

Bac Phong West   Bac Phong East

Figure A6-17   "Forested" areas at the end of 1989 in Bac Phong commune

The "forested" areas in each project site at the end of 1989 are summarized in Table A6-7.

Table A6-7   Evaluated "forest" area at the end of 1989

Site name	Area in Original project boundary	Forest area
Bac Phong West	163.2 ha	24.2 ha
Bac Phong East	83.8 ha	0.0 ha
Xuan Phong North west	25.8 ha	0.0 ha
Xuan Phong North east	74.6 ha	0.0 ha
Xuan Phong Lake	144.7 ha	14.8 ha

5   Summary and Conclusion

■ "Forest" and "non-forest" areas in the project sites at the end of 1989 were evaluated using 4 satellite images (Landsat/TM sensor, 1987, 1989, 1993, and 2007) and there were some areas defined as "Forested" in Bac Phong West, and Xuan Phong Lake.

■ The Lau lach (a kind of gramineae) and thick shrub less than 3m in height might also be evaluated as "forest" by the method used in the Study, as shown in Table A6-5. With regard to the area evaluated as "forest", it is desirable to check the land covering situation at the end of 1989 using other methods for to reinforce the result.

■ The classification category did not contain plantation area (refer to "2. Data Specification and Classification Method "). It may be necessary to distinguish the areas which were plantation areas in the project site at the end of 1989.

■ The training data adopted in this study are typical spectrum patterns. It is also desirable to check out the land covering situation at the same time of satellite images.