C. "CASE STUDY"
Monitoring of the Forest Land Use by Means of Remote Sensing in Thailand

1. Outline

This case study using LANDSAT data for 2 periods gives one example of forest land use monitoring by remote sensing for a part of the national forest area in the west of Thailand.

In this monitoring, land cover classification was conducted mainly based on digital image analysis and LANDSAT data for understanding of the land use condition.

In this understanding of the land use condition, existing land use maps were used to verify a part of the classification result, and annual variations in land use were also examined.

The study area is located in a national forest area adjoining the Srinagarind dam in the north-west part of Kanchanaburi in western Thailand. The study area covers approximately 21,000 ha.

The study was carried out to know the land use condition in two different periods using the land cover classification made based on LANDSAT data for the two periods (13 Dec. 1983, and 30 Jan. 1987). In addition, a shift in the land use condition during these two periods was examined after forest type maps were verified.

Consequently, the comparison in the land use condition between 1983 and 1987 showed that the forest land decreased from approximately 15,000 ha to about 10,000 ha with an increase in cultivatd fields from approximately 2,000 ha to 5,000 ha. Namely, the forest land decreased form approximately 76% to 50%.

2. Details of the Survey

2.1. Purposes of the Survey

This study was conducted as a case study of forest investigation by remote sensing. This study used LANDSAT data for two periods to elucidate the condition of land cover through digital image processing for the variance between these two periods. The purpose of the study is to understand the change in forest area within the study area.

2.2. Range of the Survey

The area for the study is shown in Figure 19. The study area covers a national forest area adjacent to the Srinagarind dam upstream of the Kanchanaburi in the west part of Thailand. The study area is approximately 21,000ha. This area located in dense tropical rain forests has been cultivated more and more with immigration. This area requires precise understanding of forest distribution and appropriate forest management.

2.3. Items to Be Surveyed

Major items to be surveyed are shown below. Figure 20 shows a flowchart of the survey.

(1) Rectification of LANDSAT MSS data
(2) Land cover classification by Maximum Likelihood
(3) Understanding of forest land use
(4) Understanding of annual variations
(5) Verification of accuracy in the land cover classification
(6) Summarizing

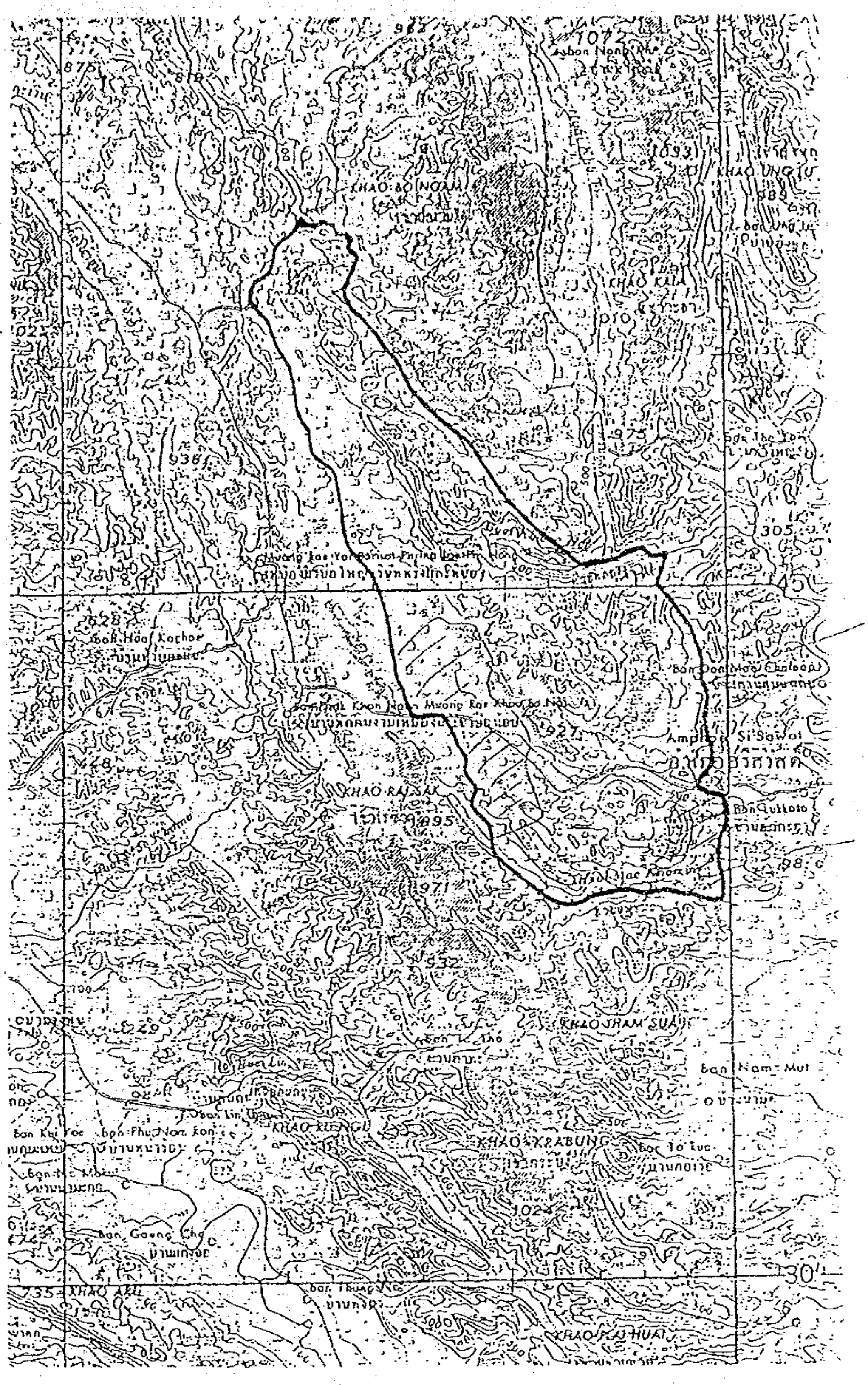

Fig. 19 Location of the study area (1/250,000)

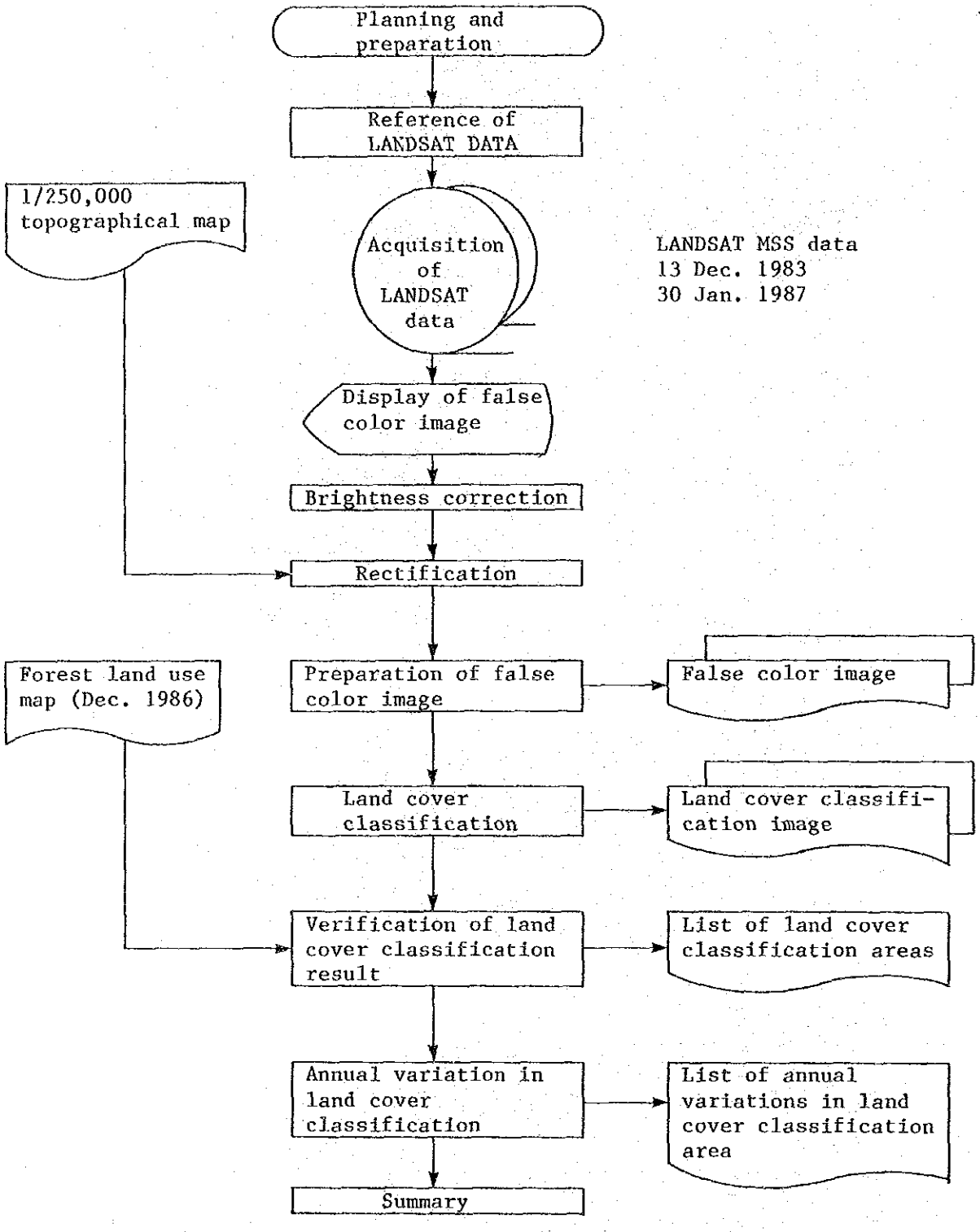

Fig. 20 Flowchart of the forest land use monitoring study

2.4. Used Data

(1) LANDSAT MSS data

Two sets of MSS data of two different periods covering the study area were used. Table 7. lists the used LANDSAT data.

Table 7 List of used LANDSAT data

Sensor	LANDSAT No.	PATH-ROW	Date
MSS	L-4	130 - 50	1983.12.13
MSS	L-5	130 - 50	1987. 1.30

(2) Topographical maps of Thailand

The 1/250,000 scale topographical maps were used for confirmation of the study area and rectification of the LANDSAT data. Figure 21 gives divisions of the used topographical maps.

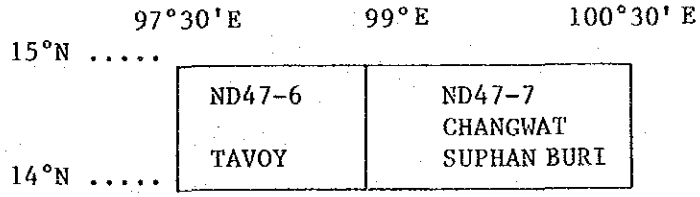

Fig. 21 Divisions of the used topographical maps of Thailand

(3) Land use division maps of the study area

The 1/10,000 scale land use division maps were used for input of land use division data. The preparation of these land use division maps was made by summarizing the interpretation result of 1/20,000 aerial photos taken in December 1986. The interpretation result is grouped into the following categories.

2.5. System to Be Used

The composition of the digital image analysis system used in this study is illustrated in Figure 22. The central part of this system consists of a VAX-11.730 and an image processor. The input system has a digitizer for geographical information input and a video digitizer for photographic information input. The output system has a color display, a graphic camera for photographic recording of image and a hard copying machine. In addition, a color drum scanner for input of photographic information and geographical and map information on offline, a photo printer for recording image analysis result, a FACOM S3500 system and an image processor for assisting computation, and a personal computer PC 9801E.

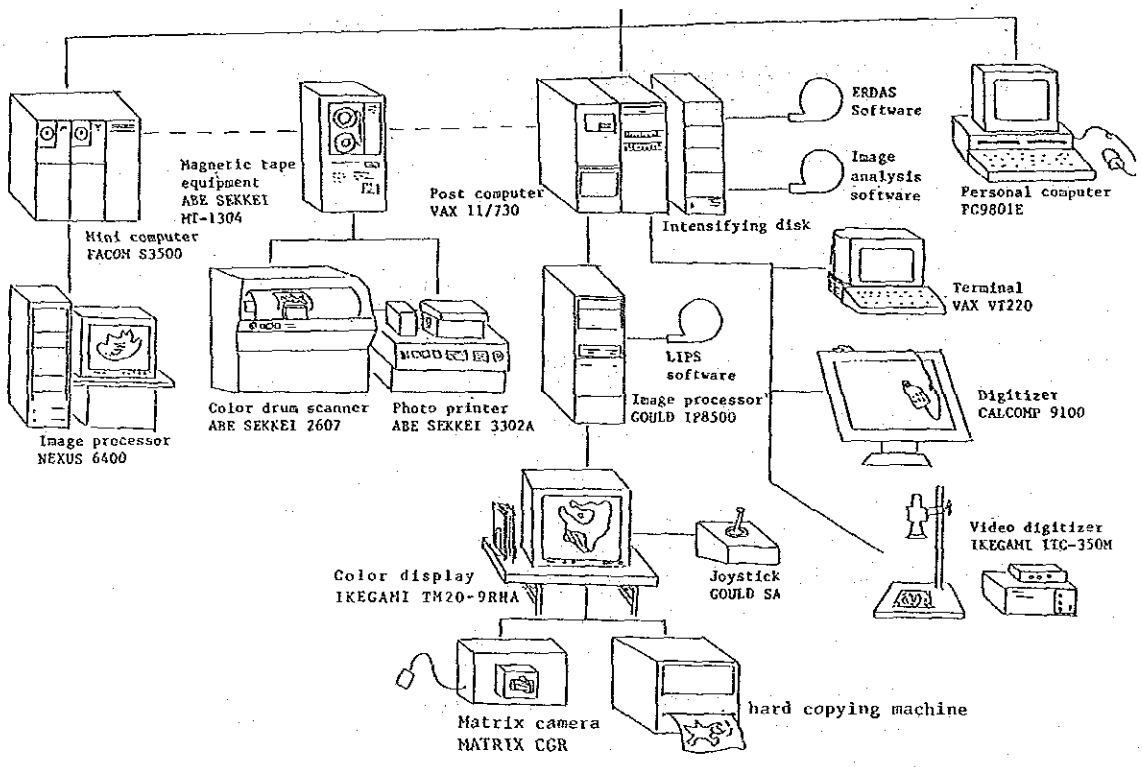

Fig. 22 Used image analysis system

2.6 Study Procedure and Results

(1) Acquisition of LANSAT data

Of LANDSAT MSS data covering the study area, cloud cover data and image quality data were checked using a cloud cover list, and the LANDSAT data for two different periods were obtained in CCT(Computer Compatible Tape).

(2) Brightness correction

Since the observation data for these two periods were different in season and weather, brightness correction is required to reduce the temporal error between the two periods to some extent. Histograms were made for images of the two periods to conduct brightness correction.

(3) Rectification

Rectification was carried out so that the LANDSAT data were coherent with topographical maps. Topographical maps in 1/250,000 scale were used to select a ground centred point (GCP) which could be easily distinguished on both the LANDSAT images and the topographical maps. The nearest neighbour method was adopted and the size of picture element after rectification was 50m x 50m.

(4) Preparation of False Color Image

The rectified LANSAT MSS data were used to prepare false color images. Each band of MSS corresponds to the following output image color:

Red : Band 7 data (near-infrared)
Green : Band 5 data (visible red)
Blue : Band 4 data (visible green)

The false color images were put out on a color image display to use for GCP measurement and selection of training fold for land cover classification.

Figures 23 and 24 give the false color images.

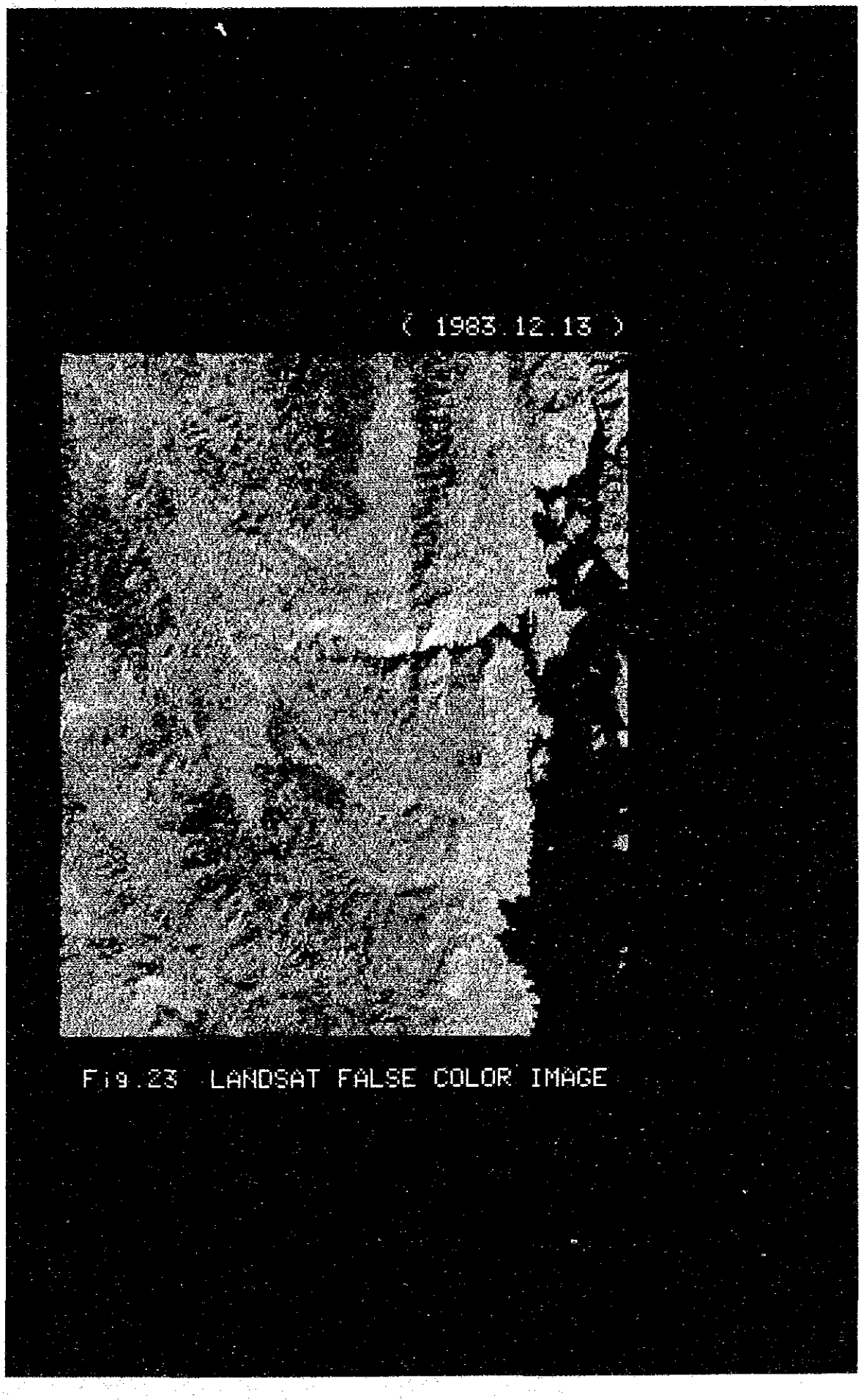

Fig.23 LANDSAT FALSE COLOR IMAGE

Fig.24 LANDSAT FALSE COLOR IMAGE

(5) Land-Cover Classification

The rectified LANDSAT MSS data for the two periods were used for land cover classification by the nearest neighbour method. The nearest neighbour method provides a statistical technique to judge to which one of previously designated categories a set of image data in element unit belongs. In this study, 6 categories — ① forest, ② field, ③ grasses, ④ waste land, ⑤ rough field, and ⑥ water — were set.

1)	Forest	: Forest (Forest I: deep red, Forest II: purple, Forest III: light red, Forest IV: dark red)
2)	Field	: Cultivated land
3)	Grasses	: Green land such as bush and grassland
4)	Waste land	: Area covered with rocks and sands with almost no vegetation
5)	Rough field	: Area with no vegetation, but with exposed rocks and stones
6)	Water	: Water area such as rivers and lakes

Figures 25 and 26 show land cover classification images. Tables 8 and 9 give lists of judgement effectiveness.

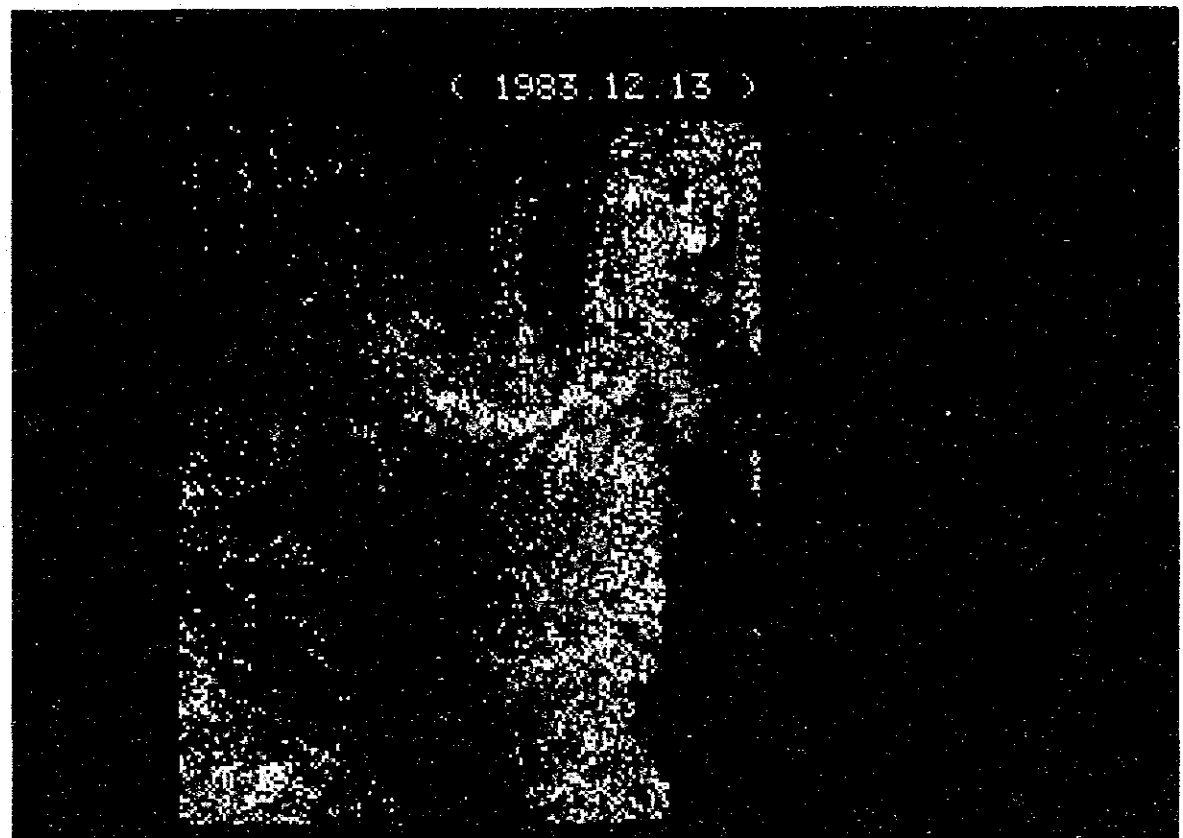

Fig.25 LAND COVER CLASSIFICATION MAP

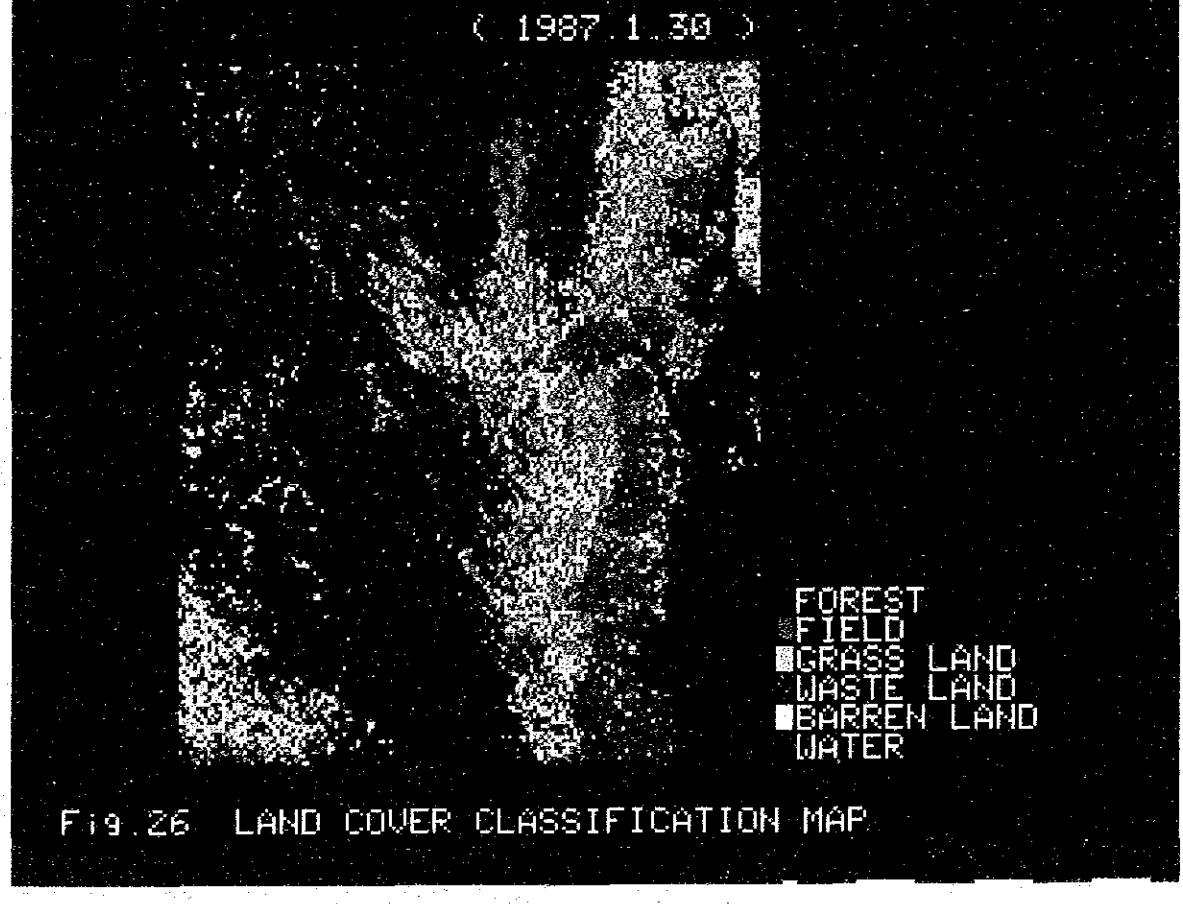

Fig.26 LAND COVER CLASSIFICATION MAP

Table 8 Image classification contingency table (1983)

(%)

Training field / Result	Forest I	Forest II	Forest III	Forest IV	Cultivated field	Grasses	Waste land	Barren land	Water
Forest I	57.4	0	21.1	3.1	3.8	0	0	0	0
Forest II	0	100	0	0	0	0	0	0	0
Forest III	38.3	0	74.6	1.6	3.8	0	0	0	0
Forest IV	2.1	0	0	68.8	5.7	8.3	0	0	0
Cultivated field	2.1	0	2.8	4.7	83.0	8.3	0	0	0
Grasses	0	0	1.4	21.9	3.8	83.3	0	0	0
Waste land	0	0	0	0	0	0	100	0	0
Barren land	0	0	0	0	0	0	0	100	0
Water	0	0	0	0	0	0	0	0	100

Table 9 Image classification contingency table (1987)

(%)

Training field / Result	Forest I	Forest II	Forest III	Forest IV	Field	Grasses	Waste land	Barren land	Water
Forest I	100	0	0	0	0	0	0	0	0
Forest II	0	100	0	0	0	0	0	0	0
Forest III	0	0	100	0	0	0	0	0	0
Forest IV	0	0	0	93.5	0	0	0	0	0
Field	0	0	0	6.5	96.7	8.7	0	0	0
Grasses	0	0	0	0	3.3	91.3	0	0	0
Waste land	0	0	0	0	0	0	100	0	0
Barren land	0	0	0	0	0	0	0	100	0
Water	0	0	0	0	0	0	0	0	100

① Observation data on Dec. 1983.

Areas by categories are shown in Table 10.

Table 10 Result of land cover classification

ha (%)

Category	Forest	Cultivated field	Grasses	Waste land	Barren land	Water	Total
Area	15724.75 (75.8)	1838.50 (8.9)	1949.25 (9.4)	1011.75 (4.9)	185.25 (0.9)	12.25 (0.1)	20721.75 (100.0)

According to the data for this period, an approximately 76% of the study area is covered with forest. Fields spread along the valleys and around the forest areas, while waste lands and rough fields distribute mainly along the lake front. As far as one judges from the images, natural tropical rain forests distributes in this area.

② Observation data on Jan. 1987

Areas by each category are shown in Table 11.

Table 11 Result of land cover classification

ha (%)

Category	Forest	Cultivated field	Grasses	Waste land	Barren land	Water	Total
Area	10433.00 (50.3)	5140.75 (24.8)	3432.75 (16.6)	1599.50 (7.7)	80.25 (0.4)	34.50 (0.2)	20721.75 (100.0)

The data for this period indicate that deforestation has proceeded widely and that fields spreads in the periphery of forests and in the wide inland area. Waste lands and grasses spread widely from the lake front to the inland, showing a great loss in forest area. As to the study area, the increase of cultivated field area is marked.

(6) Accuracy verification in Land-cover classification

The land use condition based on aerial photos taken in 1986 and the land cover classification results obtained from 1987's LANDSAT data were overlayed to verify the accuracy in the land cover classification.

In the verification of the land cover classification result, forest type maps which were prepared based on interpretation of aerial photos taken almost in the same period with the LANDSAT data for a part of the study area were processed to images with a poligon digitizer (Figure 27). The geometrical coherency with the land cover classification result of (5) was thus assured.

Table 12 shows a check list for the land cover classification result from the LANDSAT data and the land use areas from the forest type maps.

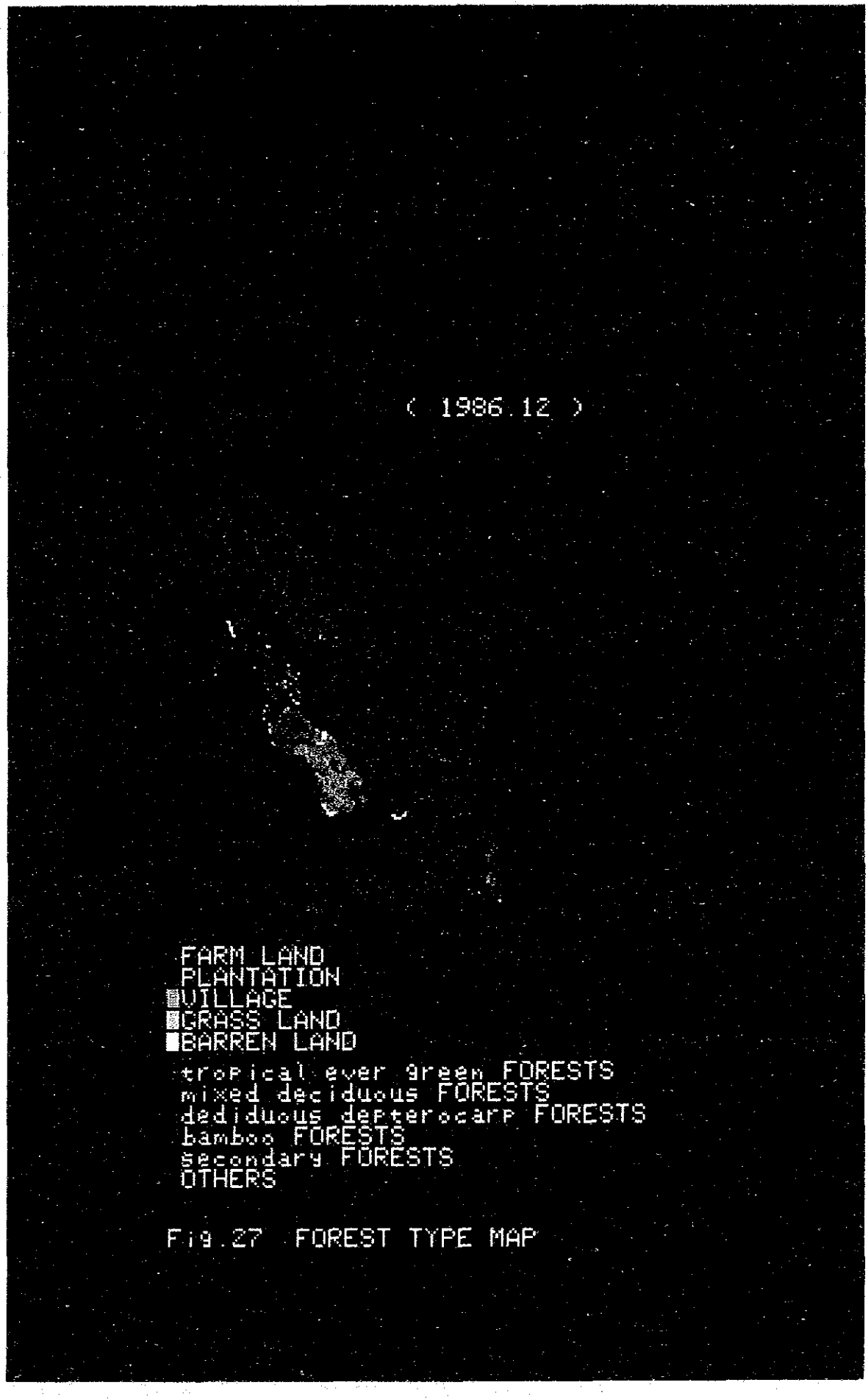

Fig.27 FOREST TYPE MAP

Table 12 Cross checking list between land cover classification data and forest map data

(ha)

LAND COVER		Forest	Cultivated field	Grasses	Waste land	Barren land	Water	Total
Forest	TE	1,123	35	12	0	0	2	1,172
	MD	3,092	972	563	645	18	0	5,290
	DD	0	8	0	63	0	0	71
	BF	54	17	12	45	1	0	129
	SF	116	22	4	36	0	0	178
	Total	4,385	1,054	591	789	19	2	6,840
A		213	90	21	34	2	0	360
G		28	13	1	0	0	0	42
B		94	8	2	2	0	0	106
P		0	2	1	16	1	0	20
V		4	7	1	1	1	0	14
Total		9,109	2,228	1,208	1,631	42	4	14,222

(7) Understanding of Annual Variances

The results of the land cover classification for the two periods were overlayed to know annual variances (Figure 28). Table 13 summarizes area by category.

Table 13 Annual variances of land cover

(ha)

1983 \ 1987	Forest	Cultivated	Grasses	Waste land	Barren land	Water	Total
Forest	2285.25	6698.75	3204.75	460.75	25.75	23.25	12698.5
Cultivated field	49.25	2454.25	1184.5	94.75	2.25	1.00	3786.0
Grasses	19.5	975.0	1128.25	568.75	22.0	0.25	2713.75
Waste land	1.0	427.0	438.25	430.75	14.0	0.25	1311.25
Barren land	3.25	30.5	55.5	94.5	16.25	0	200.0
Water	0	0.75	5.5	0	0	6.0	12.25
Total	2358.25	10586.25	6016.75	1649.5	80.25	30.75	20721.75

The result of the estimation of these annual variances indicates the followings:

1) In 1983, more than 3/4 of the study area was covered with forests, while in 1987 the forest area has decreased below 1/2 of the study area. More than half the deforestated area has shifted to cultivated fields. These figures suggest very clearly that the deforestated land has been converted to cultivated land. Next to cultivated field, a shift to grasses is marked. This area seems to indicate unutilized areas after deforestation.
2) Cultivated field, grasses and rough field have similar physical characteristics of data, and on the field, too, annual variances among them are quite high. In terms of area, these three categories are mixed. Vegetation can be seen more or less for each category. This can be justified, because these three categories have similar soils.
3) The water area is different between 1983 and 1987, and also total variances to other categories are summarized. These variances are assumed to be due to annual changes in the water front lines. The water area in 1987 is greater than that in 1983, and the most part of this increase seems to have been forest.

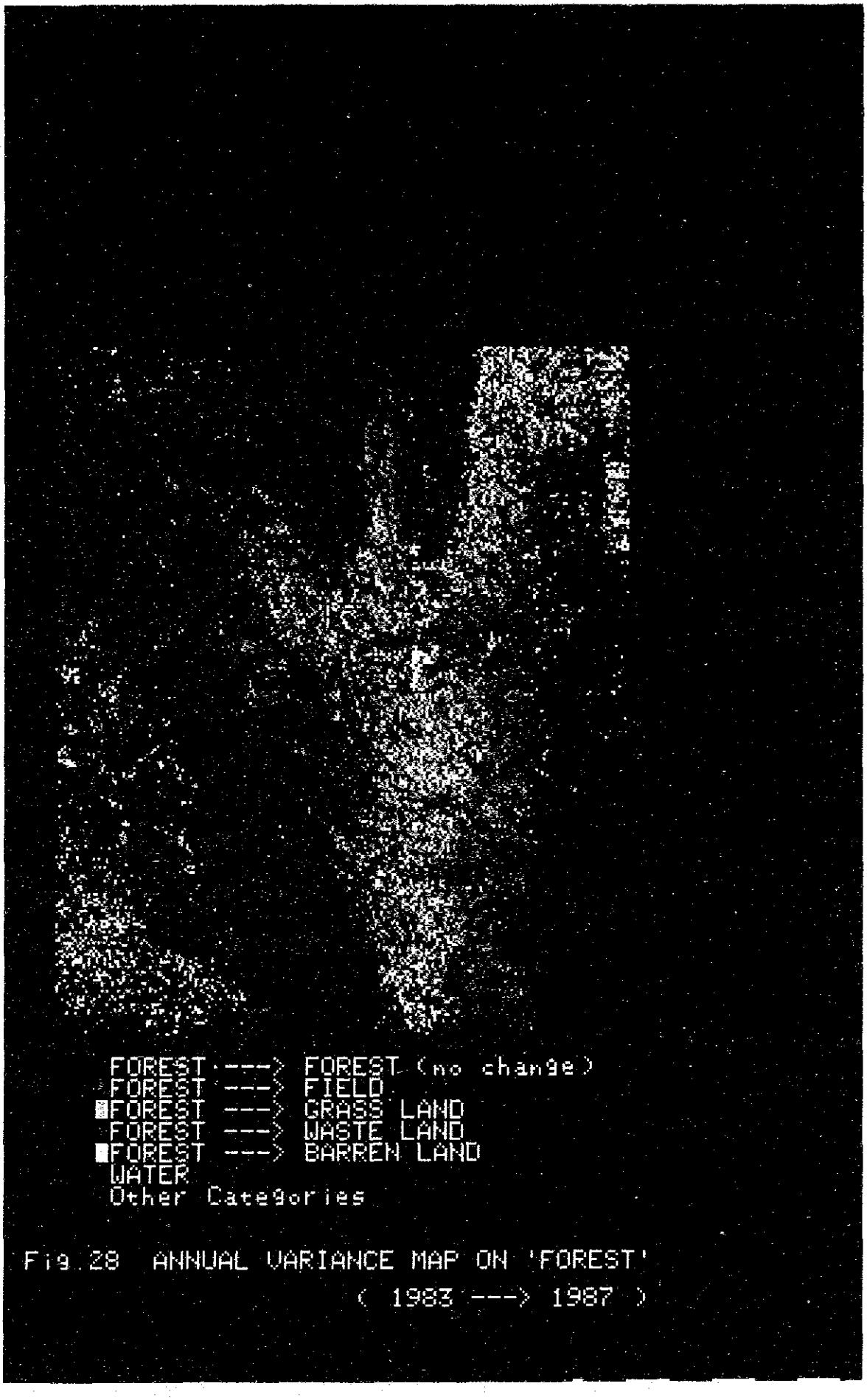

Fig.28 ANNUAL VARIANCE MAP ON 'FOREST'
(1983 ---> 1987)

3. Conclusion

This case study shows a monitoring technique to know annual variances in forest area using LANDSAT data. This technique is largely characterized by sampling changes in land cover classification by LANDSAT data between two different periods through overlaying. Since there is no limitation in area for analysis because of the use of satellite images, this technique can process a wide area. Although the small PIXEL size of 50m x 50m of this technique limits the utilization for small area vegetation classification, it provides a effective mean to know a wide area in a global scale such as a change in wide forest areas where a field survey is practically impossible.