ISE-TR-85-53

ANALYSIS OF MANGROVE FOREST IN OKINAWA USING AIRBORNE REMOTE SENSING DATA

by

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November 14, 1985

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Abstract

The present study was carried out by processing airborne remote sensing data on mangrove forests on Ishigaki Island, Japan. These remote sensing data were classified under unsupervised and supervised classification analysis. As a result, it revealed that it was possible to identify mangrove forest areas. And then, by comparing the spectral characteristic of corresponding pixels to the areas that involved two species of mangrove trees, that is, Yaeyamahirugi (Rhizophora stylosa) and Ohirugi (Bruguiera gymnorrhiza) with mixture proportion taken by ground survey, it was believed to be able to estimate the distribution of two species on the basis of airborne MSS data.

Contents

1. Introduction

Mangrove forests are extensively distributed along a coast or in a brackish water area in tropical and sub-tropical regions. An existence of the forests influences soil erosions along rivers, tide within these areas and wave from sea. They form a typical ecosystem. In this ecosystem, the forests play important roles not only as a resource but also as a place where young aquatic plants and wild animals inhabit, and for decreasing the destruction of natural calamity such as a typhoon. But so far, the forests have been recognized only as firewoods, building material and raw materials of a pulp and some of them are suffered from artificial destruction, so it is important to manage the forests properly.

However, in many countries, research data are not sufficient both in quality and in quantity to find out the distribution area, constitutive tree kinds and growth history of the forests. These main reasons are demonstrated as follows. 1) As mentioned, the economic value of these trees is inferior comparing with other trees. 2) Most of locations where the trees grow are inconvenient for traffic and transportation because the locations are calm water areas as deltas. 3) In most regions where the trees grow, the sanitation condition is bad. 4) It is impossible to view the total area of large region of mangrove forest by standing in the field because of flat relief. 5) It is very difficult to enter mangrove forest because of intricate aerial roots and muddy soils.

But now, these reasons have not held correct, because the trees have got more worthy and the fading out of forests, especially tropical forests, has become world-side issue. Judging from above-mentioned facts, remote sensing techniques may be considered as a potential to survey the forests. Baines and Fosberg set to make an investigation into the application of remote sensing techniques to the forests identification <Baines(1968),Fosberg(1975)> and Siripong et al tried to map the trees on Panga Bay in southern part of Thailand <Silipong(1982)>. The previous study was conducted both on Kapoe and Ranong district in Thailand, using Landsat digital data <Hoshi et al(1983)>. As a result, the forests were identified with the accuracy of more than 95 percentage <Hoshi(1984)>.

In order to advance the previous study, the aim of present study is limited to explore whether two major species of the trees, namely, Yaeyamahirugi (Rhizophora stylosa) and Ohirugi (Brugurera gymnorrhiza), can be classified, and to discuss the correlation between mixture proportion of two species taken by ground measurements and radiances taken by airborne data. Though the forests grow on a small scale in Okinawa Island, they include Baines and Fosberg set to make an investigation into the application may be applied to the studies at other areas.

2. Selection of test site

After taking a census of mangrove forests in Japan <Nakasuga(1979)>, both Ishigaki Island and Iriomote Island belonged to Okinawa prefecture were selected as candidates for a test site, where the mangrove forests are growing fine. Then, after examing remote sensing data taken over these areas, it came to the conclusion that Ishigaki Island was more appropriate as a area studied. Because it was easy to acquire Landsat multispectral scanner (MSS) data, airborne MSS data and color aerial photographs. Ishigaki Island is (involved in Yaeyama Islands which are) located in south-western part of Ryukyu Islands in a row between Kyushu Province and Taiwan. Annual average temperature of this Island is 23.8°C, average daily minimum temperature is 21.5°C and the annual precipitation 2072 mm. At Itona area which is located in the mouth of Fukido River, Yaeyamahirugi is dominant on the seaward side and Ohirugi on the landward side. Both species grow in the intermediate zone. In addition to above mentioned tree kinds, Mehirugi (Kandelia candel) and Shimahirugi (Excoecarine agallocha) are also found out, but they are very sparse. Therefore, Itona area was selected as a test site for making an investigation into mixture condition of two species.

Ground surveys had been executed on Iriomote, Ishigaki and Okinawa Island from 1981 to 1983 to select field survey spots. Color aerial photograhps were utilized in extensive ground survey. Meantime, unsupervised classification map produced by airborne MSS data was also utilized in intensive survey. The reason why the classification map was especially put into practical use for ground survey was that data regarding near and thermal infrared wavechannels came into additional information. Based on these materials and the growth condition of the trees, 8 field survey spots (about 20m X 20m) were finally determined (Fig-1).

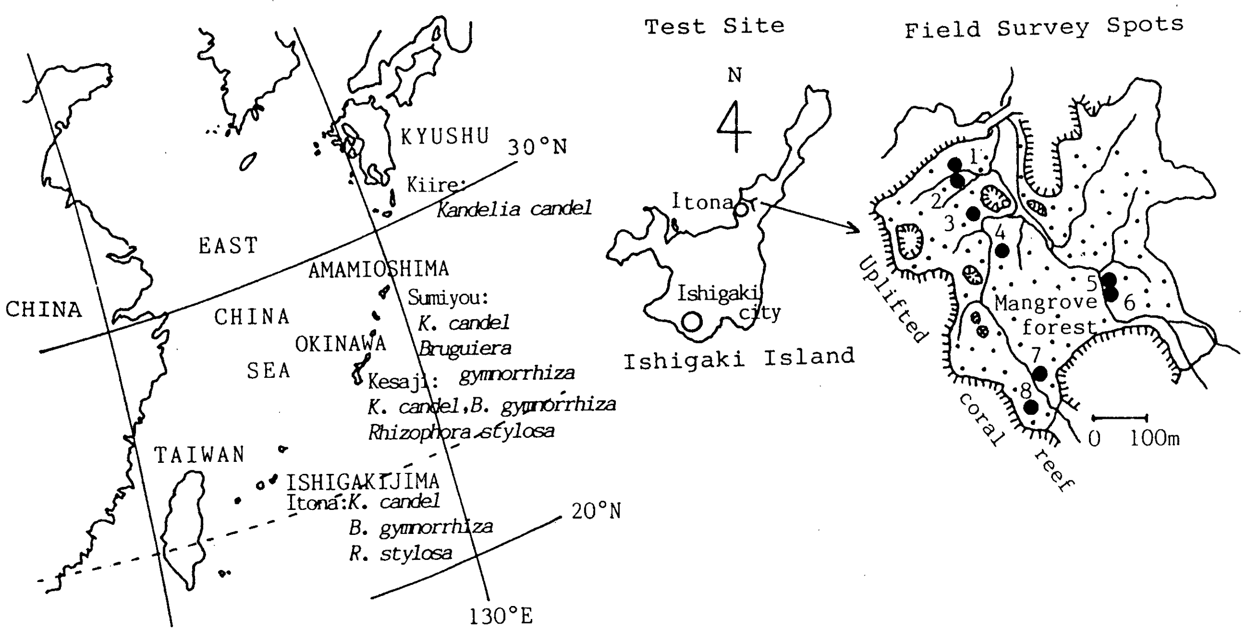

Fig-1 Mangrove forests and distributed species in Japan and location of test site and field survey spots

3. Materials

3.1 Materials for image analysis

Landsat MSS data, airborne MSS data and color aerial photographs were found out. Of these data, airborne MSS data were most suitable.

a) Airborne MSS data

Airborne MSS data were collected on 7th Jan, 1975 at an altitude of 3,000 meters. These MSS data were converted from frequency modulation (FM) tape to computer compatible tape (CCT) so as to obtain instantaneous field of view (IFOV) being about 2.5 mm redian. The dimension of a pixel corresponds to about 7.5 meters on ground. The MSS worked in 11 channels of wavelength as seen in Tabel-1. However, only 6 channels labeled open-circle were adopted for image analysis.

Table-1 Spectral Range of MSS

Channel Number	CCT	Spectral Range (um)
1		0. 30- 0. 42
2	○	0. 42- 0. 45
3	○	0. 45- 0. 50
4		0. 50- 0. 55
5	○	0. 55- 0. 60
6		0. 60- 0. 65
7	○	0. 65- 0. 69
8		0. 70- 0. 79
9	○	0. 80- 0. 89
10		0. 92- 1. 10
11	○	8. 00-14. 00

b) Color aerial photograph

The aerial photographs were taken on Dec. 1977 on the scale of 1:10,000 at 23cm X 23cm picture format. These aerial photographs were installed to drum scanner for Red-Green-Blue encoding at 100μm interval. The product is refered to 'aerial image data'. The dimension of a pixel corresponds to about 1 meter on grond.

3.2 Measured items with ground survey

In 8 field survey spots, the species of all trees within each spots were identified, the cross sectional area at breast height and the mixture proportion of two main species were mesured (Table- 2). The measured items consisted of :

A) Ratio of one species to the other species on the basis of the number counted of the trees.

B) Ratio of one species to the other species on the basis of the cross sectional

area at breast height.
C) Per hectare, percentage of sum total of cross sectional area at breast height with Yaeyamahirugi.
D) Per hectare, percentage of sum total of cross sectional area at breast height with Ohirugi.

These measurements were carried out on Dec. 1983, so it was about seven years late since remote sensing data had been collected. However, these forests may be considered as stationary during these years, because mangrove forests are assigned to the natural protection vegetation under government policy. In addition, as the growth rate of mangrove forests are more slow than other trees, it may safely be said that the interval between remote sensing data and field survey data collected could be ignored .

4. Procedure and method

This study proceeded as follows.
a) To choose a suitable test site.
b) To digitize the aerial photographs of the selected test site with Red-Green-Blue and then to produce the natural color composite map by digitalized data.
c) To display airborne MSS data on color CRT and then to produce the false color composite map and unsupervised classification map which includes 20 clusters.
d) To choose field survey spots for extracting information concerning mixture proportion.
e) To perform supervised analysis using ground survey data.
f) To reconfirm usefulness of field survey spots, with viewing the supervised map and to record CCT counts of identified pixels that belonged to the spots on line printer.
g) To discuss the correlation between CCT counts of MSS data and mixture proportion obtained by ground survey.

Of above-mentioned procedures, image analysis was performed using remote sensing image data processing system that had been developed at Science Information Processing Center, University of Tsukuba, called "Tsukusys". Hardware and software system used with relation to b) , c) , e) , f) and analysis of ground measurement with relation to g) are revealed here in detail .

4.1 Computer system

Computer system used was Facom M-380 whose main memory size is 48 M bytes. 2 color CRTs directly connected to this computer were used for image processing, with being designed so as to display 512 X 512 pixels. Color plotter that covers 550 by 860 mm was used for mapping. Fig-2 shows the structure of the computer system used and Fig-3 shows the flow chart of processing <Hoshi et al(1981)>.

Unsupervised classification analysis applied in this study was the hieralchical clustering method. Tsukusys has the capability to handle the clustering method which includes the 6 different components, i.e. the nearest neighbour method, the furthest neighbour method, the group average method, the median method, the centroid method and the Ward method. The centroid method was adopted in this study, by comparing the results with other methods.

Tsukusys also has the capability to handle the supervised classification analysis which includes 3 different methods, i.e. the euclidean distance method, the discriminant method and the maximum likelihood (M.L.H.) method. The method applied in this study was M.L.H. method because it leaded the less misclassification.

Below-mentioned procedures are the process to reach M.L.H. method.
a) Selecting a analysis area and producing natural and false color composite maps.
b) Pre-processing, that is, enhancement , universal transverse mercator (U.T.M.) projection and geometric registration.
c) Extracting training area samples and test area samples.
d) Calculating of statistical quantities (mean vectors, standard deviations, variance covariance matrices, correlation coefficients and others).
e) Specifying one kind of these supervised methods (euclidean distance method, discriminant method and M.L.H. method).
f) Selecting color scheme of classified image on color CRT.
g) Evaluating classification performance, i.e. equivocation quantity and ratio of correct pixels with uncorrect ones.
h) Producing a color classification map.

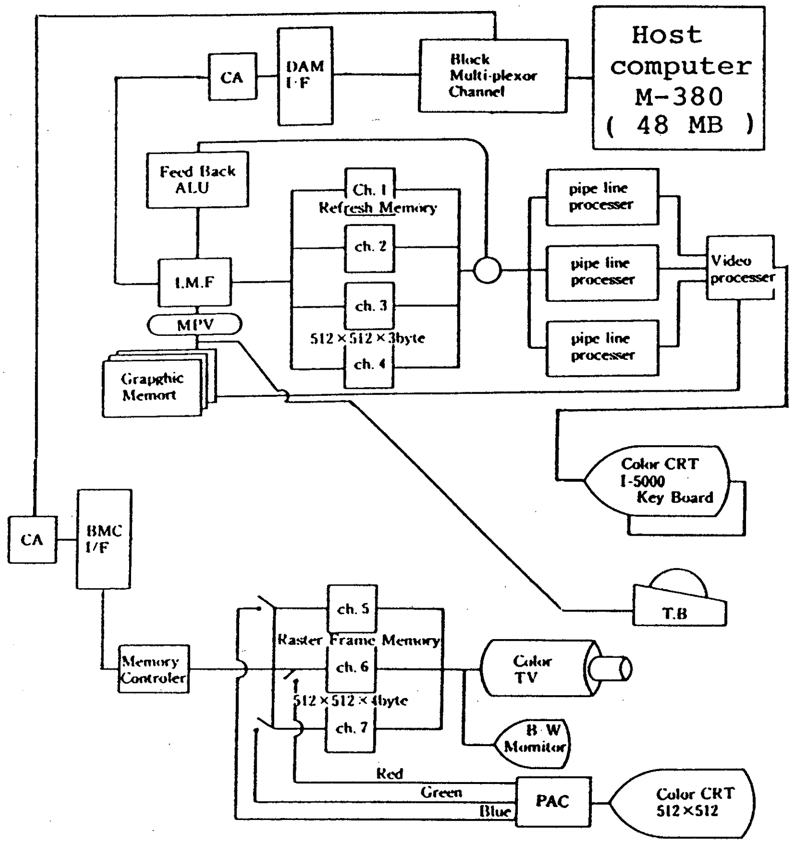

Fig-2 Structure of the computer hardware system

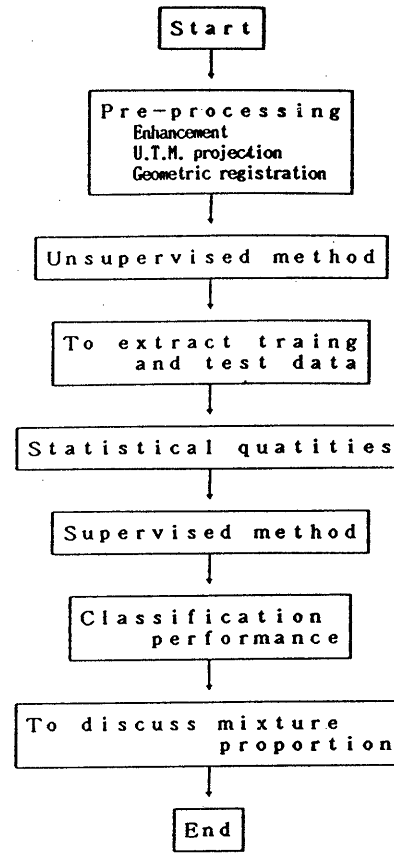

Fig-3 Flow chart of image processing

4.2 Analysis of ground measurement

Mixture proportion of two species was estimated from number counted of the trees. Cross section area was computed from diameter at breast height, assumed to be circle. As these quantities are not closely concerned with density of mangrove forests. Percentage of cross section area of each species per hectare was also calculated.

Table-2 Ground measurement data gathered on each spot

Spot No.	Number of Tree			Mixture prop. of Yae.		Mean of DBH		Prop. of TABH per hr.		
	Yae.	Ohi.	Total	A	B	Yae.	Ohi.	C	D	(C+D)
1	16,800	800	17,600	95.5	99.8	4.4	1.0	0.317	0.001	0.318
2	9,275	100	9,375	98.9	99.8	6.1	2.5	0.308	0.001	0.309
3	5,725	2,725	8,450	67.8	70.2	7.5	6.3	0.269	0.114	0.383
4	3,350	3,350	6,700	50.0	59.7	9.3	6.7	0.245	0.165	0.410
5	850	4,450	5,300	16.4	20.7	9.9	8.0	0.070	0.267	0.337
6	475	4,875	5,350	8.9	14.5	10.3	7.4	0.044	0.258	0.302
7	200	1,875	2,075	9.6	6.5	9.6	11.6	0.018	0.255	0.273
8	275	3,400	3,675	7.5	7.4	9.9	9.7	0.024	0.306	0.330

Yae. : Yaeyamahirugi
Ohi. : Ohirugi

A : mixture proprotion with number of tree(%),
B : mixture proprotion with TABH(%),
C : proprotion of Yae. TABH per hr.(%),
D : proprotion of Ohi. TABH per hr.(%)

5. Results and discussion

Although it is desirable that all pixels within a test site are submitted to a clustering algorithm for producing "a resulting map", it is not efficient in terms of caluculating time. Hence, in this study, a approach to improve classification speed is adopted according to below-mentioned procedures.

a) The 256 pixels that are randomly located are extracted from sub-test site encompassing the forests interested. They are regarded as representative of test site.

b) The centroid method is performed within the 256 pixels.

c) The 256 pixels are finally combined into 20 clusters. Each pixels of full image is then assigned to the cluster whose mean vector is closest to the pixel vector.

d) For display, each pixel assigned to same cluster is labeled with one corresponding color. A color scheme is manually altered so as to match well.

The result obtained was mapped using color plotter. This classification map was on the scale of 1:5000, and covers 33.8 by 37.0 cm (Fig-4). The area involved mangrove forests in this map contained of 5 clusters. These 5 clusters were also found out on mountains area where laurel trees exist. It is therefore suggested that it was difficult to separate mangrove forests from laurel trees, only with the spectral signatures. As the data in channel 9 that corresponds to near infrared range had greater reflectance comparing with that of other channels, 3 representative clusters were selected according to the data in channel 9 and were illustrated in Fig-5. In Fig-5, the clusters belonged to seashore vegetation and water body are superimposed, that were located in the neighbor of the forest. Ground survey was carried out on the area where spectral signature of Cluster No.3, No.5 and No.13 in Fig-5 were measured, mainly in order to determine the mixture proportion of the forests. The obtained result revealed that Cluster No.3 corresponded to the area that Yaeyamahirugi was dominant, Cluster No.13 corresponded to the area that Ohirugi was dominant, and Cluster No.5 corresponded to the area that two species was in about half shares.

By comparing the ground survey result, the results of unsupervised classification map reached are systematically written as follows.

1) It is possible to classify between Yaeyamahirugi and Ohirugi with the data in channel 9.

2) It is necesarry to study the mixture of two species from macroscope further.

3) Mangrove forests can be easily separated from seashore vegetation and water body near them.

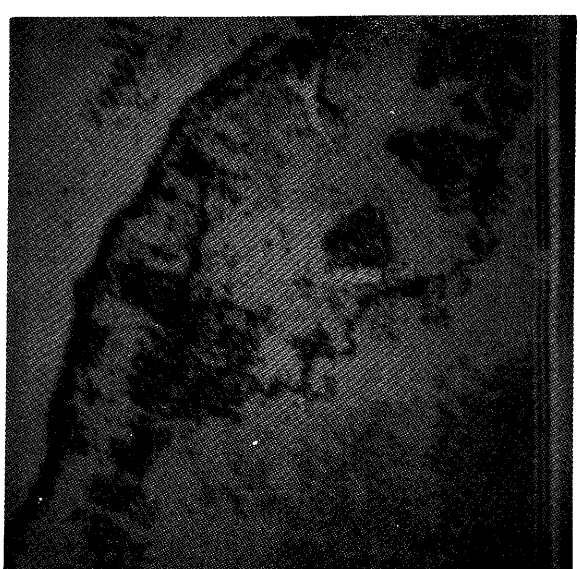

Fig-4 Unsupervised classification map

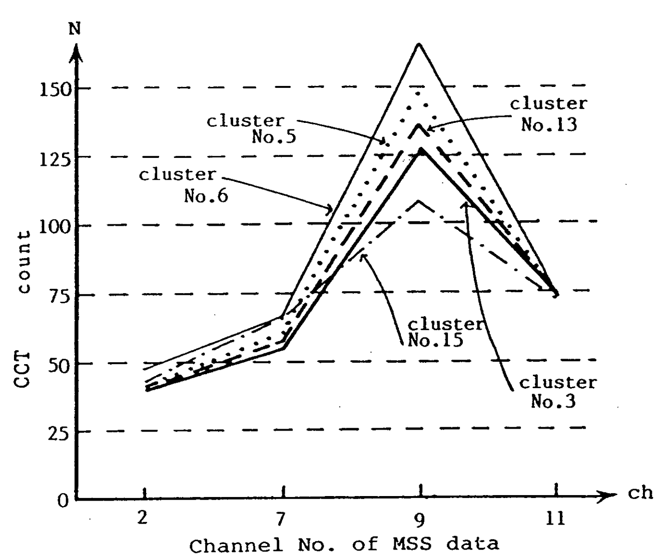

Fig-5 Spectral characteristic of some clusters, as sensed by airborne MSS data
No.3 represents dominant area of Yaeyamahirugi
No.5 represents dominant area of Ohirugi
No.6 represents seashore vegetation
No.13 represents mixed area
No.15 represents water body

Based on the results mentioned above, ground survey was carried out on species was extremely dominant and where two species were mixed. Finally selected survey spots are No.1 to No.8, labeled close-circle in Fig-1.

Yaeyamahirugi and Ohirugi were dominant on survey spots No.1 and No.2 and on survey spots No.5 and No.8 respectively. Survey spots No.3 and No.4 involved two species in about half shares.

With refering to the result of ground survey, supervised classification analysis was performed on airborne MSS data and digitalized aerial image data using image processing system as shown in Fig-2 and Fig-3. The results are shown in Fig-6 and Tabel-3 (a),(b).

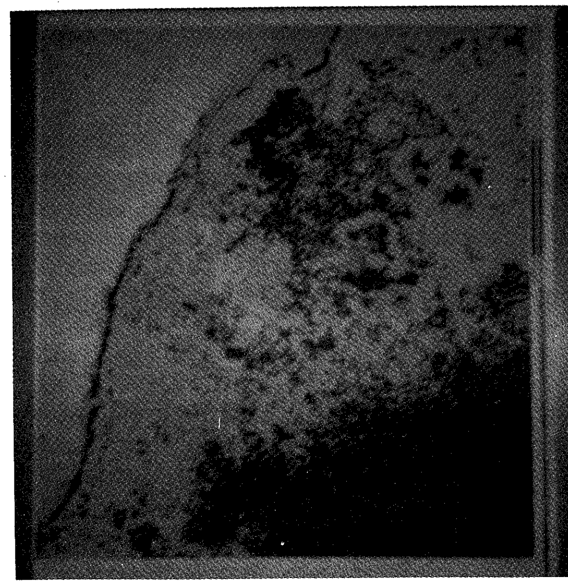

Fig-6 Supervised classification map

Table-3 Contingency table of M.L.H. method

(a) MSS data

Classification Item	Pixel no.	1	2	3	4	5	6	7	8	9	10	11
1.Mangrove 1	76	64.5	26.3	5.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.9
2.Mangrove 2	135	17.0	48.9	24.4	3.0	0.0	0.0	0.0	0.0	0.0	0.0	6.7
3.Mangrove 3	112	0.0	12.5	67.0	10.7	0.0	0.0	0.0	0.0	0.0	0.0	9.8
4.Littoral	224	0.0	2.7	12.5	83.5	1.3	0.0	0.0	0.0	0.0	0.0	0.0
5.Laurel forest	1309	2.5	1.1	0.6	1.5	93.9	0.0	0.0	0.0	0.0	0.0	0.4
6.Grass	165	0.0	2.4	1.8	30.3	0.0	61.9	0.0	1.8	0.0	0.0	1.8
7.Sugarcane	250	0.0	0.0	0.0	0.0	0.0	60.0	24.0	11.2	0.0	0.0	4.8
8.Farm	91	0.0	0.0	0.0	0.0	0.0	14.3	0.0	83.5	0.0	0.0	2.2
9.Bare field	145	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	80.0	0.0	0.0
10.Waters	90	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.9	91.1	0.0
11.The others												

pc=78.6% $T(G,\overline{G})$= 0.718

(b) Color aerial image data

Classification Item	Pixel no.	1	2	3	4	5	6	7	8	9	10	11
1.Mangrove 1	30	70.0	16.7	0.0	13.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.Mangrove 2	77	23.8	45.3	23.1	1.2	3.9	2.7	0.0	0.0	0.0	0.0	0.0
3.Mangrove 3	84	6.0	22.6	41.7	0.0	29.7	0.0	0.0	0.0	0.0	0.0	0.0
4.Littoral	111	14.4	9.9	8.1	52.3	2.7	0.0	0.0	12.6	0.0	0.0	0.0
5.Laurel forest	138	14.5	12.9	26.8	1.9	44.1	0.0	0.0	0.0	0.0	0.0	0.0
6.Grass	30	0.0	0.0	0.0	0.0	0.0	10.0	70.0	20.0	0.0	0.0	0.0
7.Sugarcane	70	0.0	0.0	0.0	0.0	0.0	20.0	61.4	18.6	0.0	0.0	0.0
8.Farm	20	5.0	0.0	0.0	30.0	0.0	0.0	0.0	65.0	0.0	0.0	0.0
9.Bare field	84	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	67.9	32.1	0.0
10.Waters	133	0.0	0.0	0.0	0.0	0.0	21.1	0.0	8.3	60.1	10.5	0.0
11.The others												

pc=46.8% $T(G,\overline{G})$= 0.528

Mangrove 1 : dominant stand of Yaeyamahirugi, Mangrove 2 : mixed stand, Mangrove 3 : dominant stand of Ohirugi, $T(G,\overline{G})$: equivocation quantity, pc : diagonal mean proportion of correct pixels.

Table-3 (a) is the contingency table of M.L.H. analysis on the MSS data. Mangrove-1 and Mangrove-3 in this table corresponds to the class belonged to area that distinguished species was Yaeyamahirugi and Ohirugi respectively. Mangrove 2 correspond to the class belonged to area where two kinds was distinguished. As shown in Table-3 (a), classification accuracy revealed that mixture proportion of two species was correctly identified. Contingency table of M.L.H. analysis on digitalized aerial image data (refer to Tabel-3 (b)) is similar to the table on MSS data. However, by comparing two tables, it was concluded that airborne MSS data was prefered to aerial image data on identifying mixture proportion. The difference within the two data, may not be due to the resolution of data but to the wavelength analyzed.

8 ground survey spots were determined on color CRT, based on the classification map produced on two data sets and then spectral signatures of pixels encompassing these spots were recorded on line printer. Table-4 shows the number of pixels, the mean vector, the standard deviation on these spots.

Table-4 Mean and standard deviation calculated from aerial image and airborne MSS data sets

Spot No.	Color aerial image data				Airborne MSS Data			
	n	Red	Green	Blue	n	Ch.2	Ch.9	Ch.11
1	30	149.6± 9.0	161.7±10.4	157.3± 6.4	80	39.1± 7.8	123.7± 8.9	75.1± 2.4
2	25	138.0± 5.8	152.3± 4.1	151.4± 5.2	30	41.2± 7.1	112.2±11.6	73.8± 2.8
3	42	136.1± 7.4	151.5± 8.6	150.5± 6.4	63	33.1± 8.5	144.7± 7.3	75.6± 3.3
4	42	127.7± 9.6	141.0±11.5	145.0± 6.7	99	33.1± 8.6	144.6± 9.2	75.2± 2.0
5	40	134.6± 8.5	150.6± 9.6	149.3± 5.8	45	33.8±10.5	153.8± 6.4	77.1± 1.9
6	29	133.6± 9.2	148.8±10.7	148.9± 5.7	35	26.6± 9.5	146.5±10.1	74.9± 2.3
7	63	125.0±11.1	143.3±13.5	145.2± 7.8	60	29.3± 8.5	156.7± 5.5	72.8± 2.9
8	30	123.4± 9.5	141.9±11.2	145.6± 6.4	40	34.6± 9.5	147.9±12.3	71.8± 1.9

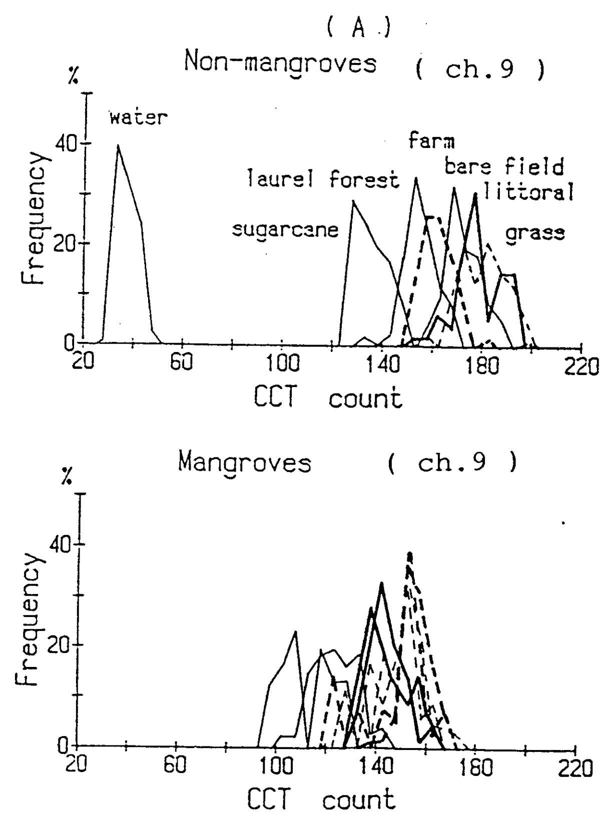

Fig-7(A) Frequency distribution in Ch.9

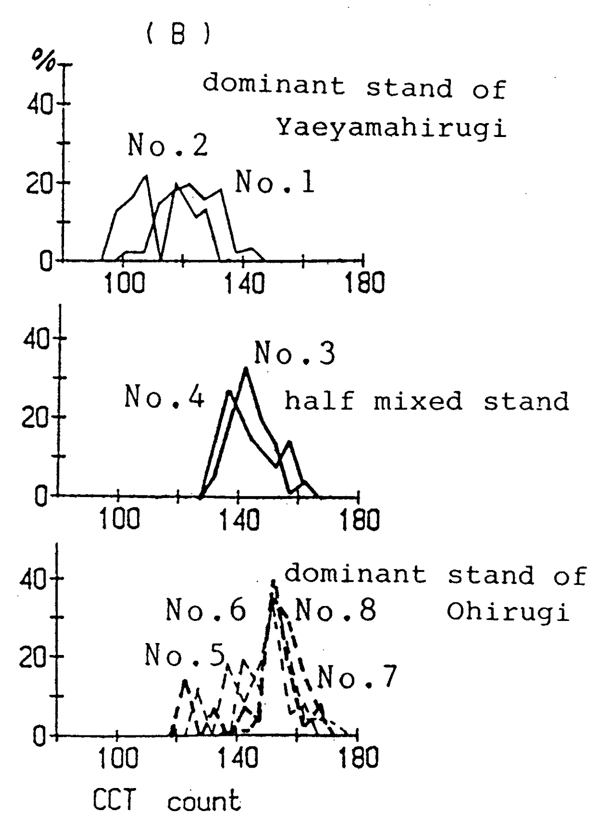

Fig-7(B) Frequency distribution in Ch.9 only with Mangrove forests

As shown in Table-4, it may be easy to separate mixture proportion of two species with the information from the data in channel 9. Histogram of signature in channel 9 was demonstrated for every classes in Fig-7. In Fig-7 (B), Class 1,2, Class 5,8 and Class 3,4 correspond to the area belonged to the forest that involues Yaeyamahirugi, Ohirugi and two kinds respectively.

These 3 mixture proportions and spectral signatures may match well. Tabel-5 shows the correlation matrix to find the statistical relationship between mixture proportion and some signature of corresponding MSS data and aerial image. Red/Green, channel (Ch) 2, channel (Ch) 9, Ch2/Ch9 and Ch11/Ch9 appeared to have some influence on the relationship and then these good parameters were demonstrated in Fig-8.

Table-5 Correlation matrix of parameter concerning mixture proportion in Table-2 and means of data in Table-4

A	B	C	D	R.	G.	B.	R./G.	R./B.	B./G.	2	9	11	2/9	2/11	11/9
——	0.955*	0.970*	-0.990*	0.749	0.673	0.725	0.784	0.746	0.668	0.798*	-0.880*	0.204	0.866*	0.753	0.897*
	——	0.984*	-0.983*	0.757	0.666	0.721	0.830*	0.765	0.650	0.777	-0.868*	0.263	0.844*	0.723	0.890*
		——	-0.944	0.691	0.581	0.638	0.822*	0.713	0.563	0.711	-0.781	0.317	0.758	0.650	0.807*
			——	-0.780	-0.708	-0.754	-0.801*	-0.799	-0.724	-0.749	-0.888*	-0.192	-0.849*	-0.706	-0.907*
				——	0.978*	0.983*	0.864*	0.987*	0.929*	0.540	-0.674	0.506	0.616	0.451	0.735
					——	0.991*	0.741	0.942*	0.960*	0.517	-0.617	0.442	0.580	0.438	0.675
						——	0.776	0.942*	0.946*	0.576	-0.683	0.383	0.640	0.506	0.724
							——	0.914*	0.679	0.486	-0.677	0.593	0.578	0.385	0.741
								——	0.889*	0.492	-0.651	0.604	0.579	0.389	0.729
									——	0.403	-0.622	0.311	0.529	0.346	0.660
										——	-0.818*	-0.012	0.950*	0.987*	0.814*
											——	0.036	-0.952*	-0.812*	-0.985*
												——	-0.045	-0.169	0.116
													——	0.943*	0.945*
														——	0.785
															——

2 : ch.2
9 : ch.9
11 : ch.11
2/9 : ch.2/ch.9

R. : red, G. : green, B. : blue
A, B, C, D : shown in Table-2
* : significant with 1 % ievel

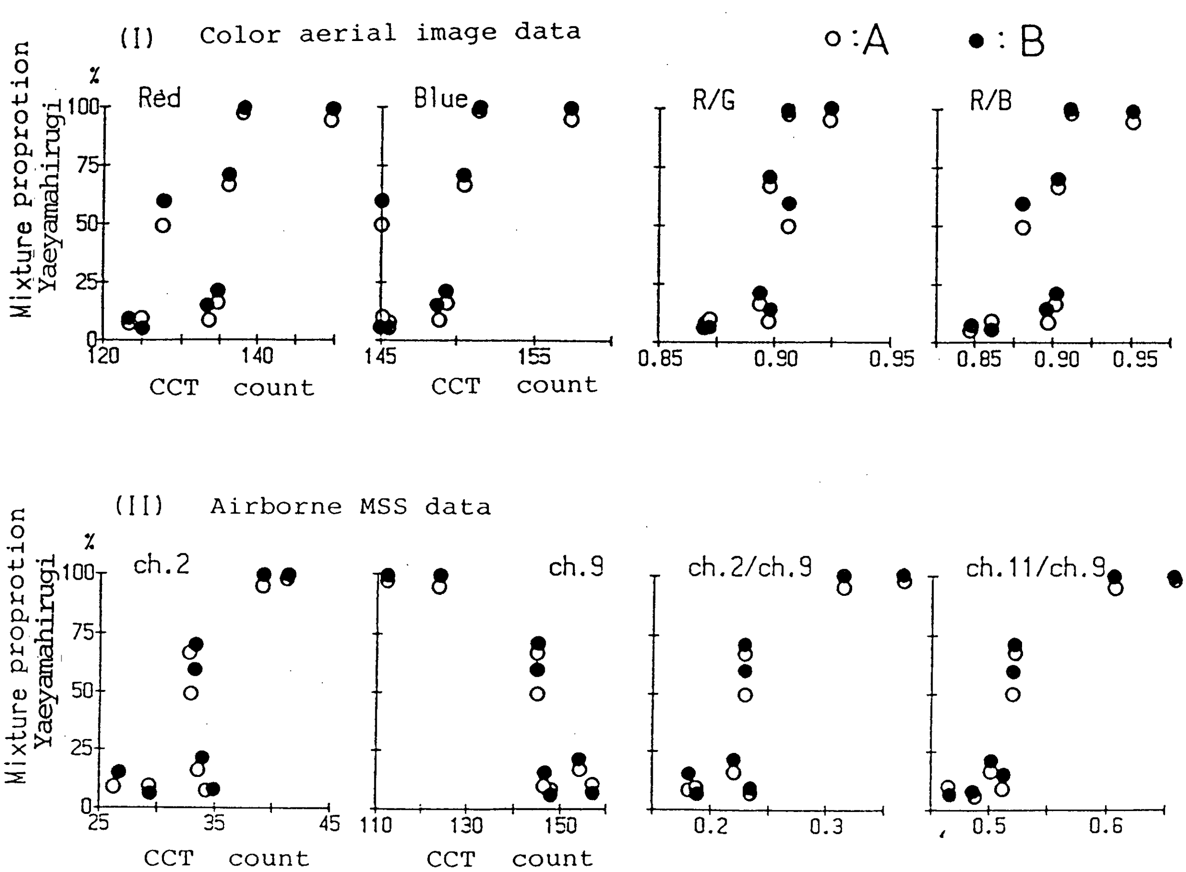

Fig-8 Relationship between parameters obtained from airborne remote sensing data and mixture proportion of Yaeyamahirugi

6. Conclusions

The present study was applied to the classification between Yaeyamahirugi and Ohirugi that were main species of mangrove trees on Okinawa Island, in order to find out the possibility to identify any species using airborne remote sensing data. By compared ground measurements with the analysis of the airborne MSS data and digitalized image data from color aerial photograph, the conclusions consisted of six major points:

1) Both airborne MSS data and aerial image data are effective to identify the entire portion of the mangrove forests, however, MSS data is more effective to classify between Yaeyamahirugi and Ohirugi.
2) Unsupervised classification map has the potential to select the ground survey spots.
3) Pre-processing for spatial accuracy using U.T.M. transformation was so good that pixels belonged to the ground survey spots can be correctly extracted.
4) Success in producing classification maps depends not on the attention paid to improve the classified accuracy of full image, but on that to separate mangrove forests from other ground cover types.
5) Red/Green with respect to color aerial image; Ch 2, Ch2/Ch9 and Ch11/Ch9 with airborne MSS data could be considered as the parameters to represent good relationship with mixture proportion.
6) Airborne MSS data was more effective than color aerial image to quantify analysis extensively regarding the distribution of two species, so Landsat digital data may be thought of a usefulness on the larger area of mangrove forests .

Furthermore, it seemed to be necessary for ground measurements to acquire more detail data, in order to investigate the possibility whether statistical models to estimate mixture proportion of them could be constructed.

Acknowlegement

The authors wish to express deepest appreciation to Mrs. Zhang shaoxing for helpful advice and for the use of figures.

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REPORT DOCUMENTATION PAGE	REPORT NUMBER ISE-TR-85-53

TITLE

Analysis of Mangrove Forest in Okinawa using Airborne Remote Sensing Data

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REPORT DATE	NUMBER OF PAGES
November 14, 1985	9
MAIN CATEGORY	**CR CATEGORIES**
Remote Sensing	4.0

KEY WORDS

Mangrove analysis, Remote sensing system, Classification

ABSTRACT

The present study was carried out by processing airborne remote sensing data on mangrove forests on Ishigaki Island, Japan. These remote sensing data were classified under unsupervised and supervised classification analysis. As a result, it revealed that it was possible to identify mangrove forest areas. And then, by comparing the spectral characteristic of corresponding pixels to the areas that involved two species of mangrove trees, that is, Yaeyamahirugi (Rhizophora stylosa) and Ohirugi (Bruguiera gymnorrhiza) with mixture proportion taken by ground survey, it was believed to be able to estimate the distribution of two species on the basis of airborne MSS data.

SUPPLEMENTARY NOTES