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STUDIES ON THE EVALUATION OF WATER DEPTH AROUND SEASHORE AND THE LAND CLASSIFICATION IN YAP ISLANDS USING SATELLITE DATA

Etsuji ISHIGURO, Katsumi TATSUNO, Motoi KAWAKATSU, Shinsaku HIRAYAMA, Din Ara WAHID, Sentaro KONGO, Kiyoshi SHIMADA, Masataka HIGASHI, Akimasa HABANO, Takafumi AZUMA, Hiroyuki KIKUKAWA, Masao MORIYAMA, Andy TAIFILEICHIG, Patrick P. PECKALIBE, Tamdad SULOG, Francis LIYEG, and Edward Tukasa KANEMASU

Abstract

Remote sensing technique is an effective technology for monitoring and analyzing environmental changes on the Earth surface. We have tried to clarify environmental changes in Yap islands using satellite data, especially, on the distribution of water depth around the Yap islands and land classification. To serve our purpose, a sea-truth and ground truth data were collected, using a portable spectrometer and a digital camera.

Key words: remote sensing, water depth, land classification, monitoring

Introduction

This project is a joint program with the Research Center for the Pacific Islands in Kagoshima University. The project seeks to enhanced the self-reliance of Yap Islands in Micronesia. Remote sensing is an effective procedure simultaneously to analyze and to monitor environmental changes because of its potentials to cover a large area and generate time series analysis. Many researchers have been undertaking studies using satellite data[2-6, 9-11, 13]. Especially, it was clarified that the water depth, shallower than 20m can be estimated by satellite data[1, 7, 8, 12].

If the distribution of water depth map can readily indicate a waterway easily for a native person and also evaluate the rising sea surface for purpose of understanding the greenhouse effect. And if a method of classification the land can be achieved, it will be possible to evaluate and analyze biomass and surface temperatures on the ground and thus the potential of yield of several crops. Our primary results highlights these methods to be effective for the Yap Islands.

Principle of the Evaluating of Water Depth

It is assumed that the extinction coefficient of the sea water α_λ, is homogeneous vertically at a point. At the sea surface, radiance intensity, I_0, become I_1 at the bottom. I_1 are expressed as $I_1=I_0\exp(-\alpha_\lambda h)$, where h is the depth. As the radiance I_1 is reflected by the sea-bed, I_1 becomes I_2, $I_2=\gamma_\lambda I_1$, where γ_λ denotes bottom reflection coefficient. When the radiance reaches at the sea surfaces, the intensity becomes I_3, $I_3=I_2\exp(-\alpha_\lambda h)$. Then I_3 is expressed as $I_3=\gamma_\lambda I_0\exp(-2\alpha_\lambda h)$. I_3/I_0 is the reflectance at the sea surface. If the extinction coefficient of the water collected at the

Yap and reflectance are measured, the depth will be evaluated.

Methodology

Sea Truth

Actual sea depths were measured by throwing a rope from our boat at several points. Spectral reflectances were measured by a handheld spectroradiometer (Model: 2703, Abe-sekkei Co. Japan), ranging from 400nm to 1050 nm at 25nm intervals. Sea sediments were collected at the same points and spectral reflectance was measured by the handheld spectroradiometer. Seawater, in the middle depths, was collected at the same time, and extinction coefficients of water at several wavelengths, from 400nm to 1100nm, were measured by the spectrometer (Model: 121-0001, Hitachi Co.). These points were recognized and recorded by handheld GPS instruments (Model: GPS-315, Magellan Co.).

Ground Truth

Spectral reflectances of the leaves of several crops and trees, grown in the Yap islands, were measured by handheld spectroradiometer. Making a land classification map for Yap islands, several points were surveyed. The data were recorded by digital camera and video camera. The points were recognized and recorded by handheld GPS instruments.

Image Analysis

In recent times, many satellites have been observing the Earth surface. Satellite data for the West Pacific have been received mainly at bases in Hatoyama, Japan, Beijing, China etc. Few data based on observing Yap islands have been available. Moreover, reflected and emitted radiation from ground objects cannot penetrate clouds. For these reasons, we determined to use the

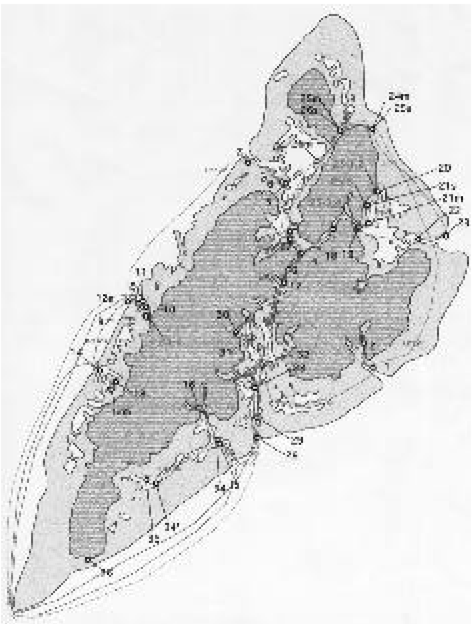

Fig. 1. Measured points in Yap.

satellite data of Landsat-2/MSS (L-2/MSS) and MOS-1/MESSR.

L-2/MSS data consist of 4 bands; Band-4 is from 0.5μm to 0.6μm, Band-5 is from 0.6μm to 0.7μm, Band-6 is from 0.7μm to 0.8μm, and Band-7 is from 0.8μm to 1.1μm. MESSR consist of 4 bands, too, but it regions are slightly different, Band-1 is from 0.51μm to 0.59μm, Band-2 is from 0.61μm to 0.69μm, Band-3 is from 0.72μm to 0.80μm, and Band-4 is from 0.8μm to 1.1 μm. The resolutions are 80m and 50m for L-2/MSS and MESSR, respectively.

Results and Discussion

Spectral reflectance of sea-sediment

Spectral reflectance of several sea-sediments, collected at many positions, is shown in Fig.2. In the case of sea-grass, the spectral reflectance curves have a low peak at 575 nm, a red-edge between 600nm to 700nm and a higher reflectance in the infrared region. This is the same tendency as for plants grown on land. For mud and sand, spectral reflectance increased with increased wavelength. These results are the same as on bare land.

Coral and sea-grass are randomly distributed on the seabed around these islands.

Moreover, we found sludge in some parts of the area. If the seabed was classified into several categories, it become possible to estimate sea-depth by adapting the reflectances of each category.

These measured reflectances were divided into corresponding bands of satellite calculated. The result is shown in Table 1.

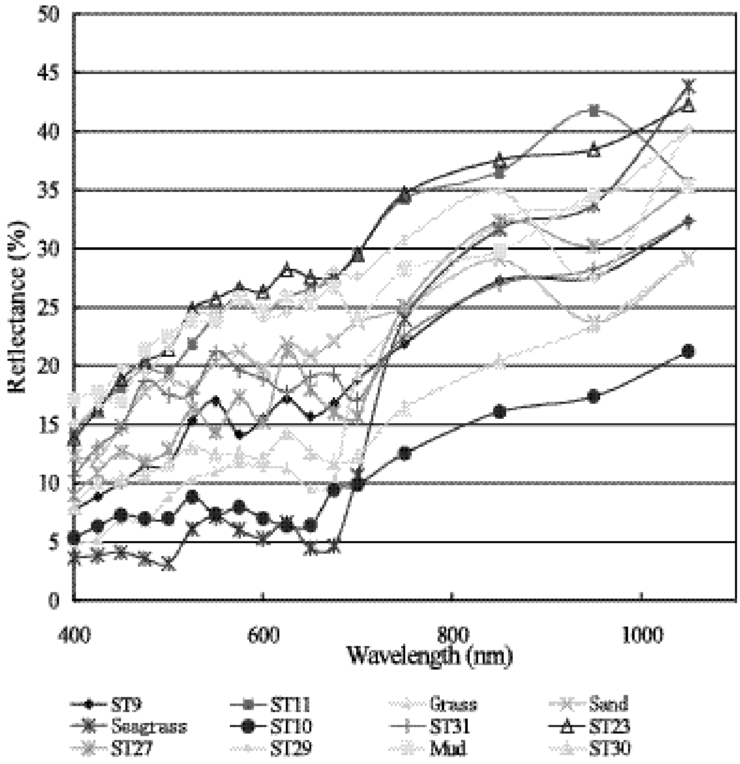

Fig. 2. Reflectance on several measured points.

Table 1. Characteristics of measured points

Point	Depth (m)	Sediment
St-5	1.1	Sand + Sea grass
St-12	1.75	Sand
St-14	8.0	Mud
St-18	2.5	Sand + Mud
St-19	9.0	White sand
St-21	2.4	Clay
St-22	21.0	Coral + Sand
St-26	6.5	Coral
St-30	13.5	Mud + Clay

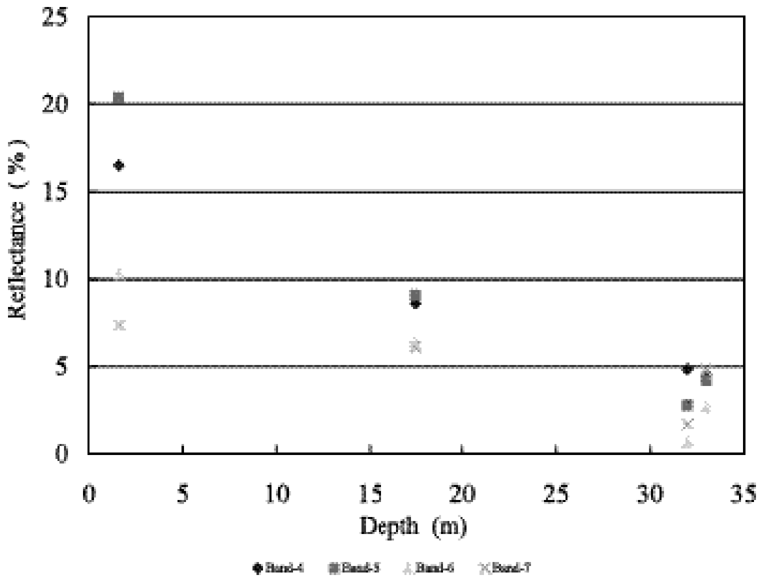

Fig. 3. Relationships between reflectance and depth at each MSS Band on sand.

Changes of spectral reflectance with sea depth

Relationships between the spectral reflectance of sand and mud, which correspond to Lasndsat-2/MSS and water-depth, are shown in Figs.3 and 4, respectively. These relationships are indicated by the following equations.

On sand

B4: $y=-0.3718x+16.444$, $R^2=0.9743$
B5: $y=-0.5308x+20.270$, $R^2=0.9643$
B6: $y=-0.2804x+10.863$, $R^2=0.9480$
B7: $y=-0.1358x+7.8323$, $R^2=0.6736$

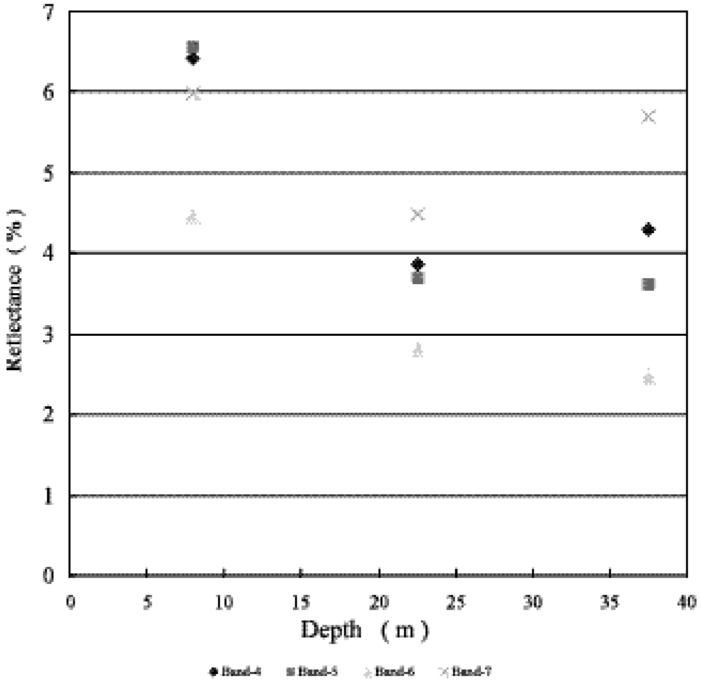

Fig. 4. Relationships between reflectance and depth at each MSS band on mud.

On mud

B4: y=-0.0715x+6.4792, R^2=0.5901
B5: y=-0.0993x+6.8819, R^2=0.7596
B6: y=-0.0672x+4.7687, R^2=0.8609
B7: y=-0.0095x+5.6078, R^2=0.0306

Where y is the mean reflectance of each MSS band and x is depth. The decreasing rate in the case of sand is larger than in the case of mud. These results correspond to the principle of evaluating the water depth.

Extinction coefficient of the seawater

The absorbencies of the collected water were changed at wavelength and collection points as shown in Fig.5. As wavelength increase absorbance decreases. At 900 nm, it shows the bottom for all curves as the typical absorbance of the water. From this curve, the extinction coefficients of seawater corresponding to the L-2/MSS band was calculated as shown in Table 2.

Table 2 shows the extinction coefficient collected on Yap and at Izumi, Kagoshima, Japan, for corresponding bands with L-2/MSS and L-5/TM, respectively. It is evident from Table 2 that the values of extinction coefficients decrease with increasing wavelength, which accords with the Rayleigh Scattering Theory.

Distribution of the water-depth

The distribution of sea-water-depth at Izumi, Kagoshima Japan using L-5/TM data is shown in Fig.6. White and black color indicate shallow and deeper waters, respectively, from 0 to 20 m.

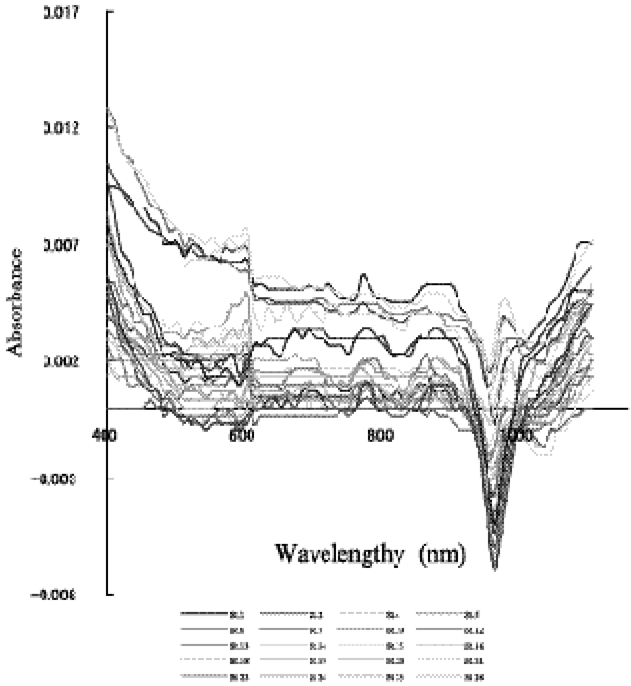

Fig. 5. Changes of absorbance at each wavelength on collected sea water.

Table 2. Extinction coefficients of seawater

On Yap ('99 Oct.) for L-2/MSS		
Band	Wavelength	Extinction coefficient
Band-4	500〜600nm	0.0022
Band-5	600〜700nm	0.0016
Band-6	700〜800nm	0.0014
Band-7	800〜1100nm	0.0009
On Izumi ('98 Oct.) for L-5/TM		
Band-1	450〜520nm	0.0080
Band-2	520〜600nm	0.0082
Band-3	630〜690nm	0.0077
Band-4	760〜900nm	0.0064

The sea-truth points were recorded by GPS and actual depths were also measured. The linear regression coefficient between depth and indices (color) was 0.8562. This procedure shows the potential for measuring the sea-depth around Yap islands.

Spectral reflectance of crops

Spectral reflectances of the leaves of crops and trees grown in Yap islands are shown in

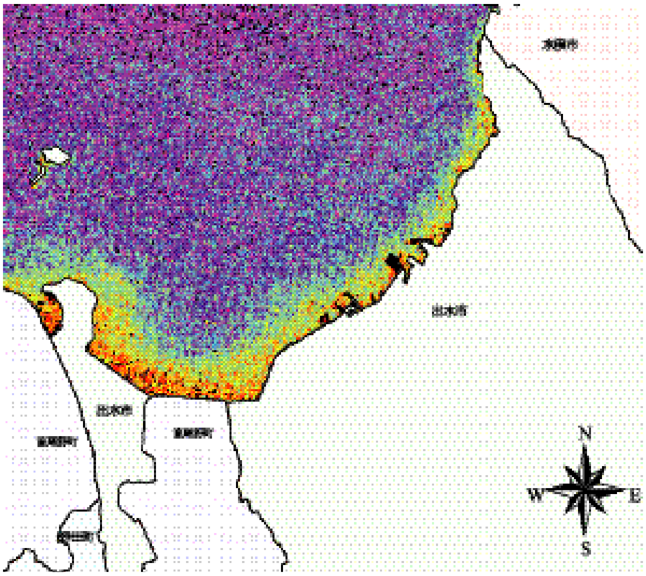

Fig. 6. Distribution of the water depth using by L-5/TM (1997 Oct).

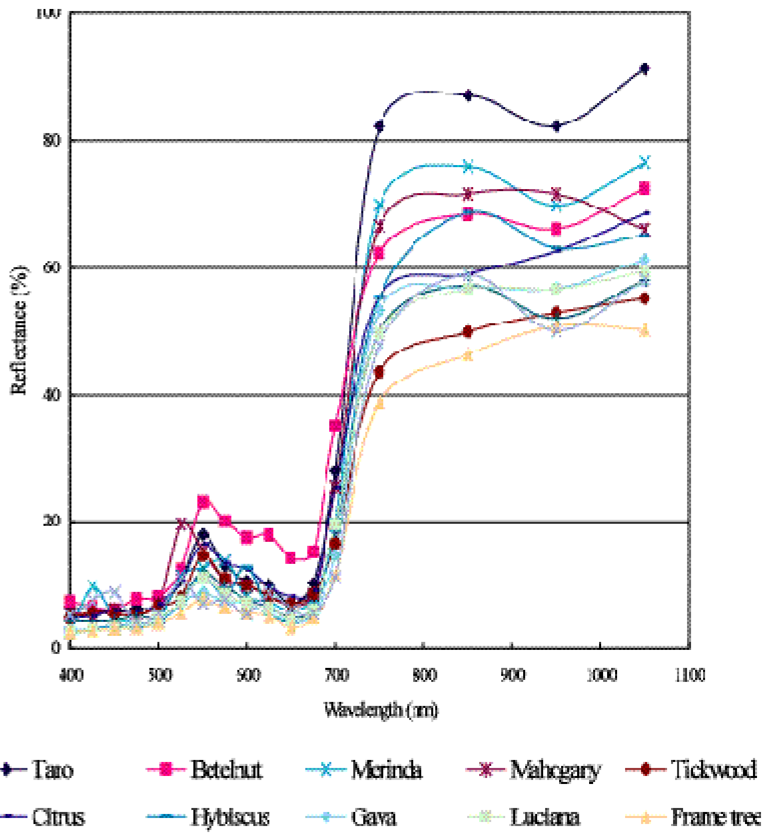

Fig. 7. Spectral reflectance on several crops.

Fig.7. In the visible region, differences of spectral reflectances are not recognized and lower reflectance for all crops. However, peaks occurred at about 575 nm. On the other hand, higher reflectances in the near-infrared region were shown with different crops. These results show the possibility of land-classification using satellite data.

Conclusion

Sea truth and ground truth show the possibility of estimating the sea-depth around the Yap islands and also land-classification using satellite data.

We are now in the process of collecting satellite data from NASA in USA and NASDA in Japan. We hope to succeed in making visual maps which will indicate environmental changes over the passed during 30 years.

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