Estimation of the Area of Rice Paddy Field Using Satellite Data : By Multi Level Slice Method and Band Ratio Method

Mem. Fac. Agr. Kagoshima Univ., **29**, 113-119, 1993

Estimation of the Area of Rice Paddy Field Using Satellite Data

—By Multi Level Slice Method and Band Ratio Method—

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Received for Publication September 9, 1992

Introduction

Various kinds of satellites have been put into orbit in a couple of decades. They include major civilian use satellites as MOS-1, LANDSAT and HIMAWARI, a Japanese climatic satellite. They have been contributing climatic observation, consolidation of communication and investigation of earth resources.

Spaceborne measurements of the spectral characteristics of crop canopies have been widely used for the identification of different crop types and the estimation of their areas in the world. The typical example is Large Area Crop Inventory Experiment (LACIE) in the U.S.A. In this attempt two satellites, NOAA and LANDSAT/MSS were employed[7)].

Unfortunately, in Japan, however, satellites have rarely been applied to assess agricultural environments. The geographical complexities of farm lands and intricate cropping systems devised to use limited lands intensely cause the various difficulties in the practical use of satellites in Japan. The development of efficient means to identify crops and to estimate the area of rice paddy fields are, however, important for making crucial decisions for various kinds of agricultural policies. The purpose of this study is, therefore, to develop the functional methods to overcome these obstacles found inevitable in Japan.

Radiometric studies on paddy rice were reported[2,4,9-11)], but the wavelength or bands used in their studies were particularly restricted to LANDST/MSS bands. Various spectral indices were proposed by several workers for monitoring crops[1)]. Dusek *et al.* (1985) and Gardner *et al.* (1985) developed the indices of VIS and MIR for winter wheat and corn fields, respectively[1-2)]. They reported that Band-5 (1550 nm-1750 nm) and Band-7 (2080 nm-2350 nm) were more useful as compared with Band-4 / Band-3 ratio for characterizing agronomic variables. The utilization of the TM bands was suggested to distinguish vegetation more correctly than the LANDSAT/MSS bands[8)].

Considering the results of these works, the use of TM regions seems promising to monitor rice fields, though few studies have been done on rice canopies[5-6)]. Based on this conclusion, in this study, the efforts were focused on the identification of rice fields more accurately than our previous work[3)].

Materials and Methods

1. Description of the study area

Hishikari Town was selected as a model area since it locates in the middle of a typical rice growing region in Kagoshima Prefecture. The town is situated near the mountainous region along the Sendai River. The area consists of both agricultural and non-agricultural areas. There are farms for horticultuaral production, rice paddy fields, small hills and mountains. Urban centers are also spotted in the area. The paddy rice fields vary in size and most of them are around 30 m by 100 m.

2. Ground truth

A few ground truths were made in the cropping season during years, 1988 to 1991. Ground maps at the scale of 1:250,000 were used for verifying the images as well as identifying the sampled areas (training areas) for the series of digital analyses. Color aerial photographs of November 7 and 8, 1988 were obtained from the office of Hishikari Town to be compared with the results.

Spectral characteristics of significant ground objects like rice plants, soil of bare ground surface, ceder trees, turf, asphalt paved roads and greenhouses were measured with a handheld spectroradiometer (Abe-sekkei Ltd.).

3. Satellite data

LANDSAT-5/TM data consist of 7 channels of sensors that receive refelctance of ground objects from visible to infrared region. Since clouds on the observation point intercept these reflectance the data should be collected on fine days. Therefore, among LANDSAT-5/TM data sets of this area (path-row No.112-38) surveyed during the harvest season of rice plants, those with less than 50% cloud coverage were selected. Considring cost and other factors, geometrically and radiometrically corrected data of them were obtained from the Remote Sensing Technology Center of Japan (RESTEC), Tokyo, on floppy disks on the three different dates (September 26, 1986, October 20, 1989 and September 21, 1990).

Although depending on the orbits of the satellite the corresponding ground areas surveyed differ from data to data, all data sets used in this study contains the most paddy rice fields in Hishikari Town.

4. Data analysis

First, five categories (urban area, paddy rice field, upland field, woods and river) were defined. Then, the training areas were chosen by comparing the map prepared by the field survey and the areal photographs. CCT values of each training area were statistically evaluated and the properties of the areas were analyzed by relating them with spectral characteristics of each band. Subsequently, categorical classification was performed by Multi Level Slice and Band Ratio Method by a color image processor, SPICCA (Avio Ltd.). In the end, the total area of rice paddy fields estimated by the image processing and that reported by the local government were compared.

Results and Discussion

1. Characteristics of spectral reflectance

Spectral reflectance of paddy rice field and the other objects were shown in Fig. 1. The reflectance of the paddy field in the visible region, from 400 nm to 700 nm, show low values while those in the infrared region present high readings called "Plateau-rounding"[4]. Turf and cedar trees shows similar responses. Chlorophyll in their leaves incites this reaction.

Significant changes in the other objects were not observed in the region observed. Refelctances of the soil surface and the asphalt paved surface are low in any wave lengths, contrasting to a green house that has high radiance in all wavelengths.

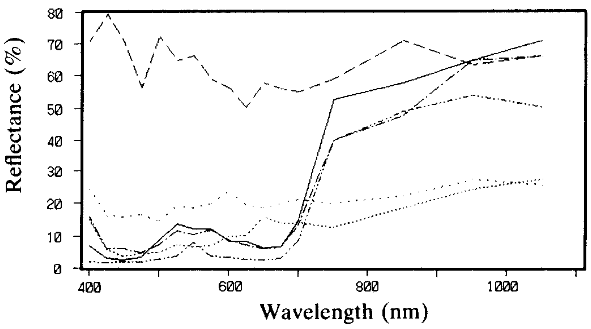

Fig. 1. Spectral reflectances of ground objects.
——Rice ······Soil - - -Asphalt — —Greenhouse
-·-Turf -··-Cedar tree

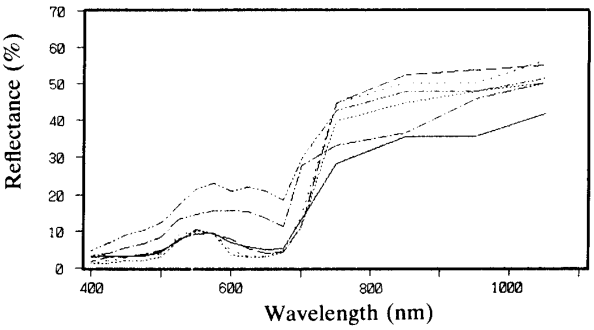

Fig. 2. Change in spectral response with the growth of rice.
——Jul. 6 ······Aug. 3 - - -Aug. 11 — —Aug. 30
-·-Sep. 20 -··-Oct. 2

Fig. 2 shows the changes of spectral reflectance of rice in its growth period. The reflectance seems to depend on the growth stage of a plant. Immature plants have higher reflectance in green and near-infrared regions than in the other regions while mature ones reflect red regions. This result suggests the possibility of classification and identification of rice paddy fields by analyzing satellite data.

2. Frequency

Fig. 3 demonstrates the frequency of CCT counts of Band-1 in each category (1989). On this property, it is difficult to clearly tell a paddy field from an upland field. Both present similar count-distribution and have a single peak at 72 and 70, respectively. Forest and river also have a

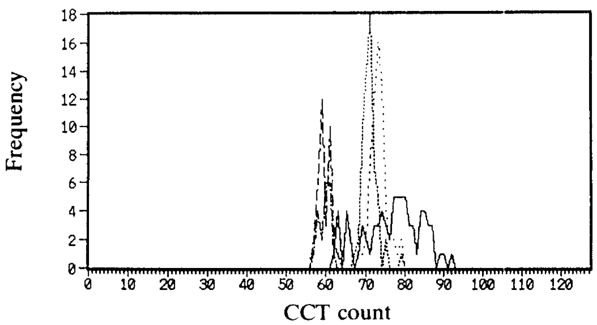

Fig. 3. Frequencies of CCT counts of Band-1.
——Urban area ······Upland field — —Woods
- - -Rice Paddy field -·-River

single peak at 59 and 60, respectively, resembling to each other. They exhibit rather similar property on reflectance of the wavelength of Bnad-1. On the other hand, town area characteristically shows fluctuation from 61 to 93 and several peaks. Judging from these results, it may not be reasonable to depend on the data of only a single channel, Band-1 to identify the manner of ground use. The other bands offered the similar results.

3. Identification paddy rice fields by Multi level Slice Method

Multi Level Slice is a method frequently used to analyze remote sensing data in a supervised classification. This method uses the intersection threshold of CCT counts in each category of each band. These values are decided with 95% of confidence level of CCT counts in rice category of the respective bands.

Among various combinations, the association of Band-2 and Band-5 yielded the most optimal result for the identification of paddy fields. Figs. 4–6 show the identified areas for the respective data. In these images, Band-4 was intensified for the area of Hisikari Town to lighten its color density and overlayed the blackened images of rice paddy fields extracted by MLS. In each season, a series of three images was analyzed during the harvesting period.

Comparing these images with ground truth, the data of October shown in Fig. 4 were found to be consistent with the result of ground truth. But those of September data (Fig. 5, 6) did not successfully agree with the ground truth.

4. Identification of paddy rice fields by Band Ratio Method

The features of objects can be shown by the spectrum subtraction or by the raio of bands. In remote sensing, enhnced images obtained by taking the difference of two band data or by calculating the inter-band ratios will make the classification of objects easy. These treatments also reduce the fluctuations caused by atmospheric effects such as different solar radioation or sun elevation and by the dimension of analysis.

The imges processed by subtracting Band-5 from Band-4 identified paddy fields most accurately[3]. But the result of this method depended on the period of LANDSAT observation. Therefore, Band Ratio Method was adopted in this study. The optimal band combination was found to be that of Band-2 and Band-1 and the results are demonstrated in Figs. 7–9. Paddy fields around the Sendai River and in the mountainous areas are easily recognizable in each figure, showing the effectiveness of this method.

Table 1. Comparison of the estimate and the actual area

Deta	Stastistical report (ha)	Estimated MLS	area (ha) Band Ratio
86' 9/26	1220	747.54 (61.2%)*	1400.0 (114.7%)*
89' 10/20	930	563.4 (60.6%)*	815.0 (87.7%)*
90' 9/21	820	1024.9 (125.0%)*	889.2 (108.4%)*

* Percentage to the value of statistical report.

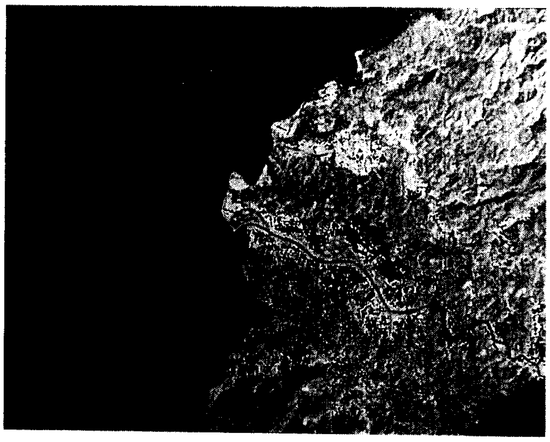

Fig. 4. Image processed by MLS (Sep. 26, 1986).

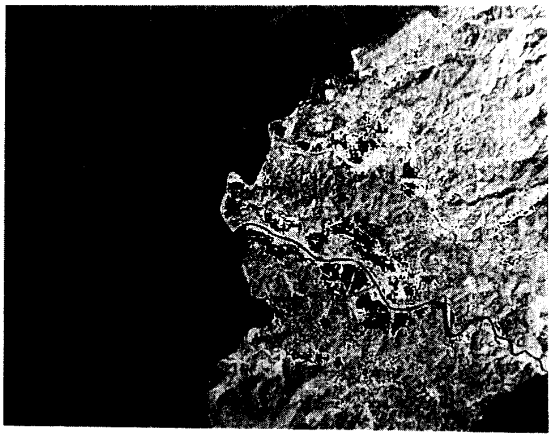

Fig. 7. Image processed by Band Ratio Method (Sep. 26, 1986).

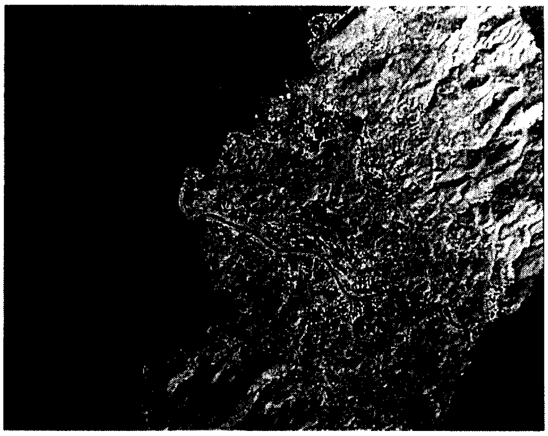

Fig. 5. Image processed by MLS (Oct. 20, 1989).

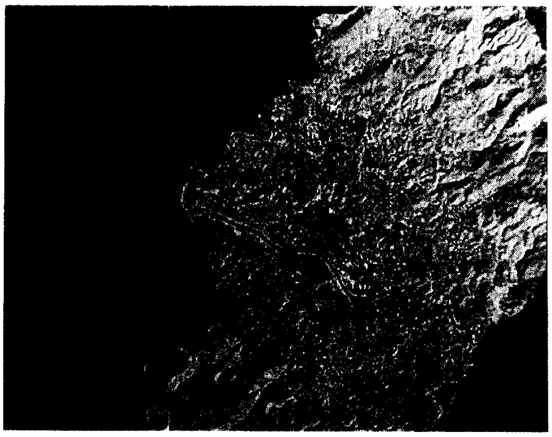

Fig. 8. Image processed by Band Ratio Method (Oct. 20, 1989).

Fig. 6. Image processed by MLS (Sep. 21, 1990).

Fig. 9. Image processed by Band Ratio Method (Sep. 21, 1990).

5. Area examination

The total estimated areas of paddy rice fields are shown and compared with statistics based on ground survey reported by the town office in Table 1 for three years. Since one pixel of LANDSAT-5/TM data corresponds to 30 m by 30 m on the ground, the unit of estimates depends on the resolution.

As shown, MLS method extremely overestimated or understimated the areas. Since the confidence level of 95% was adopted as previously described, it might be assumed that about 90% of fields be identified. The result was, however, overstimated by 25% for the data of Sep. 21, 1990. It is not clear why this misleading result occurred.

On the other hand, Band Ratio Method fairly well estimated the acutual values, deviating less than 15%. This method overrated the data of September in both 1986 and 1990. This may due to some confusional objects with rice plants of this growth stage on the ground.

Overall results suggest that Band Ratio Method is the most reliable one to estimate the areas of paddy fields from the LANDSAT-5/TM data. This method was proved to have excellent potential to survey land uses, through it needs more refinement. It is hoped that further study will eventually fruit the reliable indices to show not only the area of the crop but also its growth level and its yield.

Summary

Identification of rice paddy fields and estimation of their areas were attempted using computer complemented Multi Level Slice (MLS) Method classification and Bands Ratio Method for LANDSAT-5/TM data. The paddy fields for the Hishikari Town near Kagoshima City were selected for the evaluation cite. The results were verified by video recorded aerial photographs and by ground observations.

Between these two method, Band Ratio Method was superior to MLS method and yielded better figures close to the statistics published by the local town office on the area estimation. The present study demonstraed the plausibility of image processing of satellite data to identify or to estimate land uses in agricultural fields.

Acknowledgement

The authors wish to acknowledge the assistance in ground truth and in analysis provided by Dr. Mishra K. K. in PASO Co. Ltd.

The statistical reports, ground map and aerial photograph used in the present analysis were provided by Hishikari Town Office.

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