

**MONITORING OF PADDY RICE PLANTING WITH COMPLEX CROPPING
PATTERN USING SATELLITE REMOTE SENSING DATA
-A CASE OF WEST JAVA, INDONESIA-**

Satoshi UCHIDA
Development Research Division
Japan International Research Center for Agricultural Sciences (JIRCAS)
1-1 Ohwashi, Tsukuba, Ibaraki 305-8686, Japan
Tel: (81)-29-838-6614 Fax: (81)-29-838-6614
E-mail: uchidas@jircas.affrc.go.jp

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ABSTRACT: Paddy rice is widely cultivated in Asian region by various types of cropping. In the temperate climate zone, the growing season of rice is limited in the summer and planting stage tends to be harmonized among locations. However in the tropical area, temperature could not be significant limitation factor for growing through the year and paddy rice might be cultivated in condition that the water supply is adequate. This caused to appear complex landscape of mixing of different types of land cover condition for paddy field and to make difficult to discriminate the time of planting paddy rice using satellite remote sensing data. In this study, West Java Province of Indonesia is selected for the study site, where spatially small to large scale irrigation systems are presented. Firstly, the author analyzed multi-temporal Landsat data to characterize the pattern of paddy rice planting and found that block-shaped feature in various size could be a unit of planting at the same time. Then he examined the temporal changes of surface condition by using NDVI, NDWI and EVI obtained from MODIS data for paddy field in sequential cultivating stages extracted from Landsat data. As a result, a maximum of NDWI around transplanting stage and remarkable decrease of NDWI as well as increase of NDVI or EVI to the stage of heading were assumed as a key to discriminate time of planting rice. The estimation of time of planting rice from MODIS data by using a model employing these features could show properly the spatial and temporal pattern not only for paddy fields of large scaled irrigation blocks in the north coastal plain but also for paddy fields located in the inland area of the site.

1. INTRODUCTION

1.1 Background

Rice is one the most significant staple food and cultivated widely in Asian region. Indonesia is the world 3rd rice production country and produced about 54 million tons in 2005 according to the FAOSTAT. Even though the high production amount of paddy rice from this country, Indonesian government faces to the food security problem to meet with the demand of rice for increasing population and also the management of agricultural land resources for sustainable utilization.

Cultivation of paddy rice is constrained by the condition of availability of physical factors such as solar radiation, temperature, water. In the most part of Indonesia, temperature could not be a limiting factor for cultivation so that the cropping season of rice would be planned by a schedule of irrigation or even arbitrary decision by farmer. Such condition caused to show complex landscape mixed with different growing stages of rice at the same time. This complexity would be an obstacle to obtain information to be analyzed quantitatively for the purpose of understanding the actual distribution of paddy rice cultivation both in time and space.

Satellite remote sensing has been expected to provide continuous spatial information periodically and to be capable to monitor agricultural land use in various regions. Recently, a number of researches has been attempted to map paddy rice planting area in wide extent of Asian region using MODIS data (e.g. Takeuchi and Yasuoka, 2004, Xiao et al., 2005, Sakamoto et al., 2005, Sakamoto et al., 2006, Xiao et al., 2005, Xiao et al., 2006, Uchida, 2006, Takeuchi, 2007). They employed a kind of indices derived from MODIS data and discriminated paddy fields by employing phonological characteristics of rice. The results were successful in terms of mapping paddy fields for a wide area for recognizing spatial pattern of distribution which could not be described by statistical data. However, owing to the rather coarse spatial resolution of MODIS data, the applicability of MODIS data to monitor paddy fields mixed with complex cropping pattern has not yet been examined.

1.2 Objectives

This study has two major objectives; one is to characterize the pattern of rice planting appeared in the study site, and the other is to develop a method to monitor rice planting using MODIS data adaptable to the site. The first objective aims at understandings of level of homogeneity or heterogeneity of planting time of rice and how it to be related with physiographic conditions. This examination would be carried out by using multi-temporal Landsat data. The second objective would be beneficial to predict seasonal production of rice as well as to grasp variation of production by agricultural disasters.

2. DATA AND METHOD

2.1 Study Site

West Java Province of Indonesia was selected as study site in this case. The harvested area (1.895 million ha in 2005) and production (9.787 million tons in 2005) of paddy in West Java were the largest among 33 provinces in Indonesia and planting times per year was also highest as shown in Figure 1. The high productivity of rice in this province could be based

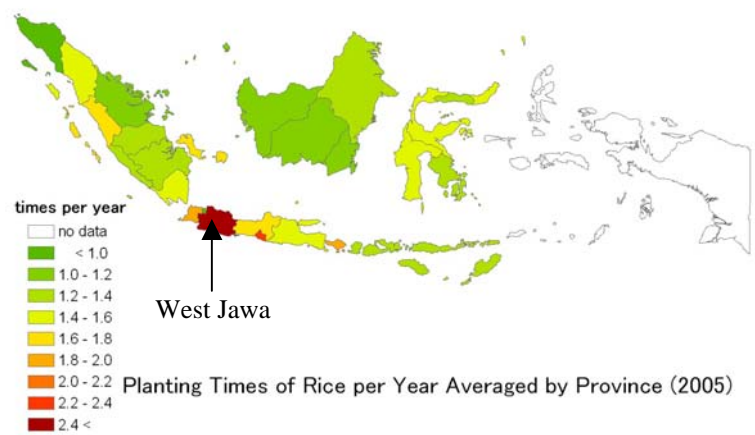


Figure 1 Cropping intensity of paddy rice by Province.

on the conditions that organized irrigation network was constructed in the northern coastal alluvial plain and sufficient amount of rainfall was given over mountainous areas located in the middle of island.

2.2 Data

As for the case of tropical rainfall climate zone, available cloudless scenes of Landsat data over the study site were limited. I collected in total 14 scenes of Landsat TM and ETM+ (Path-122, Row-64, 65) during the period from 1988 to 2002, of which 13 scenes were taken in dry or transition from rainy to dry season (May to September). The scene taken in December 22, 2001 was the only data which could be applied to analyze seasonal pattern of land cover condition. Therefore, additional scenes taken in May 12, 2001 and August 3, 2002 were employed for the analysis.

MODIS data used in this study was downloaded from the web site of Institute of Industrial Science, University of Tokyo (Takeuchi et al., 2003). Employed dataset was half-kilometer grid 15-days composite reflectance channel data and indices data (Takeuchi and Yasuoka, 2004).

Land use information and administrative boundaries of West Java were provided by Indonesian Center for Agricultural Land Resources Research and Development (ICALRD). Land use data was obtained by identifying the boundary of land use with manual interpretation of imagery of Landsat data in consideration with empirical knowledge. Figure 2 shows land use map. Because paddy field could not be discriminated optimally by digital image processing of satellite data, the class “Seasonal Crop in wetland” in this figure was employed as the area of paddy field for the further analysis.

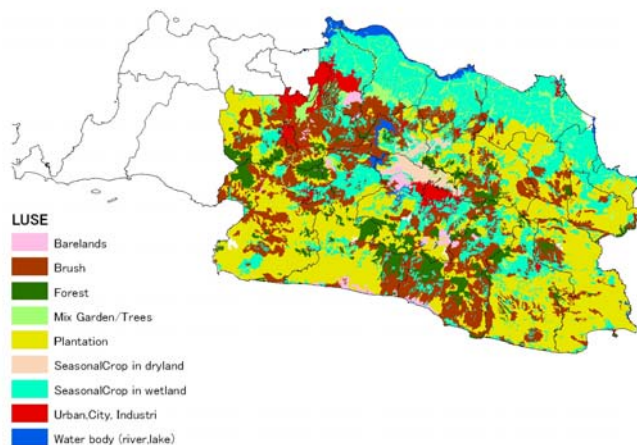


Figure 2 Land use map of West Java produced by ICALRD.

2.3 Method

In order to characterize the growing stage of paddy rice, 2 indices NDVI and LSWI were calculated from Landsat data. Multi-temporal data of these indices was classified by ISODATA method and seasonal changes of land cover which could be associated with growing stage of paddy rice were estimated by examination of features of class. Paddy fields considered for the analysis was the area extracted from land use map mentioned above. The formula of NDVI and LSWI calculated from Landsat TM/ETM+ band data are as follows;

$$NDVI = \frac{(B4 - B3)}{(B4 + B3)}, \quad LSWI = \frac{(B4 - B5)}{(B4 + B5)}$$

The cultivation stage from preparation of transplanting to early growing rice was sequentially discriminated from Landsat data taken in December 22, 2001. Then the relation between the discriminated classes and indices obtained from MODIS data was examined. Employed indices were NDVI and NDWI processed by Institute of Industrial Science, University of Tokyo and EVI calculated from reflectance data. The formula of NDVI, NDWI and EVI calculated from MODIS reflectance data are as follows;

$$NDVI = \frac{(R2 - R1)}{(R2 + R1)}, \quad NDWI = \frac{(R1 - R6)}{(R1 + R6)}, \quad EVI = 2.5 \times \frac{(R2 - R1)}{(1 + R2 + 6 \times R1 - 7.5 \times R3)}$$

3. RESULTS AND DISCUSSIONS

3.1 Seasonal Changes of Land Cover over Paddy Fields

Collected Landsat data for the period from 2001 to 2002 were optimally distributed in season, i.e. May, August and December. Spatial pattern of cropping could be generally depicted by producing color composite image of 3-temporal NDVI. Figure 3 represents an example of color composite image (Red:2001.5.12, Green:2001.12.22, Blue:2002.8.3) around Bundung city area. From this figure, we could recognize that large scaled homogeneous blue parts were found in

the right side and smaller block shaped features were in the left side. The more random distribution of color tones mixed with smaller scaled units was appeared in the southern side. These 3 types of spatial pattern would be representatives for the case of West Java. It was allocated rather systematically in the Province as shown in Figure 4. This figure was the result of examination of changing pattern of land cover, Vegetation, Water surface or Soil, over paddy fields area.

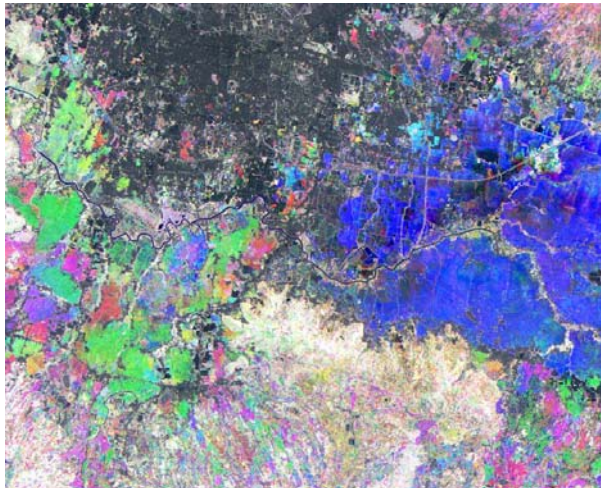


Figure 3 Color composite image of 3-temporal NDVI around Bundung.

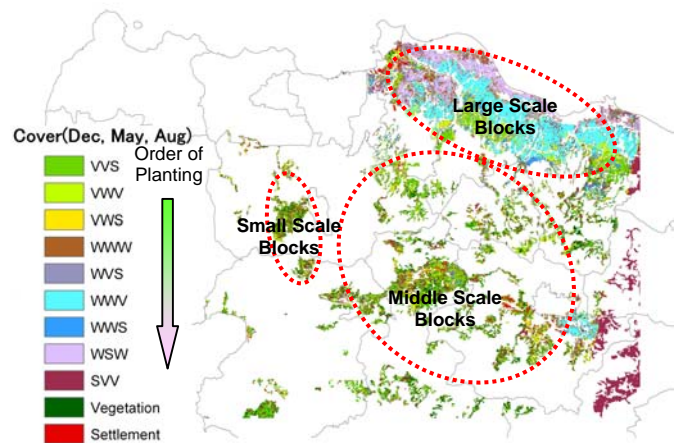


Figure 4 Distribution of type of changing pattern of land cover in West Java.

3.2 Relation between Indices Derived from MODIS Data and Rice Planting Time

When paddy rice is transplanting, land is inundated with water and then vegetative activity starts to emerge. This transition stage was classified from Class 1 (earlier planted) to Class 5 by using Landsat data of December 22, 2001. Then, the relation between these classes and indices derived from MODIS data was examined. Figure 5 shows temporal changes of these indices for

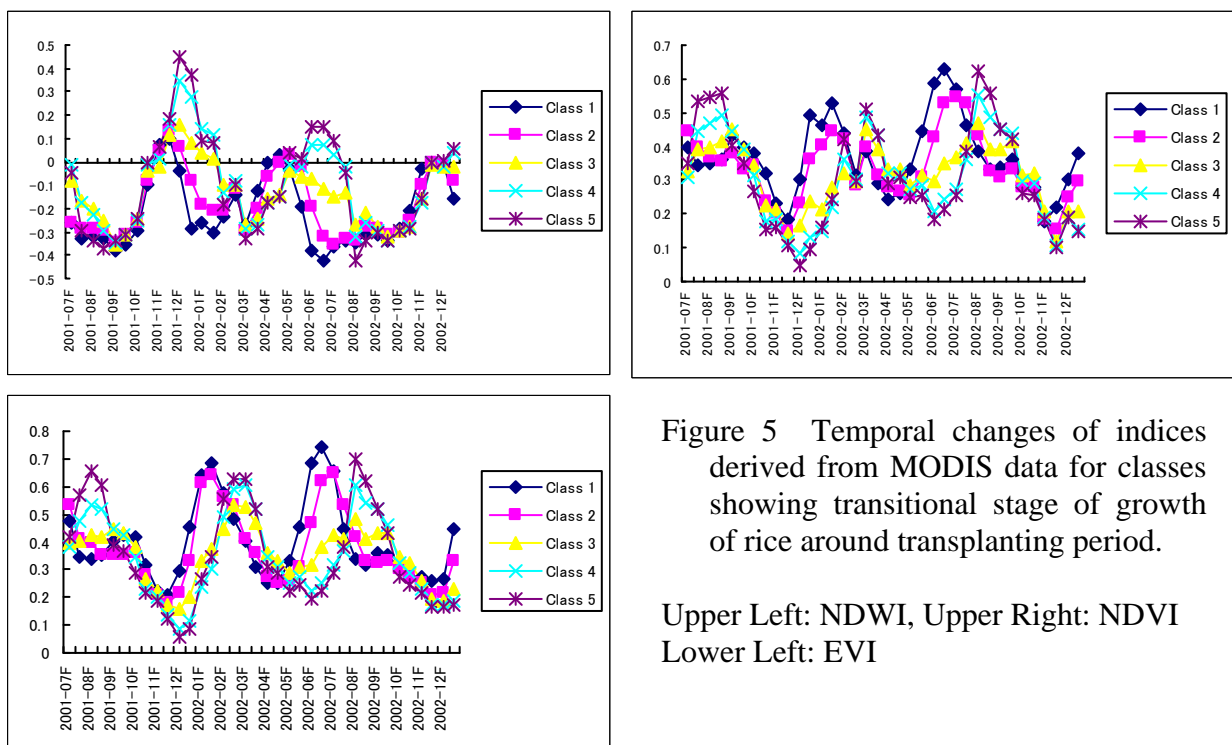


Figure 5 Temporal changes of indices derived from MODIS data for classes showing transitional stage of growth of rice around transplanting period.

Upper Left: NDWI, Upper Right: NDVI
Lower Left: EVI

each class. The figure indicates the evident maximum of NDWI at the time of transplanting and sharp decreasing after the event. Inverted tendency is shown in both the cases of NDVI and EVI. This phenological feature of rice was commonly indicated in the previous studies for the site located in other regions. It is noted that even for the area with complex cropping pattern MODIS data might extract the growing phase of rice if appropriate method of estimation was developed.

3.3 Estimation of Rice Planting Time Using MODIS Data

For the purpose of estimating rice planting time, a model employed the following scheme was tentatively adopted; 1) value of NDWI is the highest in the period from one month before to one month later, 2) NDWI decreases more than 0.2 to two to three months later, 3) NDVI increases more than 0.2 to two to three months later. This simple model generated the map of distribution of planting rice by every half-month for West Java Province. Figure 6 shows the case of latter November in 2001. This period was the major planting season in inland area of the

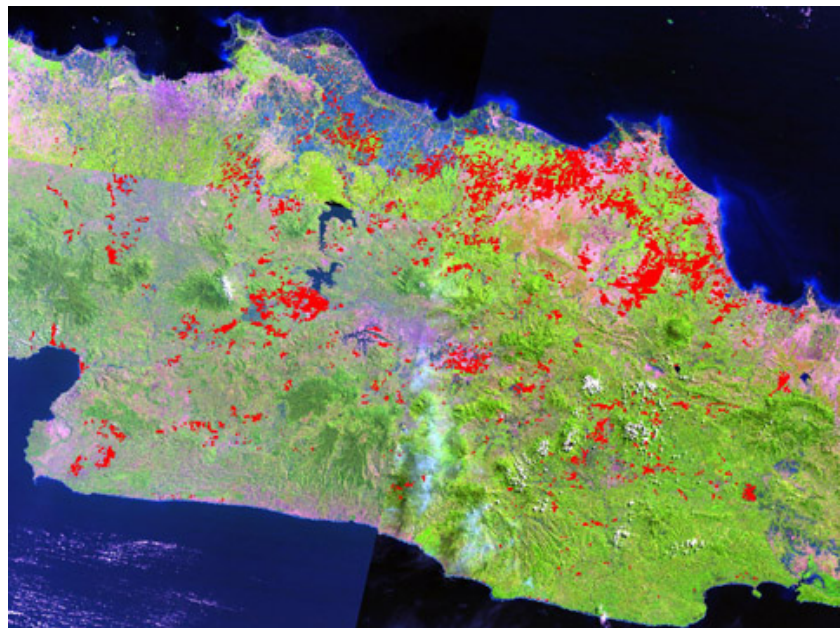


Figure 6 Estimated distribution of planting rice in the latter half of November in 2001.

Province and before planting in the northern coastal area. The pattern of distribution exhibited in the figure was generally harmonized with expected feature. Figure 7 represents the ratio of estimated area of rice planting to the total area of specific class mentioned in the previous section. According to the class specification Class 1 was the area of planting rice in the earliest among classes then Class 2 to Class 5. It is recognized that this figure showed coincident pattern of order of planting rice.

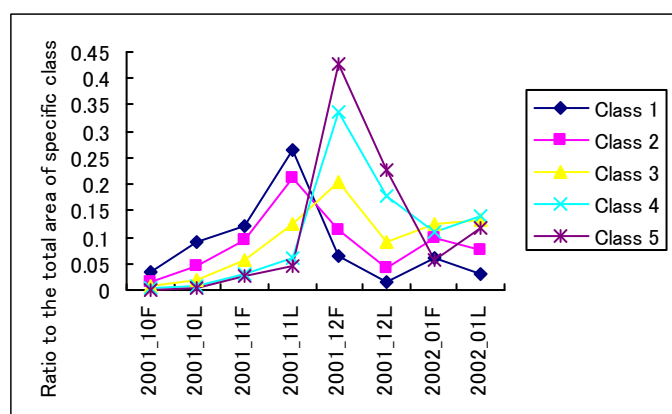


Figure 7 Ratio of estimated area of rice planting to the total area of specific class.

4. CONCLUSIONS

West Java Province of Indonesia shows complex cropping pattern of paddy rice, which could be one of typical landscapes appeared in the Southeast Asia. This complexity by mixing of different growing stages of rice and also secondary crops was an obstacle to monitor rice planting area using satellite remote sensing data. By the examination of spatial pattern of planting rice using multi-temporal Landsat data, differently scaled blocks, which exhibited to

extend similar growing stage of rice, could be discriminated. The largest sized blocks were appeared in the organized irrigation system in the northern coastal area and in a part of Bandung basin. In sloping parts on the foot of mountains, the spatial pattern of paddy fields could be evidently categorized into 2 groups, which were discriminated by the size of block, i.e. enough larger than the spatial resolution of MODIS data or not.

An attempt to estimate the time of paddy rice planting using MODIS data was carried out from the results of examination of relation between indices derived from MODIS data and rice planting time. The land inundated by water at the transplanting stage of rice was the discriminative condition from other land use using NDWI. Then the combination of identification of sharp maximum of NDWI and substantial increase of NDVI or EVI after the transplanting period proposed to be effective criteria to estimate the time of planting rice. Preliminary estimation showed promising results to the development of monitoring method of paddy rice planting using MODIS data for West Java Province and other areas where cropping patterns of rice were complicatedly mixed.

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