METHODOLOGICAL DEVELOPMENT OF MAPPING OF AGRICULTURAL LAND USE IN THE TROPICAL CLIMATE REGION USING MULTI-TEMPORAL AND MULTI-PLATFORM SATELLITE DATA - A CASE OF UPPER STREAM OF SOLO RIVER, INDONESIA -

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ABSTRACT: In order to discriminate agricultural land use for the tropical climate region, where planting season of annual crops might not be fixed in specific period, Landsat data would be possible source to represent different conditions of surface for individual land use category. However, its spatial resolution could not always satisfy to express condition of lot with small spatial scale, which was generally identified in the tropical climate region. In this study, therefore, combination of ALOS/AVINIR2 and Landsat/TM/ETM+ for discriminating agricultural land use was examined for upper stream of Solo River in Indonesia as study site. At the first procedure, two indices which represented ground surface condition of soil and vegetation, were calculated from multi-temporal ALOS/AVINIR2 data. This was based on consideration of ground surface condition, which showed at one time as covered by bare soil and at another by vegetation, for cases of agricultural land use with annual crops. The next was to obtain maximum and minimum values of these indices at every pixel of image, then to classify by using these values. Classification result could discriminate agricultural land use consisted of annual crops of upland or paddy field from other land use types. However, due to the limitation of seasonal variation of obtained data and lack of mid-infrared spectral band information, upland and paddy field could not be discriminated properly. Multi-temporal Landsat/TM/ETM+ data, on the other hand, equipped spectral information which was effective to characterize surface water condition and its seasonal changes, could be used to extract paddy field area. Combining two outputs obtained from ALOS/AVINIR2 and Landsat/TM/ETM+ mentioned above, 10 meter resolution land use data was produced. By comparing with QuickBird imagery, the method developed in this study showed proper discrimination of land use types between paddy field, upland field, forest and trees, bare and manmade, and water.

1. INTRODUCTION

1.1 Background

One of great advantage of satellite data is to provide pixel based digital data with spatially wide coverage over any site in the world. Therefore huge number of attempt to produce land cover/use maps using satellite data had been carried out. But then it was recognized serious limitation of application to specific cases, for example, land use discrimination of agricultural area in the tropical humid climate region because of existence of both spatially and temporally complicated cropping patterns as well as high probability of cloud overcastted condition. The author attempted to utilize Landsat data, which was accumulated for past decades and provided considerable number of cloudless scenes even for tropical humid climate region, to discriminate land use by pixel in case of West Java, Indonesia (Uchida, 2008, 2009, 2010). The result proved to show overall accuracy of 60 percents in case to set eight land use types, i.e. “paddy”, “upland”, “mix vegetation”, “forest”, “sparse vegetation”, “bare land”, “manmade”, “water” by comparison with interpreted type from QuickBird imagery. This was the case of area consisted with highly complicated distribution of land use, and even under such condition, user’s accuracy of “paddy” attained 88 percents. Only as a result, rather unclearly defined land use category of “mix vegetation” was employed and it was considerably confused with “upland”. Size and shape of agricultural field in the study site was varied complicatedly and also trees were existed in or around the field, so that spatial resolution of Landsat, 30 meters, could not always discriminate properly agricultural area from other land use mixed with trees.

1.2 Objectives

This study is objected to examine and develop a method to combine multi-platform satellite data, ALOS/AVNIR2 and Landsat/TM/ETM+, for producing pixel based agricultural land use data especially discrimination of paddy field and upland field applicable to tropical humid climate region. This also aimed at reducing unclearly defined land use category such as “mix vegetation” in output map.

2. MATERIALS AND METHODS

2.1 Study Site

The study site is upper stream of Solo River located in the eastern part of Central Java Province, Indonesia. This includes Districts named Wonogiri, Sukoharjo, Karanganyar and Sragen, and City named Surakarta as shown in Figure 1. Except for southern coastal area, most of site is located on foot of high mountain, Mt. Lawu, 3,266m above sea level at the peak, existed at eastern boundary of Karanganyar District. In Wonogiri District there is large reservoir "Gajahmungkur Lake", and Solo River runs from this to northward and then turns to eastward in Sragen District. Rainfall recorded yearly variations as that amount of annual rainfall was less than 1,000 mm in case of minimum but more than 2,500 mm in maximum at Wonogiri. There is distinctive dry season for the period from July to September. In terms of agricultural activities, paddy rice is cultivated widely in lowland part along Solo River and its tributaries and also in valleys located on foot of mountains. In areas with sufficient water for cultivation through the year, rice is often planted three times a year. In other parts, double cropping of rice is extensively presented, but one time cropping of rice is also common depending on availability of water. It is recognized that in paddy field upland crops are planted alternatively with rice in dry season or in case of shortage of water for cultivating rice. By this situation, there are variety of cropping patterns presented in the study site.

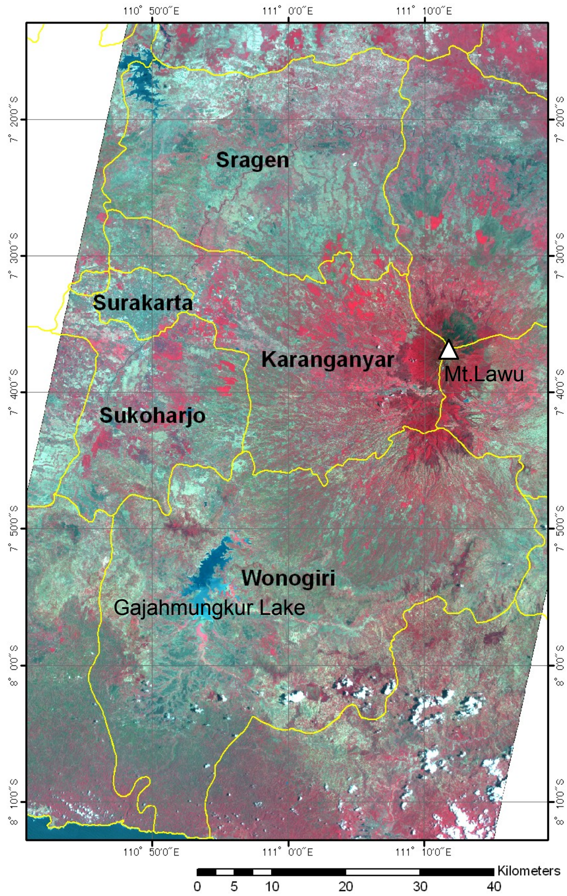

Figure 1 Administrative boundary on image of study site

Table 1 List of acquisition date of collected sartellite data

Sensor Type		
Landsat/TM	Landsat/ETM+	ALOS/AVNIR2
2000.5.28 2000.6.29 2000.7.15	2001.5.23 2002.2.19 2002.3.23 2002.4.24 2002.5.26 2002.7.29 2002.10.1 2003.5.13	2006.10.11 2008.5.31 2008.7.16 2009.10.19

2.2 Data

In this study, multi-temporal Landsat/TM/ETM+ and ALOS/AVNIR2 data were used to discriminate agricultural land use. Date of acquisition of collected data is shown in Table 1. For all the date of acquisition of Landsat data described in table, Path-119, Row-65 and Path-119, Row-66 scenes were collected, while for ALOS data, Path-103, Frame-3750 and Path-103, Frame-3760 scenes were collected. Continuous scenes on the same Path were mosaiced to one scene for further analysis. In order to examine representative pattern of crop planting season and its yearly variation, MODIS data product named Vegetation Indices 16-day L3 Global 250m product (MOD13Q1) was downloaded. MOD13Q1 contains EVI (Enhanced Vegetation Index), NDVI (Normalized Difference Vegetation Index) and reflectance values of Band 1, 2, 3 and 7 of MODIS data. Here, another index, NDWI (Normalized Difference Water Index), which could reflect the surface water condition, was calculated as the following equation from reflectance data.

$$NDWI_M = \frac{(B1 - B7)}{(B1 + B7)}$$

Besides, for comparing with result of land use discrimination and actual condition, QuickBird data acquired on September 29, 2006 was utilized. Field observations of landscape focused on a part of Wonogiri District were conducted in July 2010 and July 2011.

2.3 Discrimination of Land Use

Procedure to discriminate agricultural land use in this study consisted of two steps. The first step was to discriminate agricultural land for annual crops, which might include categories both of paddy field and upland field, from other land use types using multi-temporal ALOS data. In this, perennial trees, which might be a kind of agricultural land use such as plantations or orchards, were not discriminated individually and merged to category of forest. Discriminated agricultural land use should be separated paddy from upland field in the second step. This step was to combine with discriminated paddy field area from multi-temporal Landsat data.

As shown in Table 1, a set of collected ALOS data did not include scene acquired in middle of rainy season so that parts of paddy field of which rice planted once or twice a year might not be properly represented. Therefore, the author focused behavior of surface condition as that it was covered with vegetation or bare soil in different time. He calculated two indices for every ALOS data, one was NDBSI (Normalized Difference Bare Soil Index) representing surface condition of bare soil and the other was NDVI (Normalized Difference Vegetation Index) representing surface condition of vegetation by formula shown as follows.

$$NDBSI_A = \frac{(B3-B1)}{(B3+B1)},\quad NDVI_A = \frac{(B4-B3)}{(B4+B3)}.$$

NDBSI here was modified formula to one constructed to Landsat data, which was employed Band 7 and Band 1. In order to remove effects of cloud, cloud affected parts, which was extracted by using ISODATA classification method for each data, were changed to -1 for calculating maximum value and 1 for calculating minimum value. After this process, maximum values of NDBSI and NDVI and minimum values of NDBSI and NDVI among all ALOS data were obtained. Classification was then carried out using maximum and minimum values of indices.

Discrimination of paddy field was implemented by a method developed by the author (Uchida, 2009, 2010). This was based on characteristics that each land use showed specific temporal change of land cover features. In this method 5 indices as described in the following were employed.

$$NDBSI_L = \frac{(B7-B1)}{(B7+B1)},\quad NDSI_L = \frac{(B5-B4)}{(B5+B4)},\quad NDVI_L = \frac{(B4-B3)}{(B4+B3)},\quad LSWI_L = \frac{(B4-B5)}{(B4+B5)},\quad NDWI_L = \frac{(B3-B5)}{(B3+B5)}.$$

All indices were calculated for eleven scenes of Landsat/TM/ETM+ listed in Table 1. Here also in order to remove effects of cloud, first each Landsat scene was classified by ISODATA method and identified the cloud affected area. Then, values of all indices changed to -1 for the affected area. Consequently, calculated maximum values of 5 indices among all Landsat data represented the characteristics of variation of land cover condition at the pixel, which would be used for discriminating land use.

Final land use data showing distribution of paddy field and upland field was obtained by combination of two set of discriminated land use data produced by method mentioned above. For facilitating this process, Landsat data was rectified to the same resolution and location of ALOS data.

3. RESULTS AND DISCUSSIONS

3.1 Temporal Variation of Cropping Extracted from Time-Series MODIS Data

Information about cropping season is one of key factors to judge appropriateness of date of satellite data for discriminating agricultural land use. Therefore several points which represented typical landscape in the study site were selected, and then behavior of temporal changes of indices derived from time-series MODIS data was examined. Figure 2 shows location of selected points over color composite image of three temporal NDVI of ALOS data, where P1 to P5 are represented paddy field and P6 to P7 are upland field.

Figure 3 shows temporal changes of EVI and NDWI for selected points. Both of P1 and P2 represented irrigated paddy field with triple cropping of rice a year and demonstrated three times maximum of EVI and NDWI as shown in the figure. But seasons of having maximum value of indices were almost unified in case of P2, while varied year by year in case of P1. P3 showed three times maximum of EVI but only one time of distinctive maximum of NDWI, which suggested that cropping pattern was rice-upland-upland. For the area without planting paddy rice, maximum of NDWI was not clearly indicated as in case of P6. From this result, it was recognized that satellite data acquired in rainy season should be included for the

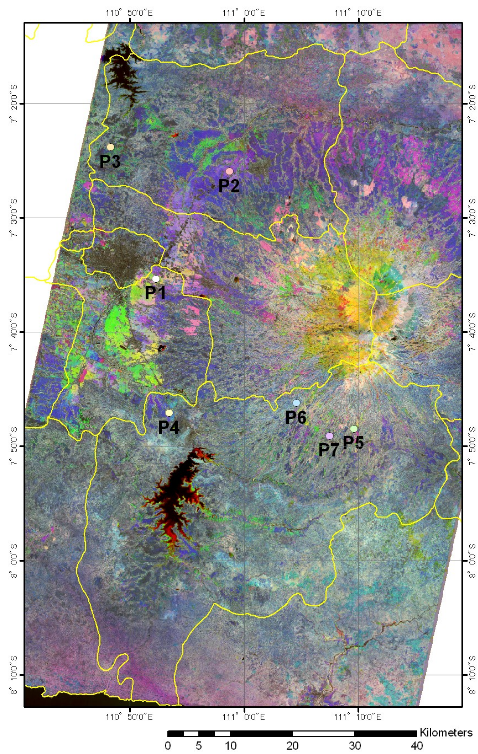

Figure 2 Location of sampled points for examining cropping season

purpose of discriminating paddy field, where rice planted at least once a year.

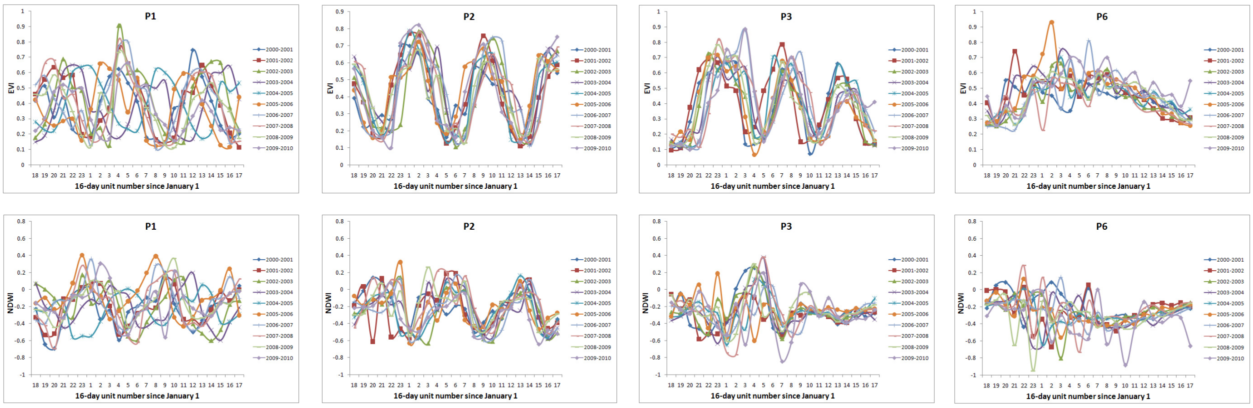

Figure 3 Temporal changes of EVI (upper) and NDWI (lower) for selected points

3.2 Land Use Discrimination by Multi-Temporal ALOS Data

Figure 4 shows discriminated land use using four parameters, which were values of maximum of NDBSI, maximum of NDVI, minimum of NDBSI and minimum of NDVI, obtained from multi-temporal ALOS/AVNIR2 data. Land use type of "Agricultural" could be represented either paddy field or upland field, in which annual crops are planted. "Bare&Manmade" denoted bared rock or soil otherwise artificial constructions such as houses or roads, and "Forest" implied area with standing perennial trees or grasses, which could involve a kind of plantation or orchard. From this figure, it is recognized that constructions existed in rural settlement and trees appeared in surrounding part of agricultural field could be discriminated as "Bare&Manmade" or "Forest", respectively. Then, parts of agricultural field without trees were extracted apart from confusion with state of mixed with vegetation.

3.3 Combination with Paddy Field Data Discriminated by Multi-Temporal Landsat Data

In contrast with ALOS data, there was possibility to detect surface condition of transplanting period of rice in paddy field, which was inundated by water, from multi-temporal Landsat data. Figure 5 shows land use data discriminated by using Landsat data. Due to its more coarse spatial resolution than ALOS data, land use class of "Mix Vegetation" was inevitably employed. As indicated in the previous work, method of land use discrimination adopted here was efficient to extract paddy field even for the case of tropical humid climate region (Uchida, 2009, 2010). Then in this study, paddy field area extracted from multi-temporal Landsat data was overlaid to land use data produced from ALOS data. The result is depicted in Figure 6.

3.4 Comparison of Estimated Land Use with QuickBird Imagery

Accuracy assessment would be executed by comparison with interpretation of QuickBird image. Collected QuickBird data covered the area in the eastern upper stream of Gajahmungkur Lake in Wonogiri District. This area is located on slopes to south with valleys and hills in between. Land use distribution pattern in this area is more complicated than that in lower part of Solo River, so accuracy of estimation scored here would presumably be lower than accuracy for whole study site.

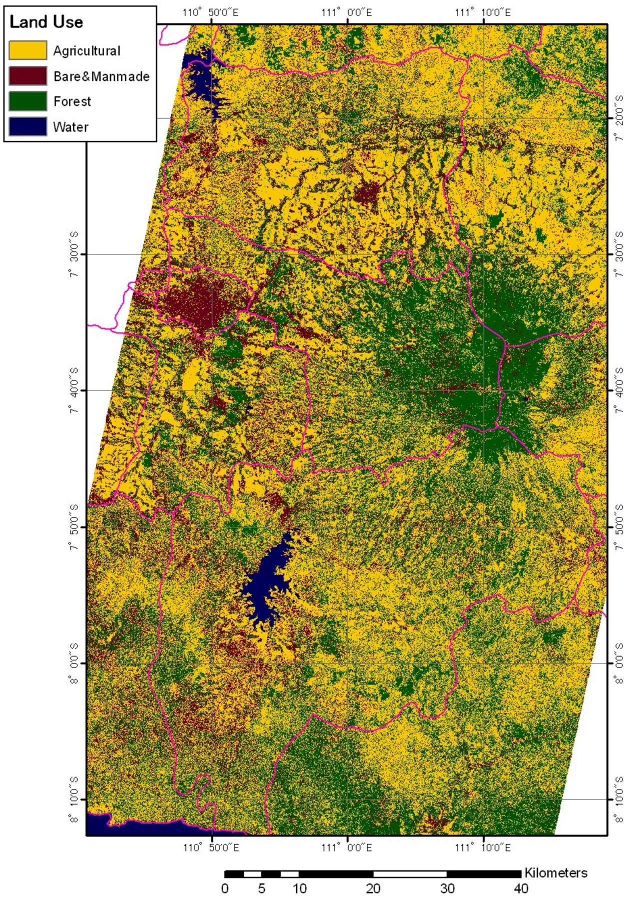

Figure 4 Land use map discriminated by using multi-temporal ALOS data

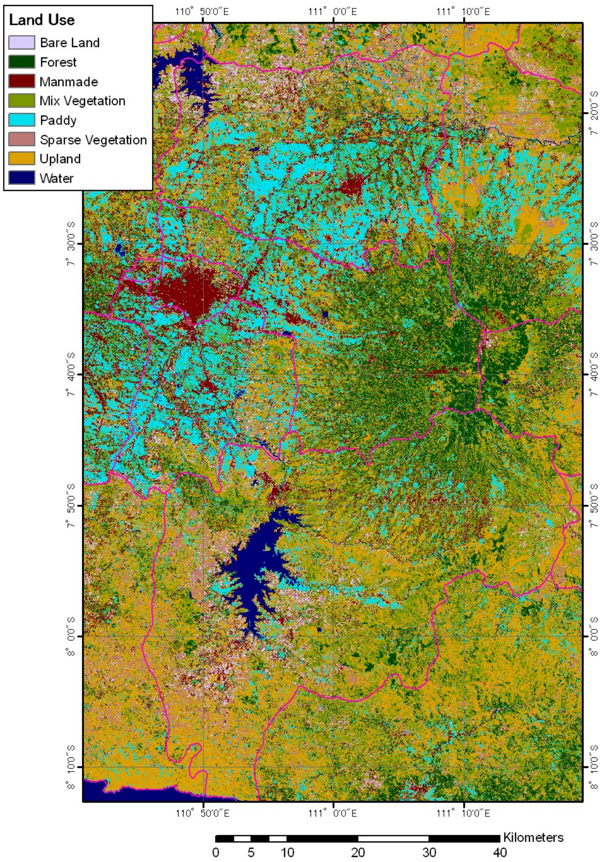

Figure 5 Land use map discriminated by using multi-temporal Landsat data

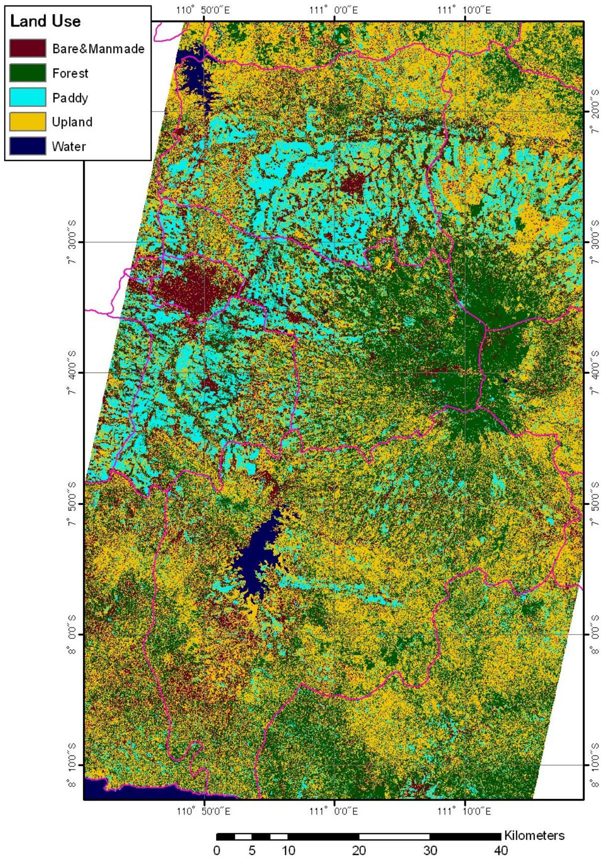

Figure 6 Land use map combined with discrimination by ALOS data and Landsat data

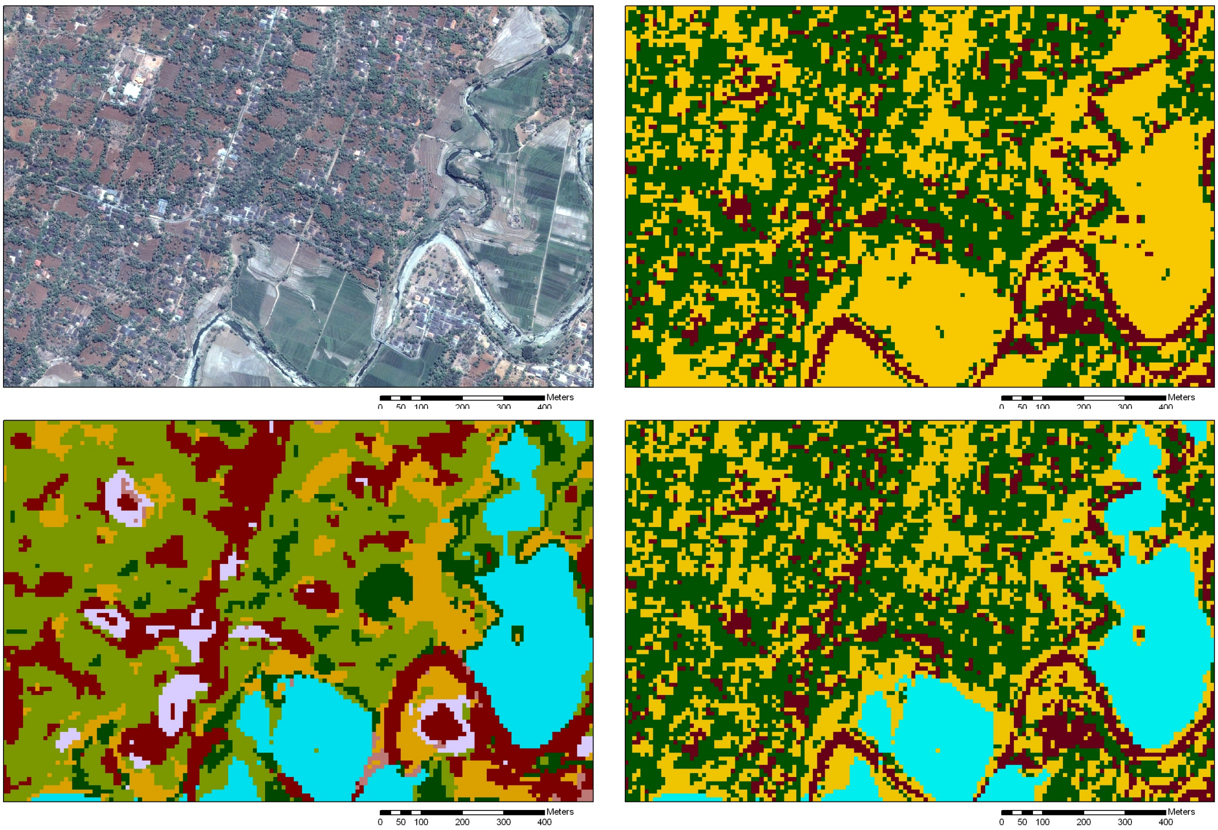

Figure 7 Example of comparison among QuickBird image and discriminated land use maps

Figure 7 represents example of comparison among QuickBird image (upper left), land use by ALOS data (upper right), land use by Landsat (lower left) and land use combined with ALOS and Landsat (lower right). It was evidently displayed that pattern of distribution of paddy field in discriminated land use map was generally matched with QuickBird image. Actual distribution of upland field shown in QuickBird image could be recognized as a space of bare land in and outside of rural settlement. Although upland field located inside of settlement was mixed with trees in many places, land use map produced by combination of ALOS and Landsat data showed more reasonable distribution pattern than land use discriminated only from Landsat data.

4. CONCLUSIONS

There are many constraints to realize for producing appropriate pixel based land use classification using satellite remote sensing data in case of applying to areas in tropical climate region. Higher spatial resolution than equivalent to Landsat level is required to discriminate agricultural area from parts of other land use types mixed with vegetation, however, time of observation, which should be represented at specific period of crop growth condition, might not be satisfied. In this study, the author examined combination use of ALOS data and Landsat data. Multi-temporal ALOS data enabled to discriminate agricultural land use planted by annual crops with more precise spatial resolution and with reducing ambiguous category such as mixed vegetation, even though there was no data acquired in middle of rainy season. On the other hand, archives of Landsat data showed more variety of acquisition time, which included scenes in rainy season, and it was effectively utilized to extract paddy field. Then combination of these two output resulted to provide rational agricultural land use map representing distribution of paddy and upland field. Accuracy assessment has been conducted qualitatively at the moment and applicability to various areas has not yet examined in detail. However, it was recognized that this method was promising technique to produce seamless pixel based digital land use data with same specification for country scale of areas.

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