# PHENOLOGICAL CHANGE DETECTION IN FLAT AND TERRACE PADDY USING ASTER SATELLITE IMAGES IN TAKAYAMA RIVER BASIN AREA.

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## ABSTRACT

ASTER data are one of the cheapest satellite images available, having fine resolution of 15m. In this study, usefulness of ASTER VNIR data to detect phenological changes has been examined for flat land paddy and terrace paddy respectively. Ground data on spectral reflectance and other biophysical parameters has been collected on a regular basis of two weeks interval. It was found that there is variation in phenology of flat land paddy and terrace paddy. Our results showed that ASTER VNIR derived NDVI from band 1 and band 3 can play an important role in monitoring paddy phenology by estimating LAI. It also suggests that standard AOI layer derived from classification of paddy can extract paddy areas in other images and can promote phenological change detection analysis. If automation of paddy LAI estimation using satellite images is done using this AOI layer, the task of biomass monitoring of paddy in Takayama will become more effective and easier. Following the same procedure other landcover/landuse class AOI can also be developed and used in the automated monitoring modeling process.

## INTRODUCTION

Information on crop phenology is essential for evaluating crop productivity and crop management (Sakamoto et al, 2005). Monitoring seasonal changes in vegetation activity and crop phenology over wide areas is essential for many applications, such as estimation of net primary production (Kimball et al, 2004). On the other hand, information on the area and spatial distribution of paddy rice fields is needed for trace gas emission estimates, management of water resources and food security. Accurate assessment of methane emissions at regional and global scales requires geospatial datasets of paddy rice fields (Xiao et al, 2005).

Remote sensing is often used for detecting seasonal vegetation changes. Various methods using Normalized Difference Vegetation Index (NDVI) data have been developed for monitoring crops and natural vegetation (Akiyama et al, 2002, Saito et al, 2002). Optical satellite remote sensing provides a viable means to meet the requirement of improved regional-scale datasets of paddy rice fields. A number of studies examined the potential of satellite images from landsat, NOAA Advanced Very High Resolution Radiometer (AVHRR), multitemporal MODIS data to identify paddy rice fields (Okamoto and Fukuhara, 1996, Van Niel et al, 2003, Xioa et al, 2005). Those studies used image classification techniques and NDVI respectively. A very few studies have been explored the potential of Advanced Spaceborne Thermal Emission and Reflection radiometer ( ASTER) satellite image for detecting crop phenology of paddy. In our study we used a combined technique of image classification and estimation of Leaf Area Index as a net primary product indicator from satellite data using ground measured relations with NDVI. Using ASTER Visible and Near Infrared data are highly promising because of its wide range and higher spectral resolution of 15m and most importantly for its cheaper price availability.

## METHODOLOGY

### Study Area

Daihachiga river basin of Takayama in central Japan was selected for Center of Excellence (COE) research area for ecological sytem monitoring studies. The study area is unique for its natural characteristics with large forest area in the upstream zone, settlements and paddy rice dominant agricultural lands in the lower and mid terrace zone, making it a complex carbon sink. The study area is shown in Figure 1.

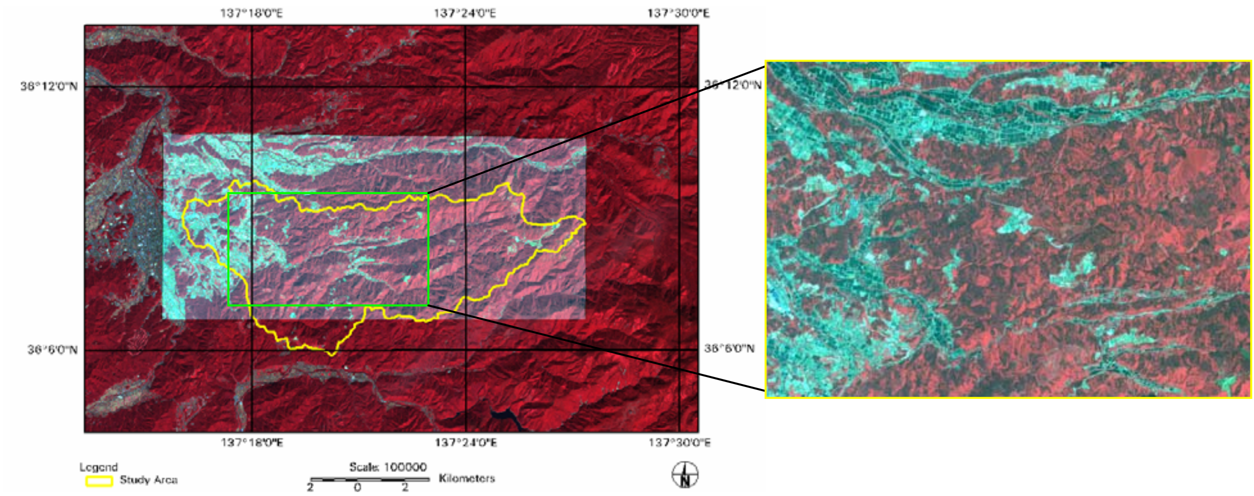


**Figure 1.** Study area showing the paddy areas on ASTER VNIR 2005, Quick Bird 2002 and IKONOS 2002 respectively.

Daihachiga river starts from south-west slope of Mt. Hikagedaira, the summit of which is 1595 m above sea level (asl) and flows down by merging to Miya river in the mid stream, to the Takayama basin at about 600m asl and finally empties to Japan sea as Jintsu river (Akiyama et al, 2005).

In this study, the lower stream and middle stream zone from 600m to 800m above sea level (asl) area was selected for its landcover is dominant with paddy fields. We call it flat paddy and terrace paddy area for the lower and mid stream zone respectively.

### Satellite Data

We used three ASTEER VNIR satellite images of 31 May, 03 August and 04 September 2006 respectively. Terrain corrected (level 3AO1) images were used for the phenological change detection study here. Satellite images are shown in Figure 2.

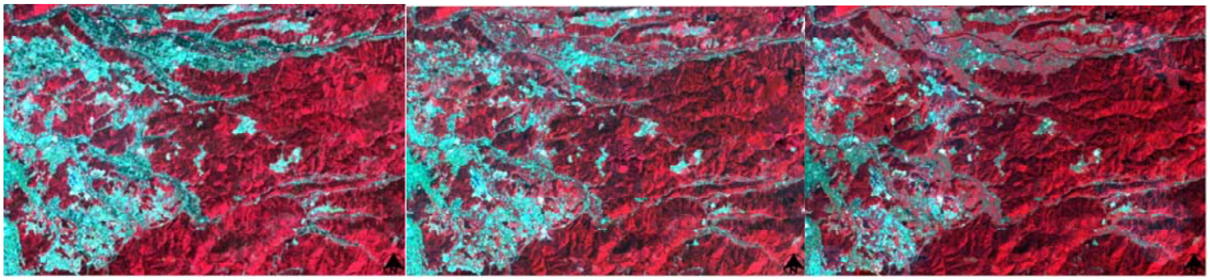

**Figure 2.** ASTER VNIR images on 31 May, 03 August and 04 September respectively.

Some parts of the images, mainly in forest areas were covered with clouds which has been replaced by overlay with the clear sky areas available in all the images respectively.

## Ground Measured Data

Two experimental plots were selected in flat and terrace paddy area at 607m asl and 766m asl respectively. Crop biophysical parameters like LAI, plant stand height, fresh weight of leaf, stem, root, and ear were also measured after separating from the plant parts. LAI defined as the total one side area of photosynthetic tissue per unit ground area surface (Watson, 1974) and it is one of the most important variable in climatic (Ewert, 2004) and agronomical research studies ( Soltani and Galeshi, 2002). LAI was measured by separating leaves from plant tissue and analyzing the total leaf area using a leaf area meter (AAC-400, Hayashi Denkoh Co, Tokyo, Japan). Plant parts were separated into leaf, stem, root and panicle components (ear), dried ($70^0$C for 3 days) and weighed to determine dry biomass.

Spectral reflectance in flat and terrace paddy were collected every two weeks after transplanting in 22 May 2006. A handheld spectroradiometer (MS 720) which measures hyperspectral data from 320nm to 1050nm wavelength range respectively, were used in this study.

Spectral data were collected from 1m above canopy level at 5 sample plots in flat and 4 sample plots in terrace paddy field respectively.

We collected data on 8DAT (Date after Transplanting), 23DAT, 42DAT, 70DAT, 89DAT, 105DAT, 117DAT, 129 DAT and 138 DAT respectively. 105DAT and 117DAT were the full heading stages for flat and terrace paddy respectively. For rainy and cloudy weather spectral data collected on 23 and 42 DAT were excluded from the analysis.

Average of the ASTER VNIR band of 1, 2 and 3 were used for the calculation of ground measured NDVI using the spectral reflectance data. NDVI values were calculated, both from the ground spectral measurements and satellite images by the widely used equation as follows (Rouse et al, 1974).

$$NDVI = Band3-Band1/Band3+Band1$$

## Preprocessing of Satellite Data

All the data were georefernced into our standard projection of Transverse Mercator, Spheroid GRS 1980, Datum JGD 2000, projection system. High resolution image of QuickBird 2002 were used as reference image. GCP's (Ground Control Points) from ASTER VNIR image of 2005 was also used to cover the extended area out of the QuickBird 2002. As the satellite images are terrain corrected the total RMS error were very low ranging from 0.2 to 0.4, providing a very good coregistration among the images.

Radiometric calibration was done on three images used here for phenological change detection study requires the satellite images to be converted from DN to spectral reflectance data. Spectral signatures are not transferable if measured in DN as these are image specific. It is far more useful to convert DN to reflectance and spectral signature with meaningful units can be compared from one image to another i.e for phenological change. Radiometric calibration using the following equations was manually done using the spatial modeler preface in Erdas Imagine 8.7. The calculations were done using the method described in Smith. 2007. as follows;

$$Lrad = (DN-1)*Unit\ Conversion\ Coefficient$$

$$Exoatmospheric\ Reflectance = (pi*Lrad*d2)/(ESUNi*COS(z)$$

Where, $d = (1-0.01672*COS\ (RADIANS\ (0.9856*(Julian\ Day-4))))$

pi=3.14

Esun is the mean solar exoatmospheric irradiance of each band, z is the solar zenith angle

## Image Classification

The basic assumption for image classification is a specific part of the feature space corresponding to a specific class. Classes have to be distinguished in an image and classification needs to have different spectral characteristics. This can be analyzed by comparing spectral reflectance curves. Image classification gives results to certain level of reliability. The principle of image classification is that a pixel is assigned to a class based on its feature vector by comparing it to predefined clusters in the feature space. Doing so for all image pixels result in a classified image (Janssen, 2001). After preprocessing of data unsupervised classification were used to get the desired paddy class.

We used unsupervised classification technique with supervised knowledge on paddy area to get the desired class of paddy only. Field verification, onscreen interpretation of high resolution satellite images and hardcopy topography maps were used to identify paddy fields in Takayama.

## RESULTS AND DISCUSSION

### Ground Measured NDVI and LAI

It was observed in Takayama that phenology of flat and terrace paddy differs by late heading and panicle initiation stage in terrace paddy. LAI, total dry weight and grain yield were also higher in flat paddy. Figure 3 shows the biophysical parameters measured for flat and terrace paddy field and their relationship with NDVI. The regression coeffient value decreased when the terrace paddy data were included as a variable component in the regression analysis. It was due to some error in spectral reflectance data for terrace paddy which gives higher NDVI in maturity stage. However, we used flat paddy derivatives as our standard equation for satellite estimation of LAI.

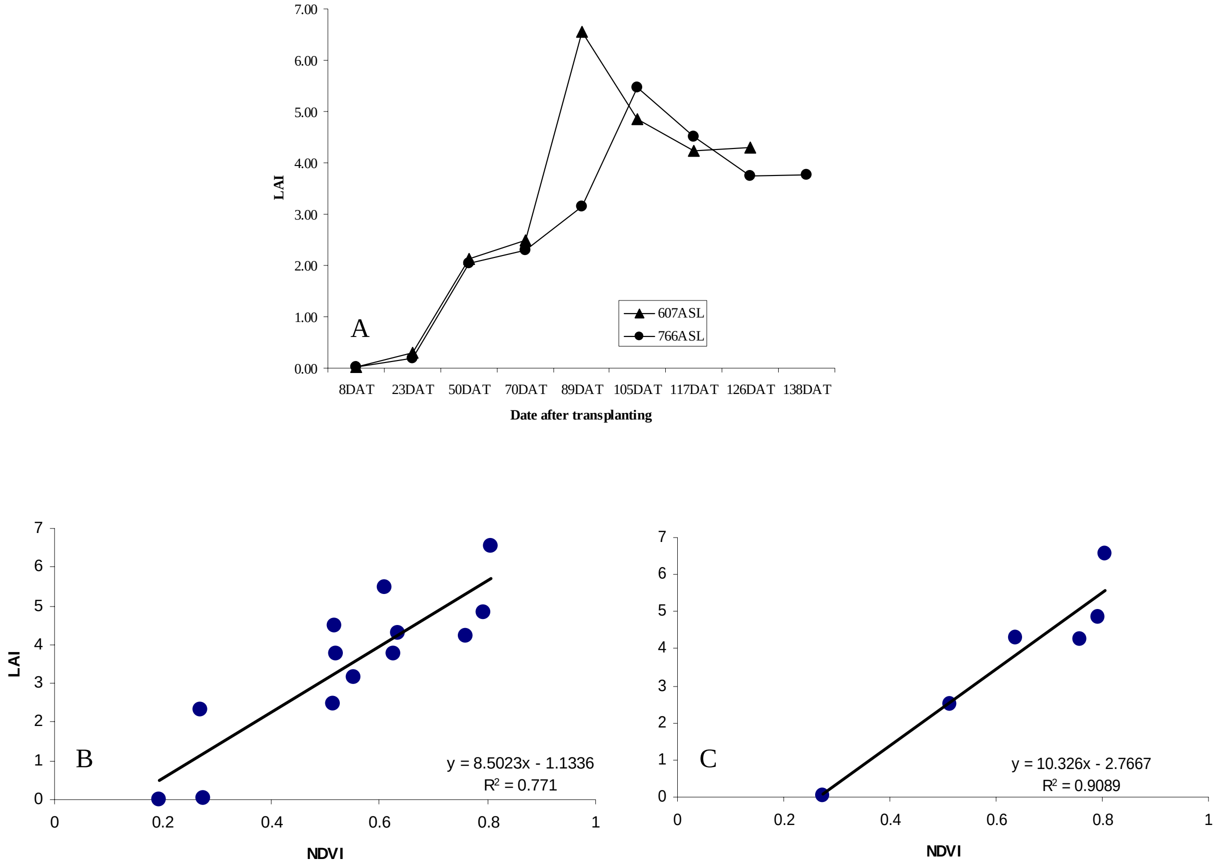


**Figure 3.** LAI and relation with NDVI using the band width of ASTER VNIR Band1 and Band3 in Takayama. A) LAI with growing days of paddy in flat and terrace, B) NDVI and LAI relation in flat and terrace paddy. B) NDVI and LAI relation in flat paddy.

### Classification of Paddy and AOI (Area of Interest)

One of our main targets of image classification was to classify paddy from the best resolution image available for the study area and make it a base for comparison of ASTER derived paddy. We used multispectral IKONOS image acquired in June 2002. An unsupervised ISODATA clustering of 50 classes were examined and assigned to one single class of paddy for IKONOS 2002 (Figure 4). It is noticeable from Figure 2 that each image of ASTER VNIR 2006 has some problem in spectral demarcation of paddy. In most cases it is very difficult to separate paddy from the surrounding forest class when the paddy reach to its maximum vegetation stage. Separation of paddy gives it best class in May- June images as paddy fields at its early growing stage is filled with water. But sometimes, it also gives misclassification result to settlement class. On the other hand, satellite images around the maximum vegetation stage of paddy gives separate spectral signatures to that of settlement. To overcome all these problems, we first identified our paddy class from 31 May 2006. We then classified settlement class from 03 August image and subtract the settlement area which was misclassified as paddy in May 31 image respectively. A comparison of how well it gives us the paddy class in Takayama is given in Table 1. At first the paddy class was overestimated due to its inclusion of some area under settlement class. After subtraction from the settlement class in August 03, it gave a pretty good estimation of paddy class.

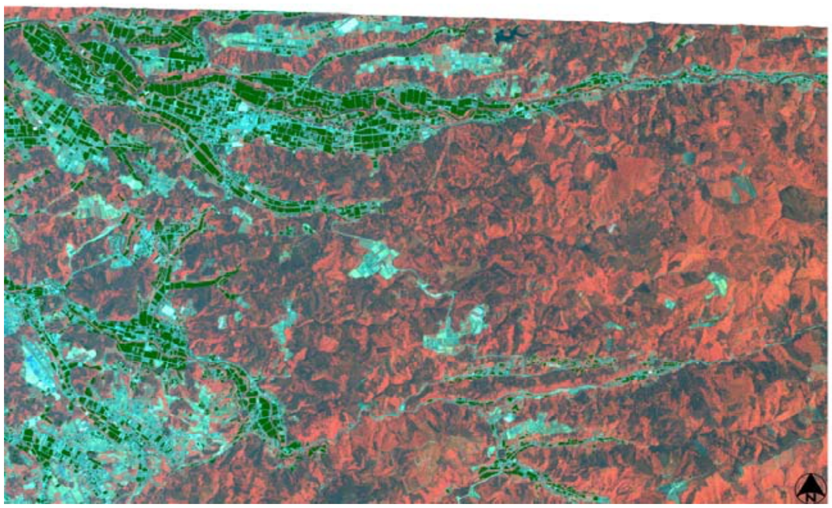

**Figure 4.** Paddy in Daihachiga river basin area derived from IKONOS 2002.

Though it was observed that the terrace paddy is underestimated with compared to IKONOS classification 2002. Terrace paddy posses an unique characteristics of terrace paddy (Figure 5), curved and situated in slopes, which make it difficult to classify using mid resolution images of ASTER VNIR with 15 m spectral resolution. From Table 1 it is clear that almost 4 to 5 hectares of paddy area are underestimated from ASTER VNIR classification. In flat land area, it gives a very good assumption of paddy coverage though little overestimated. We finalized our paddy class from 31 May 2006.

**Table 1.** Area coverage under paddy class in flat and terrace paddy

| Satellite Image | Flat Paddy (ha) | Terrace Paddy (ha) |
|---|---|---|
| 31 May ASTER VNIR before substracting | 628.695 | 19.665 |
| IKONOS | 493.949 | 21.58 |
| 31 May ASTER VNIR after substracting | 522.68 | 17.14 |

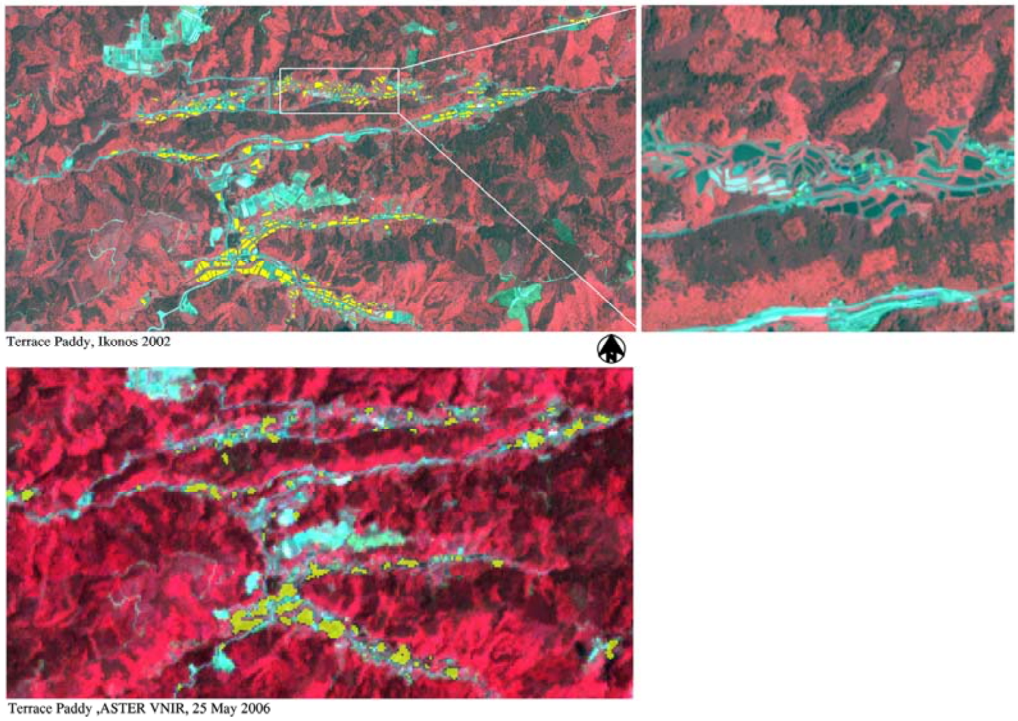


**Figure 5.** Terrace paddy showing its unique characteristics of shape feature in IKONOS 2002 above and classified paddy in ASTER VNIR image of 31May 2006 below respectively.

Our next target was to make an AOI file for paddy area to be used in extraction of the paddy only image from other images. This would help in classification and other analysis by making it easier as there will be no other mixed pixels present in the images. For this purpose image georeferencing need to be done with the minimum possible RMS error. The advantage of the terrain corrected ASTER VNIR is that it takes very little effort for the accurate georeferencing process. As the coregistrations among the images were very high, it gave a very good extraction of paddy only areas from 03 August and 04 September images using the AOI layer respectively. AOI layer was derived from classified paddy thematic layer by a convertion to vector file and then to AOI file for paddy. This technique may take several more minutes when the area coverage is larger. In this study, it worked as a standard AOI for paddy in Daihachiga river basin area. Figure 6 shows the standard AOI and the extracted Paddy only images of 31 May, 03 August and 04 September respectively. It was observed from the extracted images that some pixels other than paddy were also extracted around the paddy pixels due to the very small spatial distortions in each image. Extraction of images with paddy AOI adds some spectral enhancement as well.

We applied NDVI calculations on the separated paddy only images to get rid of the confusion arised from other landcover/landuse class with similar NDVI values. This technique is very important to correct the misclassified value added to any class, like confusion between forest NDVI and paddy NDVI in maximum vegetation stages of paddy at heading stage. As the ground measured NDVI 31 proved to work better for the estimation of LAI in flat paddy, we calculated NDVI 31 using Band 3 and Band1 for ASTER VNIR images. We used equation no 5 to get our LAI image 2006 from ASTER VNIR NDVI 31 images. Prior to that satellite NDVI were converted to ground NDVI by the best fitted regression line of Ground measured NDVI=1.88 Satellite NDVI-0.0459, with a $R^2$ of 0.99. Our results show that prediction of LAI from the satellite derived data give a good assumption for paddy accept few overestimations. But for the terrace paddy it is assumed to be overestimated compared to the ground measured data in Takayama. Figure 7 shows the LAI composite map derived from ASTER VNIR satellite images 2006. Different values for LAI from ASTER VNIR derivation ranged from 0.20-0.60 for early growing stage (31May) and 3.1-7.10 for full heading and after full heading stages ( 03August – 04 September). It is very much promising to use ASTER VNIR data for estimation of phenological change detection by LAI. More field data need to be collected for verification of the regression equation of ground measured NDVI and LAI. Several studies examined LAI to work as a key variable in most of the models developed for the simulation of carbon and water dynamics (Stroppiana et al, 2006) and as an indicator of radiation use efficiency, response of carbon assimilation to intercepted photon flux density (Salisbury and Ross, 1992).

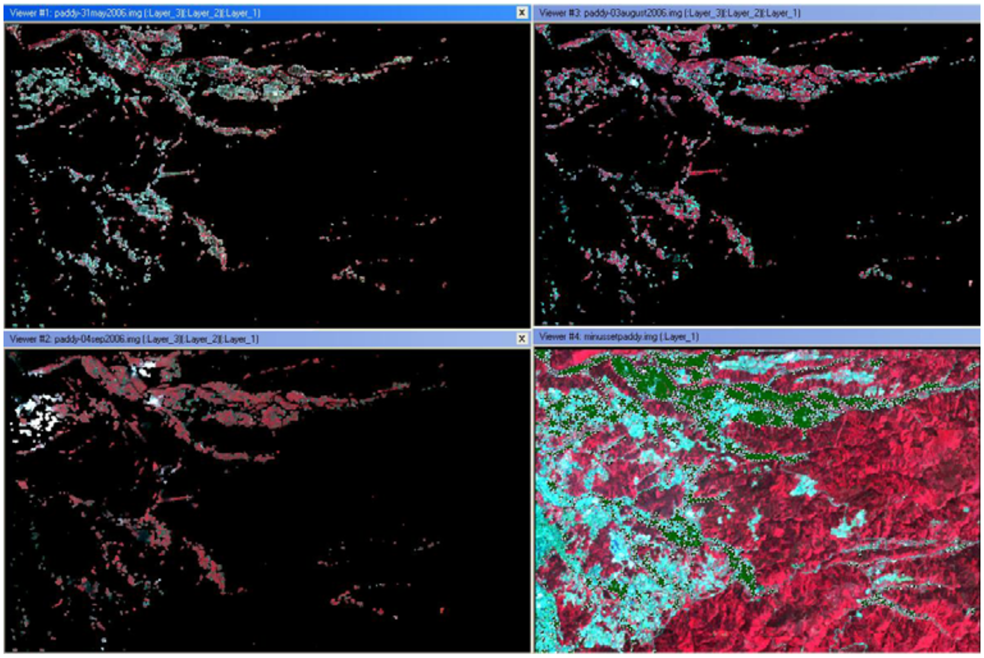

**Figure 6.** Screenshot of AOI layer of paddy in Takayama study area and extracted paddy areas from other images of 03 August and 04 September ASTER VNIR images respectively.

On the other hand fairly good correlations were found between the NDVI and $CO_2$ fluxes on a seasonal scale (Burgheimer et al, 2006). Estimation of LAI from NDVI thus indicates the potential of ASTER VNIR satellite data to understand paddy phenology and its contribution to carbon flux mechanism in the ecosystem.

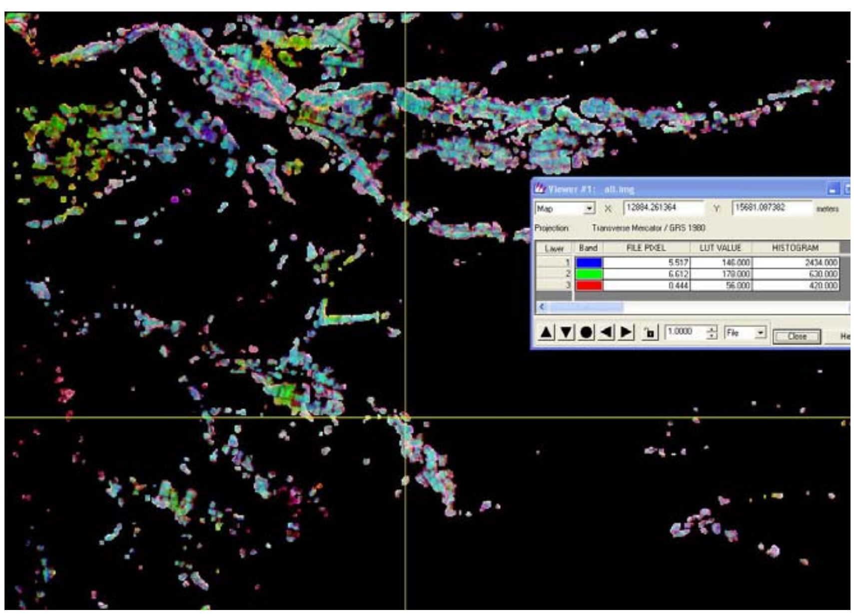


**Figure 7.** Screenshot of omposite LAI image of ASTER VNIR showing LAI values for 04 September as blue, 03 August as green and 31 May as red respectively.

## CONCLUSION

Our results showed that ASTER VNIR Band 1 and Band 3 can play an important role in monitoring paddy phenology. It also suggests that standard AOI layer for paddy work very well in extracting paddy areas in other images and makes it easy for analysis of phenological change detection. If automation of paddy LAI is done using this AOI layer, the task of biomass monitoring of paddy in Takayama will become more effective and easier. Following the same procedure other landcover/landuse class AOI can also be developed and used in the model of automated monitoring prefaces.

The study results are limited to a small no of ground truth measurements which can be verified by adding more data collected from Takayama paddy fields and high resolution images can be used for terrace paddy estimation. Cultivar variation is another limitation that has not been taken into account in this research results. Further research for verification and automation need to be carried out.

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