Study on extracting large paddy areas for the low spatial resolution satellite data

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1. Introduction

Rice is a staple food for half of the world's population. Rice production revenue has been a main income of many countries on the world. In agriculture, monitoring of rice plant characteristics and paddy land information through rice plant development stages is very valuable in agricultural management, planning and decision making to ensure the long-term sustainability of agriculture.

Nowadays, remote sensing has played a significant role in studying agriculture. One of the applications of remote sensing is to identify paddy rice fields and to extract paddy land information. To properly use satellite Earth observation for large paddy areas monitoring, high temporal revisit frequency over vast geographic areas is necessary. However, this often limits the spatial resolution. Therefore, finding the method to extract large paddy areas using low spatial resolution satellite data is very useful in present.

2. Research purpose

In order to monitor rice plant characteristics and paddy land information, it is necessary to extract paddy area and use the high temporal resolution satellite data. In Japan, since average size of paddy field is 30 meter by 100 meter, it is difficult to extract paddy area using the high temporal resolution but low spatial resolution satellite data such as MODIS data (250 meter spatial resolution). Because of this reason, we proposed extract large paddy area throughout the spatial purity. Spatial purity is the ratio of the number of Landsat paddy pixels in one MODIS pixel.

$$\textbf{Spatial purity} = \frac{\mathbf{N_{Landsat}}}{\mathbf{N_{MODIS}}} \times \mathbf{100} \quad (1)$$

$N_{Landsat}$: the number of Landsat paddy pixels in one MODIS pixel;

N_{MODIS}: the size of one MODIS pixel.

This research's objective is evaluating the ability of extracting large paddy areas through the use of spatial purity for the low spatial resolution satellite data.

3. Target region and study data

This research collected Landsat 8 OLI images on May 25th and July 12th 2015 to extract paddy area and calculate spatial purity. In this research, we used two bands of Landsat 8 OLI: red band (0.64 - 0.67 μm) and NIR band (0.85 - 0.88 μm) with 30-meter spatial resolution. Furthermore, MODIS Terra/Aqua Surface Reflectance Daily L2G Global 250m (MOD09GQ) was collected on May 25th and July 12th 2015 with two bands: red band (0.620 - 0.670 μm) and NIR band (0.841 - 0.876 μm).

The target regions are all paddy fields of Niigata prefecture (except for Murakami city and Awashimaura village).

4. Research methodology

Figure 1 shows the process of this research. Paddy field is a region that its surface condition changes dramatically by each growing period of rice plant. In transplanting period, rice plants are very small and paddy fields are covered by water. Therefore, NIR reflectance at that time is very low. In growing period, rice plants cover paddy fields. NIR reflectance in present is higher than NIR reflectance and red reflectance is less than red reflectance in transplanting period. Based on these characteristics, we proposed the rice-cropping index (RCI) to extract vegetation pixels by equation (2):

$$\mathbf{RCI} = \frac{\mathbf{NIR2-R2-NIR1}}{\mathbf{NIR2+R2+NIR1}} \quad (2)$$

NIR1: near infrared reflectance at transplanting period.

NIR2 and R2: near infrared reflectance and red reflectance at growing period respectively;

Based on field observation data, we chose the threshold for extracting vegetation pixels is greater than 0.0.

Paddy area is also flat plain region. The flat plain region is the region that its slope is less than 5 degree.

In order to extract flat plain pixel, we used the digital elevation model (DEM) 50m mesh data. The region where is both vegetation region and flat plain region is paddy region.

After that, spatial purity is determined. Based on spatial purity, we extracted large paddy areas for MODIS data. Finally, we evaluated the ability of extracting large paddy areas for MODIS data using spatial purity map.

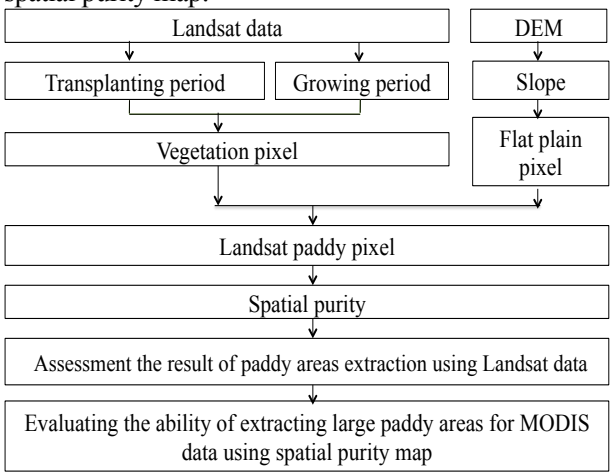

Figure 1. Research Flowchart

5. Research result

5.1 Spatial purity map

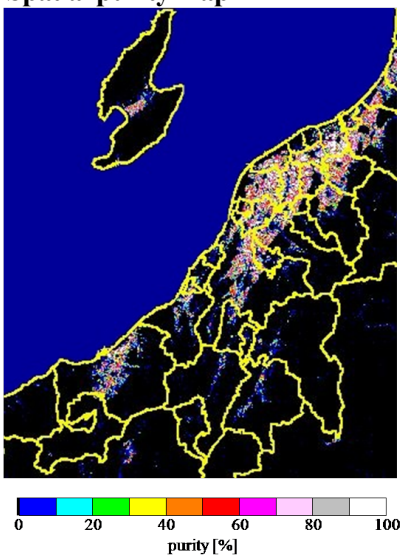

Figure 2. Spatial purity map

The spatial purity map (figure 2) shows the number of Landsat paddy pixels in MODIS pixels. The result shows that the number of pixels that has purity greater than 0 and less than or equal to 10 is biggest that accounts for 30% pixels of total. The number of pixels tends to decrease with the increase of purity value. For example: If we choose the threshold of spatial purity is greater than 50%, we can extract 37.2% pixels of total; If we choose the threshold of spatial purity is greater than 60%, 70% or 80%, we can extract 30%, 23% or 15.6% pixels of total, respectively.

5.2 Assessment the result of paddy areas extraction using Landsat 8 OLI data

In order to assess the result of extracting paddy areas from Landsat 8 OLI data, we compared Landsat paddy area with paddy area from statistical data of 2014.

Based on the different area percentage between Landsat paddy area and statistical paddy area, we divided the cities in to 6 groups as follows:

- Group 1 (different area percentage around within ±10%) includes Niigata city, Tsubame city, Agano city, Yahiko city, Tagami city and Seiro city.

- Group 2 (different area percentage from -11% to -20%) includes Mitsuke city, Sanjo city and Kamo city.

- Group 3 (different area percentage from -21% to -30%) includes Shibata city, Nagaoka city, Kariwa city and Gosen city.

- Group 4 (different area percentage from -31% to -40%) includes Tainai city.

- Group 5 (different area percentage from -41% to -50%) includes Joetsu city and Kashiwazaki city.

- Group 6 (different area percentage greater than -50%) includes remaining cities of target region.

Note that negative value of different area percentage means Landsat paddy area is smaller than statistical paddy area. This result shows that since the moderate spatial resolution, Landsat cannot extract all paddy areas, especially mountainous paddy areas.

5.3 Extracting large paddy areas for MODIS data

To extract MODIS large paddy areas, the important thing is finding the suitable threshold of spatial purity. From the result of section 5.2, we think that the extraction result will be change when we choose different spatial purity thresholds for

different regions. Therefore, we conducted to extract large paddy areas for the entire target region and for each city of target region. For choosing threshold of spatial purity, we based on two criteria:

- Extracted MODIS paddy area is similar with statistical paddy area.

- Spectral reflectance (mean DVI value) of MODIS paddy area is similar with Landsat paddy area. According to the liner mixture model, the reflectance of the mixed pixel is written by equation (3):

$$\mathbf{R_m = A_1 \times R_1 + A_2 \times R_2} \quad (3)$$

R_m: mean DVI value of the simulated MODIS pixel (include Landsat paddy and non paddy area).

R_1, R_2: mean DVI value of Landsat paddy area and non-paddy area.

A_1, A_2: abundance of paddy and non-paddy area.

If mean DVI value of MODIS paddy region and mixed region in the same spatial purity is similar, the result of research is good. Then, we will choose this spatial purity if the spectral reflectance of extracted paddy area is same as spectral reflectance of Landsat paddy area.

5.3.1 Extracting large paddy areas for the entire target region

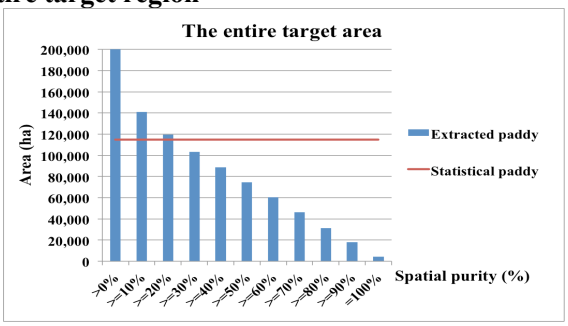

Figure 3. Comparison between statistical paddy area and extracted paddy area of the entire target region

Figure 3 shows the comparison between statistical paddy area and MODIS paddy areas of the entire target region. Based on this result, if the spatial purity is greater than 20% or 30% for the whole target area, the area of MODIS paddy region (extracted paddy area) is same as statistical paddy area. The next better threshold is 40% or 50%. From purity greater than 60%, there is a strong difference between MODIS paddy area and statistical paddy area.

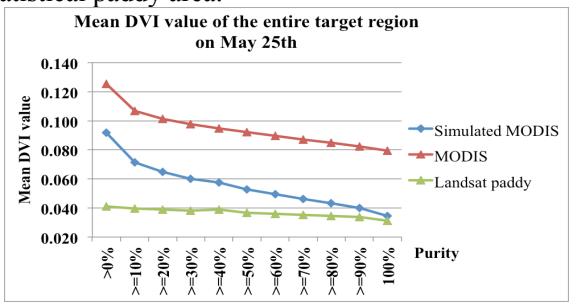

Figure 4. Mean DVI value of the entire target region on May 25th

Next, we examined mean DVI value of MODIS paddy area on May 25th (figure 4) and July 12th (figure 5). From figure 4, we found that mean DVI value is quite different between MODIS and simulated MODIS in the same spatial purity. To identify the reason, we examined MODIS May 25th image and found that its quality is not good. We continued to examine MODIS May 26th image and its quality is quite good. Then, we determined DVI and NDVI value of MODIS May 26th with spatial purity 100%, OLI data and mixed pixel. The result (table 1) shows that compared with MODIS May 25th, mean DVI value and mean NDVI value of MODIS May 26th is similar with OLI paddy region and mixed region. Then, the reason why there is the difference between mean DVI of simulated MODIS area and MODIS paddy area on 25th May is the low quality of MODIS 25th May.

Table 1. Comparison the mean value of DVI, NDVI of MODIS and Landsat data

Date	Landsat paddy	MODIS simulated area	MODIS paddy (Purity 100%)
May 25th	DVI = 0.034 NDVI = 0.157 Red = 0.091 NIR = 0.125	DVI = 0.034 NDVI = 0.156 Red = 0.092 NIR = 0.126	DVI = 0.065 NDVI = 0.432 Red = 0.043 NIR = 0.108
May 26th			DVI = 0.036 NDVI = 0.162 Red = 0.093 NIR = 0.129

The next step is checking mean DVI value on July 12th. Figure 5 shows that there is a match between mean DVI value of MODIS and Landsat paddy area in same purity region, especially in case of purity >=50%. From above result, we chose the threshold of spatial purity to extract large paddy areas of the entire target data is greater than or equal to 50% (figure 6).

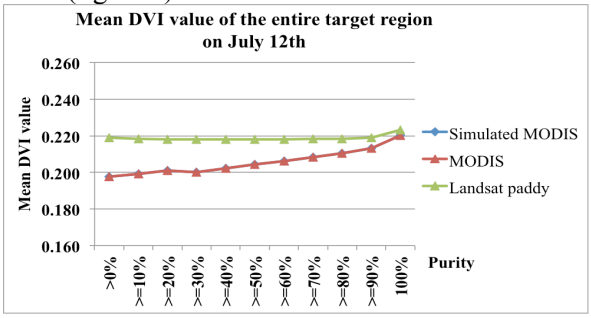

Figure 5. Mean DVI value of the entire target region on July 12th

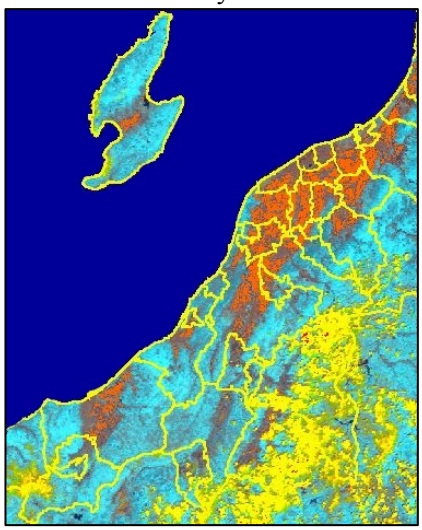

Figure 6. Large paddy areas (orange regions) of the entire target region

5.3.2 Extracting large paddy areas for the some cities in target region

In order to improve the accuracy of this research, we would like to extract large paddy areas for each seperate city. Due to limited time, we chose to conduct this step for two cities in target region. They are Niigata city (different area pecentage is around 10%) and Joetsu city (different area percentage is around 50%). The result shows that the suitable threshold for Niigata city is 60% and Joetsu city is 20%.

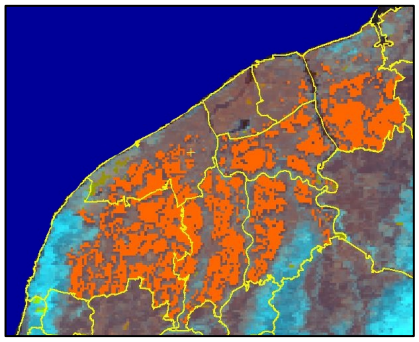

Figure 7. Large paddy areas (orange regions) of Niigata city

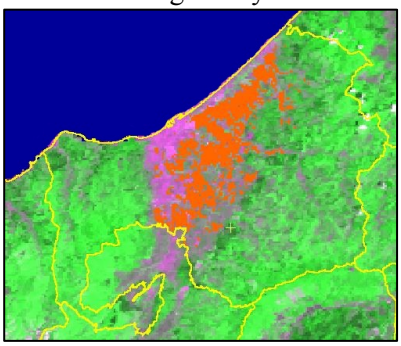

Figure 8. Large paddy areas (orange regions) of Joetsu city

6. Conclusion

This research demonstrates that spatial purity is effective for extracting large paddy areas for the low spatial resolution satellite data such as MODIS data.

The result presents that this research can extract 65% paddy areas of the entire target region. However, if we choose seperate threshold of spatial purity, the accuracy is higher. For example, in case of Niigata city, we can extract 98% paddy areas compared with statistical data with the threshold is 60%. In case of Joetsu city, with threshold 20%, we can extract 89% paddy areas compared with statistical data.

However, for monitoring the information of paddy land, it does not need to exploit the entire paddy areas exactly like statistics. Therefore, in next step, this research result can be use for monitoring paddy land information.

This research result may be improved if we select spatial purity for each separate city in target region and consider the use of other kind of DEM for extracting flat plain region.