Identification of rice field using Multi-Temporal NDVI and PCA method on Landsat 8 (Case Study: Demak, Central Java)

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Abstract. Paddy is one of the most important agricultural crop in Indonesia. Indonesia’s consumption of rice per capita in 2013 amounted to 78.82 kg/capita/year. In 2017, the Indonesian government has the mission of realizing Indonesia became self-sufficient in food. Therefore, the Indonesian government should be able to seek the stability of the fulfillment of basic needs for food, such as rice field mapping. The accurate mapping for rice field can use a quick and easy method such as Remote Sensing. In this study, multi-temporal Landsat 8 are used for identification of rice field based on Rice Planting Time. It was combined with other method for extract information from the imagery. The methods which was used Normalized Difference Vegetation Index (NDVI), Principal Component Analysis (PCA) and band combination. Image classification is processed by using nine classes, those are water, settlements, mangrove, gardens, fields, rice fields 1st, rice fields 2nd, rice fields 3rd and rice fields 4th. The results showed the rice fields area obtained from the PCA method was 50,009 ha, combination bands was 51,016 ha and NDVI method was 45,893 ha. The accuracy level was obtained PCA method (84.848%), band combination (81.818%), and NDVI method (75.758%).

1. Introduction
Rice is one of the main crops in Indonesia because most Indonesian people consume rice as a staple food. Based on data from the BPS national socio-economic survey, Indonesia’s population of rice consumption reached 78.82 kg per capita per year [1]. It is assessed by the Ministry of Agriculture is fairly high consumption. In fact, more than world rice consumption is only 60 kg per capita per year. In Asia, Indonesia’s rice consumption is the highest. The high number of national rice consumption because the grains are separated part of the food culture of Indonesia [2].
Indonesian government wants to realize Indonesia became self-sufficient in 2017. The Indonesian government therefore should be able to seek the stability of the fulfillment of basic needs for food. The first step that must be done is to map the rice fields. Map of rice lands can provide comprehensive information on the development of paddy fields. The development of paddy land area can be used as an estimate of rice production.

Many studies have proved that images such as Landsat and NOAA Advanced Very High Resolution Radiometer (AVHRR) has potential to identify paddy rice fields [3]. After the launch of Landsat 8 satellite image, many researchers are trying to explore its use for identification of land cover. Landsat 8 had the privilege of both the specification and efficiency. It is launched in 2013 and...
has a spatial resolution of 30 meters, without the cost and easy to obtain [4]. The temporal resolution of the Landsat 8 is every 16 days, so it can be possible to perform analysis in time series objects such as identification of rice field which has 4 major phases in its development phase, i.e. water, vegetative, generative and fallow [4]. The identification of rice lands using satellite images often have difficulty. This is because the rice land have the same colour and texture by fields, moor or weeds. In this study used multi-temporal satellite images Landsat 8. Multi-temporal methods have been tried are used for identification of rice fields cover effectively on a satellite image of Modis by zhang et all [5]. This method is used by assuming that the multi time to change the hue of rice land more quickly and significantly than other land. Multi temporal or time series data h identification of multi-temporal rice can be combined with several classification methods such as Normalized Difference Vegetation Index (NDVI), Principal Component Analysis (PCA) and band combination. The objective of this research are testing the best multi-temporal combination with that some method on Landsat 8. Based on the above explanation, the study was done by identifying the rice fields as an object of research, several methods are compared, i.e. the method of Normalized Difference Vegetation Index (NDVI), Principal Component Analysis (PCA) and band combination. Using multi-temporal Landsat 8 based on Rice Planting Time 1st in Demak that range between the end of October 2013 to early March 2014.

2. Methodology

2.1. Description of Study Area
The study was conducted in Demak of the Province of Central Java, Indonesia. Centred at latitude 6° 43' 26" - 7° 09' 43" and longitude 110° 27' 58" - 110° 48' 47" and is located approximately 25 km east of Semarang City (figure 1). The longest distance from West to East is along 49 km and from North to South along the 41 km [2].

![Figure 1. Location of study area](image)

2.2. Method
Method this study was followed the flowchart in figure 2. In this study is using 4 images multi-temporal with reference to Rice Planting Time 1st in Demak 2013/2014, i.e. the image on October 30, December 1, 2013, January 2 and March 7, 2014.

2.2.1 Geometric correction
Geometric correction geo-referenced image to real world coordinates. The geometric correction method of the image used image to map rectification with reference Indonesian Topographical map (RBI) of Demak, scale 1:25,000. GCP on this research taken as many as 16 points of each image. Root mean square error (RMSE) in this process were required maximum 1 pixel.
2.2.2 Radiometric correction
This stage corrected image using the conversion of digital number to Top of Atmosphere (TOA) Reflectance. OLI band data of Landsat 8 can be converted to TOA planetary reflectance using reflectance rescaling coefficients provided in the product metadata file (MTL file). MTL is the format of metadata file for Landsat 8 imagery. The following equation is used to convert digital number (DN) or pixel values to TOA reflectance for operational land imager (OLI) data as follows [4]:

\[
\rho_{\lambda}' = M\rho_{\text{cal}} + A\rho
\]

TOA reflectance with a correction for the sun angle is then [6]:

\[
\rho_{\lambda} = \frac{\rho_{\lambda}'}{\cos(\theta_{SZ})} = \frac{\rho_{\lambda}'}{\sin(\theta_{SE})}
\]

where:
\[
\rho_{\lambda}' = \text{TOA planetary reflectance, without correction for solar angle. Note that } \rho_{\lambda}' \text{ does not contain a correction for the sun angle}
\]
\[
M_{\rho} = \text{Band-specific multiplicative rescaling factor from the metadata (REFLECTANCE_MULT_BAND_x, where } x \text{ is the band number)}
\]
\[
A_{\rho} = \text{Band-specific additive rescaling factor from the metadata (REFLECTANCE_ADD_BAND_x, where } x \text{ is the band number)}
\]
\[
Q_{\text{cal}} = \text{Quantized and calibrated standard product pixel values (DN)}
\]
\[
\rho_{\lambda} = \text{TOA planetary reflectance}
\]
\[
\theta_{SE} = \text{Local sun elevation angle. The scene center sun elevation angle in degrees is provided in the metadata (SUN_ELEVATION)}
\]
\[
\theta_{SZ} = \text{Local solar zenith angle; } \theta_{SZ} = 90^\circ - \theta_{SE}
\]

2.2.3 Highlight cloud
Clouds and shadows in the image is a problem that can’t be avoided. This is an obstacle in the use of medium resolution imagery such as Landsat 8, especially in equatorial regions. This causes the loss of some of the information contained in the images. Highlight Cloud is used to discriminate or distinguish clouds with land cover [6]. Because of the clouds in the application or interpretation of land use is considered as interference to other land cover reflectance values, so that should be eliminated in the analysis. In this study, the clouds separated by digitization after sharpening cloud value.

2.2.4 Image Cropping
Cropping images do reduce the file size of the image so that the processing of data to be lighter and faster. It are made in accordance with the required area or region of interest (ROI). Moreover, in this study uses data multi-temporal for classification process, so cropping of the image is needed in order to accelerate the image processing.

2.2.5 Transformation method
In this research, transformation method by using Normalized Difference Vegetation Index (NDVI), Principal Component Analysis (PCA) and band combination (7-6-4) were used in each image. The results of image transformation at several different times are combined for a single image, it is intended to create new combinations of image so that the pattern of changes in the value of this index is used to identify rice fields and other land. This index pattern is used as a reference in the classification process. There are four image results from the transformation of the NDVI, namely on NDVI October 30, 2013; NDVI December 1, 2013; NDVI January 2 and NDVI March 7, 2014 are combined in a single layer (the layer stack). At PCA method, there were 7 PCs results from the transformation of the PCA combined 28 band (where prior to transformation, 7 band each image are
combined to produce a 28-band). While in band combination (7-6-4) there were 12 image from the combined results of band combination 7-6-4 each image.

2.2.6 Supervised Classification
Classification is performed using the supervised classification method, with type maximum likelihood. Class classification is namely water, settlements, mangrove, gardens, fields, rice fields 1st, rice fields 2nd, rice fields 3rd and rice fields 4th. The taking of ground data is done by field survey. It was used to knowing the field rice in actual area. That can be used to identification the spectral pattern on image combined.

2.2.7 Analysis of the cloud-covered area of rice fields
Analysis of the cloud-covered area of rice fields to find out the information that is lost due to clouds and shadows. It was assisted by using land use map of the Land Office of Demak 2014 that updated using Google image. The results processing digitation using Google Image 2013 as well as field survey to check the suitability of the map. Based on the result of processing, the rice fields covered area acquired cloud 6.307 ha.

2.2.8 Test the Accuracy
The classification accuracy were tested by conducting field survey (33 points), and compare the results with rice fields area is available from the Department of Agriculture in 2014[7].

![Flowchart of the research](image)

3. Result and Discussion
Identification of rice field in the image get four type of rice field. This type is based on the growth stage of paddy in the field that is different phase. Determination of the pattern of vegetation index for rice fields utilize the result of a combination of NDVI in different time. Fifty of ground data with field surveys were taken to get the pattern of rice field in four types. Fifty field data was distributed by 18 in the first type of rice field, 15 in the second type of rice field, 12 in the third type of rice field and 5 in
fourth type of rice field. The value of NDVI at the four types of wetland in detail shown in table 1, table 2, table 3 and table 4.

Table 1. Vegetation index for rice fields 1st

| Month               | Min.    | Max.    | Average  |
|---------------------|---------|---------|----------|
| October 30, 2013    | -0.041361 | 0.208411 | 0.110164 |
| December 1, 2013    | 0.409407   | 0.744219 | 0.595514 |
| January 2, 2014     | 0.587388   | 0.806071 | 0.735100 |
| March 7, 2014       | -0.229917  | 0.280647 | 0.075846 |

Table 2. Vegetation index for rice fields 2nd

| Month               | Min.    | Max.    | Average  |
|---------------------|---------|---------|----------|
| October 30, 2013    | 0.129808  | 0.227061 | 0.173888 |
| December 1, 2013    | 0.209410  | 0.429601 | 0.295438 |
| January 2, 2014     | 0.501472  | 0.807062 | 0.684695 |
| March 7, 2014       | 0.038147  | 0.501958 | 0.231346 |

Table 3. Vegetation index for rice fields 3rd

| Month               | Min.    | Max.    | Average  |
|---------------------|---------|---------|----------|
| October 30, 2013    | 0.218776  | 0.645476 | 0.393743 |
| December 1, 2013    | 0.095961  | 0.304005 | 0.185014 |
| January 2, 2014     | 0.415126  | 0.805949 | 0.671330 |
| March 7, 2014       | 0.235618  | 0.495557 | 0.358231 |

Table 4. Vegetation index for rice fields 4th

| Month               | Min.    | Max.    | Average  |
|---------------------|---------|---------|----------|
| October 30, 2013    | 0.463593  | 0.723882 | 0.565158 |
| December 1, 2013    | 0.271310  | 0.442523 | 0.340143 |
| January 2, 2014     | -0.124463| 0.292501 | 0.157182 |
| March 7, 2014       | 0.286817  | 0.639328 | 0.514898 |

The value of NDVI multi temporal indicates the condition of a growth phase at the time of image acquisition. The four table based on four types NDVI values seen that the four types of wetland have different patterns of NDVI, for example in the first field rice’s NDVI approach zero at October 2013. It shown that growth stage of paddy were first phase because dominated with water. The value of NDVI increase at December 2013 and at January 2014, it showed that growth stage of rice were also increase. At March 2014, the value of NDVI were null, it show that growth stage of rice in bera phase. Bera is the phase where the fields are not planted after the harvest.

Generate 4 patterns of vegetation index for rice fields in the four type of rice field shown in the figure 3, figure 4, figure 5 and figure 6.
The four patterns were used to identify rice fields using supervised classification. PCA multi-temporal classification and band combination classification also used the same process in NDVI multi-temporal. The results of supervised classification can be seen in figure 7, figure 8, and figure 9.

**Figure 3.** Vegetation Index for rice fields 1st

**Figure 4.** Vegetation Index for rice fields 2nd

**Figure 5.** Vegetation index for rice fields 3rd

**Figure 6.** Vegetation index for ricefields 4rd

PCA multi-temporal classification has producer accuracy of 86.67%, user accuracy of 86.67% and Overall accuracy of 84.85%. Then NDVI multi-temporal classification has producer accuracy of 80%, user accuracy of 92.31% and Overall accuracy of 75.76%. The band combination 7-6-4 classification has producer accuracy of 86.67%, user accuracy of 81.25% and Overall accuracy of 81.82%. For more details, see table 5, table 6, and table 7. While the area of rice fields classification was compared to the methods of approaching data from the Department of Agriculture of 49.657 Ha [4], PCA
classification has difference of 328 ha (0.71%), band combination 7-6-4 of has difference of 1,359 ha (2.73%) and lastly NDVI of 45,893 ha with a difference of -3,764 ha (7.58%).

Table 5. Matrix acuration of multi-temporal PCA 7 band

| Land use   | Water | Settlement | Plantation | Moor | Mangrove | Rice Field | Total | UA (%) | CE (%) |
|------------|-------|------------|------------|------|----------|------------|-------|--------|--------|
| Water      | 4     | 0          | 0          | 0    | 0        | 0          | 4     | 100.00 | 0.00   |
| Settlement | 0     | 4          | 0          | 0    | 0        | 0          | 4     | 100.00 | 0.00   |
| Plantation | 0     | 0          | 3          | 0    | 1        | 0          | 4     | 75.00  | 25.00  |
| Moor       | 0     | 0          | 0          | 3    | 0        | 2          | 5     | 60.00  | 40.00  |
| Mangrove   | 0     | 0          | 0          | 0    | 1        | 0          | 1     | 100.00 | 0.00   |
| Rice Field | 0     | 0          | 1          | 0    | 1        | 0          | 15    | 86.67  | 13.33  |
| Total      | 4     | 4          | 4          | 4    | 2        | 4          | 15    | 100.00 | 0.00   |
| PA (%)     | 100.00| 100.00     | 75.00      | 75.00| 50.00    | 50.00      | 50.00 | 86.67  | 13.33  |
| OE (%)     | 0.00  | 0.00       | 25.00      | 25.00| 50.00    | 50.00      | 50.00 | 20.00  | 80.00  |
| Overall    | 84.848|            |            |      |          |            |       |        |        |
| Kappa Coefficient | 0.792 |            |            |      |          |            |       |        |        |

Table 6. Matrix acuration of multi-temporal NDVI

| Land use   | Water | Settlement | Plantation | Moor | Mangrove | Rice Field | Total | UA (%) | CE (%) |
|------------|-------|------------|------------|------|----------|------------|-------|--------|--------|
| Water      | 4     | 0          | 0          | 0    | 1        | 0          | 5     | 80.00  | 20.00  |
| Settlement | 0     | 3          | 0          | 0    | 0        | 0          | 3     | 100.00 | 0.00   |
| Plantation | 0     | 0          | 2          | 0    | 0        | 0          | 2     | 100.00 | 0.00   |
| Moor       | 0     | 1          | 1          | 3    | 0        | 3          | 8     | 37.50  | 62.50  |
| Mangrove   | 0     | 0          | 1          | 0    | 1        | 0          | 2     | 50.00  | 50.00  |
| Rice Field | 0     | 0          | 0          | 0    | 1        | 0          | 12    | 92.31  | 7.69   |
| Total      | 4     | 4          | 4          | 4    | 2        | 4          | 15    | 100.00 | 0.00   |
| PA (%)     | 100.00| 75.00      | 50.00      | 75.00| 50.00    | 50.00      | 50.00 | 80.00  | 20.00  |
| OE (%)     | 0.00  | 25.00      | 50.00      | 25.00| 50.00    | 50.00      | 50.00 | 20.00  | 80.00  |
| Overall    | 75.758|            |            |      |          |            |       |        |        |
| Kappa Coefficient | 0.677 |            |            |      |          |            |       |        |        |

Table 7. Matrix acuration of multi-temporal band combination 7-6-4

| Land use   | Water | Settlement | Plantation | Moor | Mangrove | Rice Field | Total | UA (%) | CE (%) |
|------------|-------|------------|------------|------|----------|------------|-------|--------|--------|
| Water      | 4     | 0          | 0          | 0    | 0        | 1          | 5     | 80.00  | 20.00  |
| Settlement | 0     | 4          | 0          | 0    | 0        | 0          | 4     | 100.00 | 0.00   |
| Plantation | 0     | 0          | 4          | 0    | 1        | 0          | 5     | 80.00  | 20.00  |
| Moor       | 0     | 0          | 0          | 1    | 0        | 1          | 2     | 50.00  | 50.00  |
| Mangrove   | 0     | 0          | 0          | 0    | 1        | 0          | 1     | 100.00 | 0.00   |
| Rice Field | 0     | 0          | 3          | 0    | 14       | 0          | 15    | 81.25  | 18.75  |
| Total      | 4     | 4          | 4          | 4    | 2        | 15         | 33    |        |        |
| PA (%)     | 100.00| 100.00     | 100.00     | 25.00| 50.00    | 86.67      | 18.75 |        |        |
| OE (%)     | 0.00  | 0.00       | 0.00       | 75.00| 50.00    | 13.33      |       |        |        |
| Overall    | 81.818|            |            |      |          |            |       |        |        |
| Kappa Coefficient | 0.747 |            |            |      |          |            |       |        |        |
4. Conclusion
In this study can be concluded that PCA 7 band multi-temporal classification has better accuracy for all land use type. Over all accuracy of PCA 7 band up to 84, 85 \%. This qualifies a classification accuracy of 80 \%. However when viewed from the user accuracy of rice field, NDVI multi-temporal has better accuracy. The user accuracy of NDVI multi-temporal for rice field up to 92,31 \%.

5. References
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