Analysis of the dynamics pattern of paddy field utilization using MODIS image in East Java

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Abstract

Paddy field conversion that occurs continuously in East Java will have an impact on the production of paddy fields. Mapping the dynamics pattern of paddy field utilization is needed to support the sustainable usage of paddy field. This study conducted to explain the dynamics pattern of paddy field utilization using MODIS image MOD13Q1 h2v9 with EVI composite 16-day resolution of 250 meters data. Analysis of the temporal pattern of the year 2000-2014 conducted by the method of autocorrelation function of each centroid classification results k-mean clustering that produces changes in the cropping pattern at the province of East Java. Ground check performed as a validation of the field to determine cropping patterns and land use changes that occurred. Identification of the cropping pattern produces nine types of cropping pattern of paddy fields in East Java, there are five main cropping patterns paddy-paddy-secondary crop, paddy-paddy-bare land, paddy-secondary crop-secondary crop, paddy-secondary crop-bare land, and sugarcane then four other pattern are mixing crop, and 57.70% identification accuracy results.

Keywords: dynamic pattern; paddy field; MODIS

1. Introduction

Information of cropping pattern or phenology are essential for evaluating crop productivity and crop management [1]. Utilization of remote sensing data for a variety of research with MODIS satellite imagery has been widely performed, [2] utilizing MODIS image MOD09A18-day for mapping paddy field. In this research also use MODIS data to identify agriculture land especially paddy field [3]. Cropping pattern formed by MODIS imagery has the

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noise. Galford et al. [4] using wavelet transforms to create a wavelet-smoothed time series from cropping pattern and to reduce or filtering the noise. In addition, to using wavelet transform to filtering, the Fourier transform method may be used. However, the wavelet transform is better used [1]. Temporal pattern analysis of wavelet-filtered MODIS EVI was used to detect land use change in java island, Indonesia [5].

Adequacy of food needs can be done by ensuring the availability of agricultural land. The total population of East Java as 37,476,757 people [6], and economic development in East Java is generally followed by a land conversion from agriculture to the non-agriculture. If these changes occur in high frequency and amount, food security will be threatened. Therefore it is necessary to predict the cropping pattern in agricultural land, especially paddy in relation to cropping intensity.

According to data of village potential in 2006 [7], there are significant transitions of land use conversion of paddy field from 2003-2006. Paddy field land use was decreased and converted into 5,665 ha (31.86%) of non-paddy land use, 8,567 ha (48.16%) of residents, 1,204 ha (6.77%) of industrial building, 693 ha (3.90%) of land for office or corporation building, and 1,651 ha (9.29%) for other purpose. This transition of land use will affect the rice production in East Java [7]. The influence of El Niño and La Niña showed that El Niño did not affect agricultural production in Nganjuk, while La Niña gave some effect [8].

This study was conducted to determine the type of cropping pattern in East Java by using k-mean algorithm in MATLAB software. The Autocorrelation method detected correlation between class and another class, and also to analysis the dynamic pattern of paddy field. This method was used to help determine the intensity of land use of agricultural land, especially paddy field cultivation.

2. Methods

2.1. Study area

East Java Province geographically located between 111°0’ – 114°4’ Longitude and 7°12’–8°48” Latitude. East Java Province is bordered between Central Java and Bali. It has an area of 47,963 km² which consist of two main parts, East Java and Madura Island [6]. The regency is administratively divided into 29 Regencies and 9 Cities.

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

2.2. Method of analysis

- Collecting data and pre-processing MODIS image

At this stage, the data were collected in the form of image MODIS data. Administration map of East Java Province was obtained from the Geospatial Information Agency (BIG). Land use of East Java obtained from
government of agricultural sub-section land databases. Distribution of paddy field area of East Java obtained from Statistics Indonesia (BPS).

The MODIS product used in this study is MOD13Q1. It comprises the Vegetation Indices (VI) Composite 16-day 250 m, which provided the seasonal for the paddy field patterns. This dataset had been systematically corrected for the effects caused by gas and aerosol scattering. The EVI minimizes atmospheric influences with the aerosol resistance term which use the blue band to correct aerosols influence in red band [9]. The MODIS developed the EVI for use with MODIS data using [9] this equation 1:

\[
EVI = G \frac{\rho_{NIR} - \rho_{red}}{\rho_{NIR} + C_1 \times \rho_{red} - C_2 \times \rho_{blue} + L}
\]

Where, \(\rho_{nir}\), \(\rho_{red}\) and \(\rho_{blue}\) are the remote sensing reflectance in the NIR, red, and blue, respectively. \(L\) is a soil adjustment factor, and \(C1\) and \(C2\) describe the use of the blue band in correction of the red band for atmospheric aerosol scattering. The coefficients, \(C1\), \(C2\), and \(L\), are empirically determined as 6.0, 7.5, and 1.0, respectively. \(G\) is a gain factor set to 2.5.

Data was collected from his source must be processed. Goal from this stage is to improve the quality of image and to produce an intermediate data set which will be used in further processing. The MODIS EVI data products are still affected by bidirectional reflectance distribution factors or other residual noise; hence, we require a technique to reduce the impacts of noise on temporal data analysis.

Wavelet transform used to reduce and filtering noise. In order to analyze the fluctuation of the EVI value of each land use type, used the coiflet1 level 1 and approximate 1 because this wavelet shape is as the lowest to reduce and filtering noise. That method also didn’t change the original information from EVI value. This analysis was performed using MATLAB. The MODIS EVI data pre-processing was conducted to provide a filtered data set to support multi-temporal.

- Clustering and recognizing cropping pattern of paddy field

Classification was obtained from statistical methods, namely the k-mean clustering. This method working to distribute K data to many clusters. Every population on cluster definite from nearness any pattern (mean point). In this stage analysis using software MATLAB. Selection of the number classes (K) in the k-mean clustering algorithm based on consideration of the results of the workshop which has been conducted by Center for Food Crops Research and Development [5], they divide the types of cropping into six types based on the nature of the soil and climate. Each type has several patterns and the total of all the patterns of twenty cropping, so it can be certainly that the determination of twenty-one class in the process of analysis using the k-mean clustering is considered to represent all the existing cropping pattern.

Time-series from EVI value define the cropping pattern, [10] in java island there are eight type cropping intensities, paddy triple cropping, paddy double cropping, paddy double cropping in western java, paddy double cropping in central java, paddy triple cropping, paddy triple cropping in eastern java, paddy single cropping, and paddy single cropping in upland.

- Analysis dynamic pattern of paddy field

A set of correlation coefficients will indicate whether the temporal pattern of the data has a periodical pattern or not, and is represented by the autocorrelation coefficient (AFC). The correlation coefficient between \(x\) and \(y\) statistically is given following the function below:

\[
r = \frac{\sum(x_i - \bar{x})(y_i - \bar{y})}{(\sum(x_i - \bar{x})^2)^{1/2}(\sum(y_i - \bar{y})^2)^{1/2}}
\]

The correlation between \(x_i\) and \(x_{i+1}\) are given by:
\[
    r_1 = \frac{\sum_{t=1}^{N-1} (x_t - \bar{x}_1)(x_{t+1} - \bar{x}_2)}{\left(\sum_{t=1}^{N-1} (x_t - \bar{x}_1)^2\right)^{1/2}\left(\sum_{t=1}^{N-1} (x_t - \bar{x}_2)^2\right)^{1/2}}
\]

where \(\bar{x}_1\) is the mean of the first \(N-1\) data and \(\bar{x}_2\) is the mean of the last \(N-1\) data.

As given by Equation (3), measurement of the correlation between successive data is then called the autocorrelation. For reasonably large \(N\), as used in time series EVI data in this study, the difference between the sub-period means \(\bar{x}_1\) and \(\bar{x}_2\) can be ignored and \(r_1\) can be approximated by:

\[
    r_k = \frac{\sum_{t=1}^{N-k} (x_t - \bar{x})(x_{t+k} - \bar{x})}{\sum_{t=1}^{N} (x_t - \bar{x})^2}
\]

where \(\sum_{t=1}^{N-k} x_t\) is the overall mean.

The quantity \(r_k\) is called the autocorrelation coefficient at lag \(k\).

3. Result and discussion

3.1. Pre-processing MODIS image

Stage of pre-processing the image has several stages, including EVI is to extract value, then combining (stacking) image, cut image of East Java Province, and reduce interference (noise reduction). At this stage of noise reduction using wavelet method with the lowest level is level 1, the approximate1, and coif1. The higher the level of the selected value will be the greater value is reduced. Fig. 9 is the result of a pattern that uses wavelet level 1 and the original patterns.

3.2. Analysis Province East Java MODIS image from 2000-2014

The number of existing cropping pattern of paddy field in East Java province can be seen in Table 1. Determination the number of classes using k-mean clustering algorithm, which in this study using 21 classes. Fig. 2. is a grouping pattern based on the proximity between visual patterns.

The cropping pattern obtained from the analysis of five main cropping patterns were identified and four other mix pattern. It can be seen in Fig. 2 that the cropping pattern in East Java province has diversity. In Fig. 2 (b) which describes the cropping pattern of paddy-paddy-secondary crop, there are five classes defined as the cropping pattern of paddy-paddy-secondary crops, and in part (a) there are three classes which had common cropping pattern but differentiated based algorithm k-mean clustering that is cropping paddy-paddy-bare land. All the analysis process using k-mean clustering algorithm is convergent in the group or groups of classes are concentrated.
Fig. 3. Grouping cropping pattern (a) paddy-paddy-bare land (b) paddy-paddy-secondary crop (c) paddy-secondary crop-secondary crop (d) paddy-secondary crop-bare land (e) sugarcane (f) mix and dominantly cropping paddy in first season (g) mix and dominantly annual crop (h) mix and dominantly housing (i) mix and dominantly fishpond
3.3. Cropping pattern in paddy field East Java

The process of pattern recognition of rice plants is using EVI value, as described in the methodology. The process of pattern recognition paddy field using EVI value, as described in the methodology. Table 1 shows that the average EVI value for the pattern of one year with three planting seasons and also the average age of the planting of the pattern. In addition to cropping pattern of paddy field, other plants also detected four cropping patterns that cannot be defined. There are four types of rice cropping pattern that can be recognized with this method as shown in Table 1. Similarly, other plants can be seen in Table 1, the value of EVI and age of cropping.

3.4. Analysis dynamic pattern of paddy field

The cropping pattern that has defined identity as described above. Changes in cropping patterns that occur can be seen in Table 2. Dynamics in the cropping pattern of paddy-paddy-bare land or double cropping into paddy-paddy-secondary crop or triple cropping in the third class. Dynamic pattern occurs in October 2010 until December 2013. Dynamic pattern also occurs in a pattern paddy-secondary crops-bare land into paddy-bare land. Dynamic pattern occur in November 2010 until September 2011 and then returned to the initial pattern for a year and returned again turned into paddy-bare land in August 2013.

Dynamic pattern that can be seen in Fig. 3. Dynamic pattern are given a red arrow in Fig. 3(a) is a pattern of paddy-paddy-bare land turned into paddy-paddy-secondary crops. Then in section (b) dynamic pattern of paddy-bare land-secondary crops turned into paddy-bare land and a return to the beginning pattern and then changed again into paddy-bare land.

Table 1. Peak average value EVI each cropping season and the average age.

| Cropping pattern                              | Total data (day) | Peak of EVI value |
|-----------------------------------------------|------------------|-------------------|
|                                               | Season 1 | Season 2 | Season 3 | Season 1 | Season 2 | Season 3 |
| Paddy-paddy-bare land                         | 8.09±0.604 | 6.95±0.766 | 6.56±0.707 | 0.527±0.038 | 0.536±0.031 | 0.21±0.024 |
| Paddy-paddy-secondary crop                    | 7.524±0.823 | 6.886±0.637 | 6.504±0.768 | 0.600±0.029 | 0.542±0.035 | 0.460±0.029 |
| Paddy-secondary crop-bare land                | 8.214±1.080 | 5.929±0.593 | 3.692±1.012 | 0.541±0.029 | 0.370±0.026 | 0.251±0.023 |
| Paddy-secondary crop-secondary crop           | 7.538±0.929 | 6.923±1.14  | 5.75±0.968  | 0.54±0.040  | 0.481±0.019 | 0.484±0.028 |
| Sugarcane                                     | 18.36±0.622 | –        | –        | 0.54±0.019 | –        | –        |
| Mix and dominantly cropping paddy in first season | 18.57               | –        | –        | 0.548     | –        | –        |
| Mix and dominantly annual crop                | 18.29               | –        | –        | 0.475     | –        | –        |
| Mix and dominantly fishpond                   | –        | –        | –        | 0.271     | –        | –        |
| Mix and dominantly housing                    | –        | –        | –        | 0.379     | –        | –        |

Table 2. A summary of the dynamic pattern analysis of the nine specific paddy fields

| Cropping pattern                              | Class          | Dynamics pattern          |
|-----------------------------------------------|----------------|--------------------------|
| Paddy-paddy-secondary crop                    | 12, 16, 18, 19, 14 | No dynamic (Consistent)  |
| Paddy-paddy-bare land                         | 3, 8, 9        | Dynamic on 3rd class      |
| Paddy-secondary crop-bare land                | 7, 10, 11      | Dynamic on 11th class     |
| Paddy-secondary crop-secondary crop           | 5              | No dynamic (Consistent)   |
| Mix and dominantly fishpond                   | 4              | No dynamic (Consistent)   |
| Mix and dominantly cropping paddy in first season | 1, 6, 15, 20       | No dynamic (Consistent)   |
| Mix and dominantly housing                    | 13             | No dynamic (Consistent)   |
| Sugarcane                                     | 2              | No dynamic (Consistent)   |
| Mix and dominantly annual crop                | 17, 21         | No dynamic (Consistent)   |
The dynamics of cropping patterns that occur are influenced by water availability. Changes in cropping patterns are influenced by the availability of water and rain water [1]. In that study the cropping pattern changes occur from double cropping to triple cropping when adequate water is available. [11] Supply management approach for water availability is difficult to implement for several reasons. First, it is almost impossible to obtain accurate estimates of real water demand in all locations and during all periods owing to the large number of farmers and the variation in cropping patterns. Second, because of the lack of awareness, the water taken by some farmers is used inefficiently. Some farmers take more water than they actually need. As a result, farmers downstream face water shortages during the dry season. Meanwhile, the influence of El Nino and La Nina conducted [8] showed that El Nino does not affect agricultural production in Nganjuk, while La Nina does.

Fig. 4. The dynamic cropping pattern of paddy fields (a) pattern of paddy-paddy-bare land turned into paddy-paddy-secondary crops on third class and (b) pattern of paddy-bare land-secondary crops into paddy-bare land on eleventh class

ACF results seen from Fig. 4 is an illustration of the correlation between the data itself, the upper confidence limit and lower confidence limit are a limit that is formed from ACF to visually see the correlation of the data. The pattern that is below the line can be said to be uncorrelated or it can be said there is a change in the pattern of the situation, as indicated on the red arrows in Fig. 3. So it can be said to be the pattern of the third class and eleventh class are dynamic based on ACF were seen visually.

All classes are already defined and analyzed, then analyzing distribution in East Java using ArcGIS software. Fig. 4 is a distribution of cropping patterns that exist in East Java Province twenty-one class with nine cropping pattern. The distribution of cropping pattern illustrated in Fig. 4 is processed and obtained many pixels of each distribution pattern, from that pattern with the number of pixel scan be obtained cropping pattern area of that pattern.
Fig. 5. The inter-annual autocorrelation pattern analysis of paddy field (a) pattern of paddy-paddy-bare land turned into paddy-paddy-secondary crops on third class and (b) pattern of paddy-bare land-secondary crops into paddy-bare land on eleventh class.
3.5. Accuracy cropping pattern

Approach to the calculation accuracy of the cropping pattern method using confusion matrix. Nine cropping patterns were used then evaluated by 52 reference samples. Results of calculation accuracy for nine type of cropping pattern can be seen in Table 3. The resulting overall accuracy was 57.70% for the nine classes.

Based on the results of the calculation that shown in Table 3 are the biggest error occurred on paddy-secondary crops-bare land with error 66.67%, paddy-secondary crops-secondary crops with error 40.00%, paddy-paddy-bare land with error 25.00%, and the last paddy-paddy-secondary crop with error 12.50%. Other cropping patterns have a value of its own accuracy. Low accuracy results show definability MODIS image to identify vegetation and also the value reaches 100.00% accuracy is a lack of samples in evaluating cropping patterns that exist in the field. Detection of cropping as the table above also shows short comings MODIS image.

![Fig. 6. Distribution of cropping pattern in East Java with nine cropping pattern](image)

Table 3 Confusion matrix of cropping pattern in East Java

| Cropping pattern                                    | Reference data cropping pattern | Accuracy user (%) |
|-----------------------------------------------------|--------------------------------|-------------------|
|                                                     | P3    | P2B  | PPB  | PPal2| CT  | CT1 | CH  | T   | CY  |        |
| Paddy-paddy-secondary crop (P3)                     | 7     | 0    | 0    | 1    | 0   | 0   | 0   | 0   | 0   | 87.50  |
| Paddy-paddy-bare land (P2B)                         | 1     | 6    | 0    | 1    | 0   | 0   | 0   | 0   | 0   | 75.00  |
| Paddy-secondary crop-bare land (PPB)                | 0     | 1    | 2    | 3    | 0   | 0   | 0   | 0   | 0   | 33.33  |
| Paddy-secondary crop-secondary crop (PPal2)         | 2     | 0    | 0    | 3    | 0   | 0   | 0   | 0   | 0   | 60.00  |
| Mix and dominantly fishpond (CT)                    | 0     | 0    | 0    | 0    | 1   | 0   | 0   | 0   | 0   | 100.00 |
| Mix and dominantly cropping paddy in first season (CT1) | 1   | 1    | 0    | 1    | 0   | 3   | 0   | 2   | 0   | 50.00  |
| Mix and dominantly housing (CH)                      | 0     | 0    | 0    | 0    | 0   | 0   | 1   | 0   | 0   | 100.00 |
| Sugarcane (T)                                       | 1     | 1    | 0    | 2    | 0   | 0   | 0   | 1   | 0   | 20.00  |
| Mix and dominantly annual crop (CY)                 | 3     | 1    | 1    | 0    | 0   | 1   | 0   | 1   | 3   | 33.33  |

Accuracy procedural (%) | 46.67 | 60.00 | 66.67 | 37.5 | 100 | 75 | 100 | 50 | 100 |        |

Overall accuracy = 57.70 %

n = 52
4. Conclusion

Identification of the distribution of the cropping pattern has been conducted and obtained nine types cropping pattern paddy fields in East Java consist of five main patterns (paddy-paddy-secondary crop, paddy-paddy-bare land, paddy-secondary crop-secondary crop, paddy-secondary crops-bare land, and sugarcane) and four other patterns in the form of a mixture with accuracy 57.70%. Analysis of the dynamics pattern in wetland use showed that the changes occurred in the pattern of paddy-paddy-bare land into paddy-paddy-secondary crop in October 2010 until December 2013 and the paddy-secondary crop-bare land into paddy-bare land in November 2010 to October 2011 and December 2014.

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