The impacts of paddy field conversion and climate change on rice production in Tegal Regency, Indonesia

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Abstract. Land conversion is one of the problems in agriculture because it decreases the number of productive lands. This condition is exacerbated by climate change phenomenon. This research aimed to identify the climate change impact on paddy field area conversion and rice production in Tegal Regency, Indonesia. The research was conducted by interpreting and classifying satellite image data as well as analyzing land area changes and rice production. Support Vector Machine (SVM) was used as the supervised classification method followed by correlation tests. The results indicated paddy field area decreased in 2009-2015, from 39,365.3 to 36,629 ha. While climate conditions in 2009-2015 were fluctuating, but rice production from 2009 to 2015 increased from 350,116 to 382,161 tons. The changes of paddy field areas and climate parameters did not affect rice production (Rainfall: r = 0.32, P>0.05; Temperature: r = -0.05, P>0.05; Humidity: r = 0.09, P>0.05, n = 7). However, paddy field conversion and climate condition changes must be addressed to optimize and sustain the rice production in Tegal Regency.

1. Introduction
The sustainability of rice production needs to be given attention along with the increasing population of Indonesia year by year. According to Irawan [1], increasing rice production is an effort to improve food security. The development of rice production in Indonesia from 1980 - 2015 fluctuated with an increasing trend. And in the last 5 years, the increase in rice production was quite significant [2]. However, increasing production and quality of rice in Indonesia encounter several obstacles. These constraints include, among others, reduced numbers of productive agricultural lands due to land conversion, climate change, land degradation, and etc.

The declining of productive lands due to conversion is one of the most common hindrances encountered in rice production. The Minister of Agriculture stated that 11,000 hectares of agricultural land are converted into non-agricultural land each year [3]. Agricultural land conversions occur in areas that are also the central area of rice, such as East Java, Central Java, West Java, South Sumatra, and South Sulawesi. Irawan [1] mentioned that the impacts of land conversion are reduce in the food availability quantity, due to the production lands decrease.
In addition to the land conversion, changes in climate conditions such as drought, high or low temperatures and high level of humidity can affect the production and quality of agricultural products [4] and can spur the growth of plant-damaging diseases [5]. Climate conditions directly affect crop production, one of which is rice. The climate conditions that affect rice production are rainfall and temperature [6].

From the above description, a study on the impacts of land conversion and climate change on rice production needs to be conducted. Tegal Regency is one of the rice-producing centers in Central Java. The results of previous studies in Tegal City conducted by Pramudya [6] indicated that there had been a decrease in the number of paddy field areas from 2003 - 2014. The rate of the decline in paddy fields in Tegal City was estimated at 37.82 ha per year. The conversion of paddy fields in Tegal city led to land conversion in larger scale at Tegal Regency. By utilizing the remote sensing method, satellite imagery over paddy fields conversion in Tegal Regency can be obtained. The advantage of using remote sensing methods is that it can identify several lands uses existing on the surface of the earth without having to conduct a direct survey. Rawat and Kumar [7] explained that remote sensing with satellite imaging has the advantage in analyzing changes in these phenomena more accurately with less time and cost.

2. Research materials and method
The observation area was Tegal Regency, which is one of the regencies located in Central Java province, Indonesia. Tegal Regency has an area of approximately 901.52 Km² which is divided into 18 districts namely Adiwerna, Balapulang, Bojong, Bumijawa, Dukuhturi, Dukuhwaru, Jatinegara, Kedungbanteng, Kramat, Lebaksiu, Margasari, Pagerbarang, Pangkah, Slawi, Suradadi, Talang, Tarub, and Warureja. Tegal Regency is located at 108° 57'6" to 109°21'30" E and 6°02'41" to 7°15'30" S (Figure 1)

The study was conducted using the descriptive exploratory method. The observed variables were (1) changes of paddy field area in Tegal Regency in 2009 – 2015, (2) climate parameters including rainfall, temperature, and humidity in Tegal Regency from 2009 to 2015, and (3) rice production. The changes of the paddy field area were obtained by processing the Landsat images 5 of 2009 and Landsat images 8 of 2015. The data of climate and rice production were collected by processing statistical data from The Central Bureau of Statistics of Tegal Regency. Interviews on a total of 30 farmers were conducted to determine the paddy fields conversion and rice production directly in the field.

The methods used were (1) Interpretation of satellite image data for mapping the changes in paddy field areas, (2) Data analysis on the changes in paddy field areas, climate data and rice production data, (3) correlation between the changes in the paddy field area and production was explained descriptively, and (4) correlation between climatic conditions and rice production was determined by correlation analysis. The data analysis and image interpretation were carried out using Geographic Information Systems (GIS) software, namely ENVI 5.1 and ArcGIS 10.1. A classification system that used in this research is the Support Vector Machine (SVM) classification system, because this is better and more specific than other guided classification systems (ENVI 2013).
3. Results and discussion

3.1. Paddy field conversion

Figure 2 shows the visualization of land coverage in Tegal Regency. Lisnawati and Ari argued [8] that paddy fields appearing in the image have a rough texture and a rather dark green color mixed with magenta or blue. Forest land use in the image has irregular patterns; dark green to dark with a relatively rough texture. The use of farm/dry land is depicted in relatively long patterns with rough texture and mixed colors between green and magenta. Settlements in the image are shown in red with a rough texture and spreading throughout the study area.

The images were then interpreted using the Support Vector Machine (SVM) supervised classification method, as presented in Figure 3. The 7 classes of land use obtained were forest, moor/farm, settlements, pond fields, reservoirs, and rivers. The land use area of each classes was then
calculated and the results are presented in Table 1, while the changes of paddy field area is presented in Table 2.

![Figure 3. SVM classification of Tegal Regency in 2009 (a) and 2015 (b)](image)

| No | Land Use       | Area (ha)       |   |   |
|----|----------------|-----------------|---|---|
|    |                | 2009            | 2015| Difference |
| 1  | Paddy Field    | 39,365.30       | 36,629.00 | 2,736.30 |
| 2  | Moor/Farm      | 35,763.40       | 42,320.20 | 6,556.80 |
| 3  | Forest         | 13,183.10       | 12,118.60 | 1,064.50 |
| 4  | Settlements    | 8,442.05        | 5,144.58  | 3,297.47 |
| 5  | River          | 810.30          | 1,202.13  | 391.83  |
| 6  | Pond Field     | 780.43          | 896.53    | 116.10  |
| 7  | Reservoir      | 382.23          | 228.87    | 153.36  |
| 8  | Unclassified   | 87.03           | 273.93    | 186.90  |
|    | Total          | 98,813.84       | 98,813.84 | 0.00    |

Source: Primary data

Table 2. The changes of paddy field area and other land use in Tegal Regency 2009 – 2015

| No | Land use    | Period | Changes |
|----|-------------|--------|---------|
|    |             | 2009 (ha) | 2015 (ha) | Difference (ha) | Percentage(%) |
| 1  | Paddy Field | 39,365.30 | 36,629.00 | 2,736.30 | 0.06 |
| 2  | Other Uses  | 59,448.54 | 62,184.84 | 39,365.30 | 0.66 |
|    | Total       | 98,813.84 | 98,813.84 |               |           |

Source: Primary data

Table 1 and 2 showed that the paddy field area in Tegal Regency decreased. The paddy field area decreased by 2,736.30 ha in 2009 to 2015 (0.06%). Based on interviews with farmers, it was found...
that the benefits of growing rice paddy were constantly decreasing. This factor encouraged farmers to convert their paddy fields to other usage. In several districts of Tegal Regency, function conversion of paddy fields to brick production centers have been found and a small part of the paddy fields in Tegal Regency had also been converted into settlement. Population growth in Tegal Regency has an effect on economic needs increase as well as settlement facilities. Suputra et al (2012) [9] explained that factors that affect land use change can be grouped into 4 factors, namely; land condition, erosion related to population conditions, land use, and ineffectiveness factors. Paddy fields conversion generally affects rice production.

3.2. Correlation between paddy field conversion and rice production

The conversion of paddy field areas were then compared with rice production, productivity, and harvested area data from the Central Bureau of Statistics (BPS) of Tegal Regency, as presented in Table 3. It can be seen in Table 3 that the paddy field area in Tegal Regency decreased, but rice production and productivity increased. This means the decline in the paddy field areas did not affects on rice production.

| Year | Paddy Field Area\(^{(1)}\) (ha) | Harvested Area\(^{(2)}\) (ha) | Rice Productivity\(^{(3)}\) (ton ha\(^{-1}\)) | Rice Production\(^{(3)}\) (ton) |
|------|-------------------------------|-------------------------------|---------------------------------|-------------------------------|
| 2009 | 39,365.30                     | 61,004.00                     | 5.74                            | 350,116                       |
| 2015 | 36,629.00                     | 62,628.00                     | 6.10                            | 382,161                       |

Source: Primary and secondary data information
(1) = Primary Data of SVM classification results
(2) = Secondary data from Central Bureau of Statistics

Another explanation of Aminudin's research [10] also mentioned that the conversion of paddy fields does not affect the decline in rice production in Gowa Regency. There are several factors that might contribute to this. These factors including the intervention of the local government to increase the effectiveness of rice production. Based on the interview with local farmers, the government through the related agencies often provides counseling and assistance to farmers.

The intensification efforts conducted by farmers also affect rice production and productivity, such as the application of water pumps, rice cultivation management including varieties of seeds and fertilizers, as well as pest and disease management [11]. Another effort is the realization of agricultural policies that pay more attention to the farmers’ welfare. Sudaryanto [12] said the strategic policies that can be considered for rice farming business including: 1) increasing availability and access to technology and capital, 2) developing pump irrigation infrastructure, increasing productivity and price stabilization programs and 3) institutional empowerment of farmer groups and building the functional and institutional linkages of agribusiness elements to encourage farmers’ income and the sustainability of agricultural diversification. Pro-farmer policies are expected to reduce the rate of paddy field conversion. Based on the interviews, several farmers in Tegal Regency have applied technical irrigation channels. The use of fertilizers and superior seeds have also been applied. Technical irrigation channels allow water availability for plants to be more stable and sufficient so that rice production can increase.

3.3. Correlation between climate and rice production

Climate condition is one of the factors that can affect the quality and production of rice. According to Nazar [13], climate factors are very influential on plant growth and production. Rainfall conditions namely air temperature and sunlight can affect cropping patterns in an area. Climate data and rice production in Tegal District are shown in Table 4.
Table 4. Climate conditions and rice production in Tegal Regency

| No | Year | Rainfall (mm year⁻¹) | Temperature (°C) | Humidity (%) | Production (Ton) |
|----|------|----------------------|-----------------|--------------|-----------------|
| 1  | 2009 | 1,303.9              | 27.4            | 78.00        | 350,116         |
| 2  | 2010 | 2,428.2              | 27.9            | 81.5         | 368,459         |
| 3  | 2011 | 1,619.3              | 27.4            | 78.83        | 341,480         |
| 4  | 2012 | 521.0                | 28.1            | 77.25        | 341,007         |
| 5  | 2013 | 2,049.0              | 27.9            | 78.83        | 354,538         |
| 6  | 2014 | 1,628.0              | 28.0            | 77.92        | 325,928         |
| 7  | 2015 | 1,449.0              | 27.8            | 76.50        | 382,161         |

Source: Central Bureau of Statistics of Tegal Regency 2010 – 2016 [14]

Table 4 shows that the climate conditions fluctuated during 2009-2015. Rainfall in Tegal Regency quite varied with the lowest rainfall occurred in 2012 (521 mm year⁻¹) and the highest in 2010 (2,428.2 mm year⁻¹). The temperature ranged from 27.4 - 28.1 °C and humidity ranged from 77.25 - 78.83%. The rice production in Tegal Regency in 2009 to 2015 fluctuated with a range of 341,000 to 368,000 tons. In general, the climate conditions were still in accordance with the conditions for growing rice stated by Wahyunto [15], that the good climate conditions for rice paddy are having rainfall of 1,500-2,000 mm year⁻¹, and having a temperature between 24-29 °C.

The relationship between climatic conditions and rice production was determined through correlation analysis. The results of the correlation analysis between climatic conditions and rice production are presented in Table 5.

Table 5. Correlation analysis results between climate conditions, rice production, and rice productivity

|          | Rainfall | Temperature | Humidity |
|----------|----------|-------------|----------|
| Rice Production | 0.32 ns  | -0.05 ns    | 0.09 ns   |

Source: Central Bureau of Statistics of Tegal Regency 2010 – 2016 [14]
Information: ns: not-significant correlation

Table 5 indicates that climate conditions did not significantly correlate with rice production. Nurhayanti and Moko [16] argued that average temperature changes do not have a significant impact on rice productivity because rice productivity is determined by the season and rice development phases. An increase in temperature will positively impact rice productivity at certain optimum points. However, according to Ruminta [17], changes in climate conditions have a significant impact on rice cultivation because the water demand in rice cultivation is influenced by the conditions of rainfall and temperature. This study found that changes in climate conditions in Tegal Regency do not have a significant impact on rice production. Intensification that have been carried out by farmers are able to increase rice productivity so that changes in climate conditions only affect a small part of the production process.

Di Falco et al. [18] explained that rainfall affects crop cultivation. The higher the rainfall, the more commodities can be planted or the broader the planting area. Climate conditions are factors that are not controlled but adaptation efforts are needed to anticipate the impacts of the climate change. Good and proper plant management must be given to improve plant productivity.

4. Conclusion
The paddy field area in Tegal Regency decreased in 2009 – 2015, but did not affect the rice production. In addition, changes in climate conditions also did not have a significant impact on rice production. It is intensification that will increase rice production. However, good land management
and pro-farmer policy are urgent to overcome the land use conversion and changes in climatic conditions in Tegal Regency.

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