SPATIAL MODELING OF LAND USE / LAND COVER CHANGES FOR FLOOD HAZARD ANALYSIS ON PADDY FIELDS AND THEIR IMPACT ON RICE PRODUCTION

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ABSTRACT

Almost in every rainy season some parts of Indonesia face the same problem that is flood disaster. Floods continue to recur from year to year, suspected as a natural disaster caused by human activity. The contribution of each factor to floods in different regions will be different; one important factor is the change in land use associated with paddy fields. Rapid environmental changes such as population growth will require food, shelter, clean water and so on. The 2010-2015 population growth rate of 1.37% or the population grew 6.86% from 2010. Population growth and the development of industrial estates, increasing the need for housing, roads and industrial infrastructure that encourage the conversion of agricultural land for land use/land cover purposes other. The use of Markov chain analysis method in spatial modeling of land use/land cover change informed decreasing of paddy field and widening of settlements or industrial estates. The expansion of settlements and industrial areas has reduced the area of wetland from 51.41% in 2015 to 45.81% in 2031. The objective of this study is to implement spatial modeling of land cover changes and flood hazard analysis that can occur in paddy fields as well as its impact on rice production.

Keywords: decreasing, flood hazard, karawang, Markov, paddy fields.

1. INTRODUCTION

Population growth in Karawang regency averaged (r) 1.37% per year, with the standard consumption of rice is 98.5 kg / capita / year (BPS, 2016) resulted in increasing demand for rice. One of the geospatial-based alternative approaches is remote sensing techniques whose analysis results provide information on changes in agricultural land use, identification of flood area and food production estimates.

The development of industrial area related to Presidential Decree No. 53 of 1989 about industrial area was directed to Karawang regency, as the starting point transfer function of some agricultural land to industry. The area of paddy fields in Karawang regency in 2000 was 120,371 ha (62.83%), in 2015 the remaining wetland area was 98,462 ha (51.39%), the period of 2000 to 2015 paddy field was reduced by 21,909 ha. From various land uses, the most converted is rice fields, especially around urban and settlement development centers (Agus and Mulyani 2006). In general, the conversion of paddy fields is irreversible, since it is transformed into residential, urban and industrial areas. The rapid development and population increase, causing the conversion of rice fields quickly.

Flood suspected a natural disaster caused by human activities, because the product development is not in harmony with nature. The destruction of land affected by the impact of disaster is very wide for the community and farmers, and can disrupt food security. Basically, floods can be managed through mitigation and adaptation, mitigation as an effort to modify the source of the flood disaster that is high rainfall and modify the flow of the surface so that flood hazard opportunities can be lowered. While adaptation is an effort to reduce the impact of flooding on affected areas, and this becomes an important way to manage agricultural land as affected areas. The impact of floods depends on the frequency of floods, the length of the flood puddle, and the depth of the flood. The map of the affected area can be arranged for the usual flooded areas, so that adaptation to affected areas can be more easily planned.

Analysis of land use change performed with overlay method between thematic map in 2000, Landsat image in 2006 and Landsat image in 2015. The basic thematic map was compiled from the result of land cover extract from topography map of year 2000. Landsat image in 2006 was used as basis for updating map of 2000, resulting a thematic map in 2006. Landsat images in 2015 were analyzed by Normalized Difference Vegetation Index (NDVI) and The Tasseled Cap Transformation (TCT) methods. To recognize wetland as an indication of flood hazard areas, the Topographic Wetness Index (TWI) method was used. TWI was processed using TerraSAR-X DSM data. Flood hazard maps covered with land cover thematic maps will provide information on flood hazard areas in paddy fields that will have an economic impact on farmers. The Markov method was used to calculate the projection of wetland degradation up to 2031. The purpose of this study is to analyze changes in land use/land cover and the floods hazard that can occur in paddy fields and possibly result in the loss that will occur.

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2. MATERIAL AND METHOD

2.1 Study sites

The study was conducted in Karawang Regency which located at Longitude 107º02'-107º40' East and 5º56' - 6º34' South. Location of the study shown in Figure-1. Morphology of Karawang regency in the form of lowland with an average of air temperature 27 °C, it has variation of slope region between 0% to 2%, 2% to 15% and a small part with slope above 40%. Elevation of the northern region between 0 to 25m msl, and a small part of the southern region with an elevation of 26m to 1200m msl and an annual mean rainfall of 728 mm (BPS 2016).

Figure-1. Research location map.

2.2 Materials

Materials used in this study include Topographic map scale 1:25.000 published 2000, Landsat TM Image Year 2006, Landsat 8 OLI Year 2015, DSM TerraSAR-X in 2011 and statitics. The software used in this study were Microsoft Office, Global Mapper, ER Mapper, Idrisi, Ilwis dan ArcGIS.

2.3 Methods

Statistics data obtained from Central Bureau of Statistics Karawang regency and the spatial data were collected by sharing from Geospatial Information Agency (Topographic map in 2000 and DTM TerraSAR-X in 2011), downloading Landsat TM in 2006 and Landsat-8 images in 2015 from http://glovis. usgs.gov/. Land cover analysis were carried out to determine the land cover area in 2000, 2006, and 2015. The land cover data were analyzed using NDVI (normalized difference vegetation index) enhanchment and TCT (The tasseled cap transformation) methods. The flood hazard areas were identified using TerraSAR-X DSM data with the TWI (The topgraphic wetness index) method. TWI analysis describe an area with flood hazard potential or an area with flood potential that can be assumed to have a high probability of flooding (Riadi *et al.* 2017). Projected future land cover changes are made with the predicted changes in the present approach through spatial modeling (Figure-2). The prediction model uses CA-Markov, to predict future land use changes of 16 years or in 2031 by simulating land cover changes (Eastman 2009). The degradation of paddy fields resulted in the decreasing of rice production that can be calculated based on existing wetland area multiplied by productivity (6.9 tons / ha).

2.4 Data analysis

2.4.1 Projected population

Based on data of population in 2010 - 2015, it can be seen that the average population growth rate during 5 years (2010 - 2015) is equal to 1, 37%. With the value of (r) an average of 1.37% using the Geometirc Method (BPS, 2016) projected population growth in the following years can be calculated, with the following formula:

$$Pt = Po\ \{1 + (r.t)\} \tag{1}$$

Explanation:

Pt = Number of residents in the final year
Po = Population in the base year (2015).
t = Time period (e.g.: t = 2031 - 2015)
r = Population growth rate (1, 37 %)

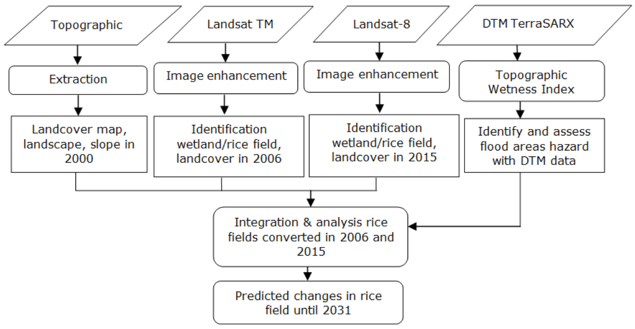

Figure-2. Flow chart of research methods.

The needs of population consumption of rice per year can be calculated by using the formula:

$$KK = SK\ x\ Pt \tag{2}$$

Conversion of grain to rice is 62, 74% (BPS, 2016)

$$KG = KK\ x\ 100/62.74 \tag{3}$$

Explanation:

KK = Needs of rice consumption of the population
SK = Standard consumption (kg/capita/year)
Pt = Population year (Projected population t year)
KG = Grain Consumption

2.4.2 Land used/land cover changes analysis

The land cover thematic maps was extracted from topographic maps of 1: 25,000 scale in 2000, this thematic map used as and initial reference for spatial analysis. The Landsat TM imagery was analyzed to update the basic thematic maps, resulting in a 2006 land cover map.

Landsat-8 Image Record data on October 18, 2015, performed an enhancement process by transforming

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the Normalized Difference Vegetation Index (NDVI) and Tasseled Cap Transformation (TCT) spectral values. Normalized Difference Vegetation Index (NDVI), vegetation index most commonly used is the NDVI. The vegetation index value based on the difference between the maximum absorption of radiation in the red channel (red) as a result of the pigment chlorophyll and maximum reflectance in the near infrared spectral channels (near infra red / NIR) as a result of the cellular structure of the leaves (Tucker 1979).

The NDVI formulation is as follows:

$$NDVI = (\rho NIR - \rho Red):(\rho NIR + \rho Red) \quad (4)$$

Where:

ρNIR = reflectance value canal near infrared
ρRed = reflectance value of the red channel

Tasseled Cap Transformation (TCT) is a mathematical formula to calculate the brightness level (brightness), greenness (greenness), and moisture (wetness) of digital numbers in each band (band 1 to band 5 and band 7) on Landsat imagery. Vegetation index is a quantitative calculation that is used to calculate the biomass or vegetation conditions. Generally made by using a combination of several spectral bands. Mathematical formulation third components TCT (Baig *et al.* 2014), are expressed in the following three equations for Landsat 8.

The Tasseled Cap Transformation Formula (5)

$$Brightness = B2 * 0.3029 + Br * 0.2786 + B4 * 0.4733 + B5 * 0.5599 + B6 * 0.508 + B7 * 0.1872$$

$$\text{Greenness} = \text{B2} * -0.2941 + \text{B3} * -0.243 + \text{B4} * -0.5424 + \text{B5} * 0.7276 + \text{B6} * 0.0713 + \text{B7} * -0.1608$$

$$Wetness = B2 * 0.1511 + B3 * 0.1973 + B4 * 0.3283 + B5 * 0.3407 + B6 * -0.7117 + B7 * -0.4559$$

where B1 = Band1, B2= Band2, B3= Band3, B4= Band4, B5= Band5, B7= Band7.

2.4.3 Land use/land cover modeling

Geographycal Information System technology provides a number of spatial analyzes that can be used to determine trends in land cover changes in a region (Ramlan *et al.* 2015). Projected future land cover changes are made with the predicted changes in the present approach through spatial modeling. The prediction model uses CA-Markov, to predict land use changes in 2031. This software has the ability to simulate land cover changes with Markov chain procedures (Eastman 2009). The first simulation that will be used as a prediction model was the land use/land cover in 2000 and 2006 to predict land use/land cover in 2015. The results of the 2015 land cover change model were validated using linear regression to the 2015 land cover map. If modeling has a good correlation followed by land cover modeling until 2031, the model based on land cover map of 2000, 2006 and land cover map of 2015. The data used in this process is the raster format data with a pixel size of 30x30 meters.

2.4.4 Identification of flood area

TerraSAR-X signals have sensitivity to wet areas, thus there is an increase in wet area information that may indicate a flood hazard area (Buchanan *et al.* 2014). DSM TerraSAR-X is analyzed by Topographic Wetness Index (TWI) method, which is derived data generated from DEM data under steady state-using flow accumulation and slope function (Chapman *et al*. 2005). The Topographic Wetness Index is a wetness index determined from the previously calculated surface variables with the following equation:

$$TWI = ln \frac{\alpha}{tan\beta} \quad (6)$$

Where α = *Flow Accumulation* and tan β are slopes.

In general, the delineation result of boundary areas of flood hazard need to be generalized by conducting selection, simplification, merging, and magnification. Selection is done for objects that need to be eliminated and / or combined, because they do not meet geometry specifications or do not fit into the classification of elements that can be displayed on the map scale. Selection is done by removing and / or aggregating segments of polygon at least 0.5 mm x 0.5 mm (BIG 2014). To recognize the flood hazard areas overlay NDVI and TCT maps with TWI maps, will show the distribution of flood hazard areas. Criteria of high flood hazard areas are in the area of the flooding frequency occurring each year, inundation height over 70 cm (> 70 cm) and flood duration of more than 7 days (> 7 days).

3. RESULTS

3.1 Population growth in Karawang regency and rice consumptionn need

The population growth of Karawang regency averages 1.37% per year with rice production in 2015 is 1, 489, 429 tons. The population of 2015 is 2, 273, 579 people with rice consumption of 98.5 kg / capita / year (BPS, 2016) the need for rice to be 223,947 tons or equivalent to 356, 945 tons of grain requirement. Thus, in 2015 the grain surplus in Karawang regency is 1,489,429 tons minus 356, 945 tons, which is equal to 1, 132, 484 tons equivalent to 710, 520 tons of rice. Projected population growth until 2031 using Formula 1. The population of Karawang regency is 2, 826, 579 inhabitants. The need for rice is 278,418 tons or equivalent to 443,765 tons of grain.

3.2 Land used/land cover change

From topography map extract, it is found that the area of Karawang regency is 191.577 hectares with rice field area of 120,371 ha (62.83%) in 2000 (Figure-3). Landsat TM image analysis for topographic map update obtained information on rice field area 112.878 (58, 92%) at 2006 (Figure-4), more details are presented in Table-1.

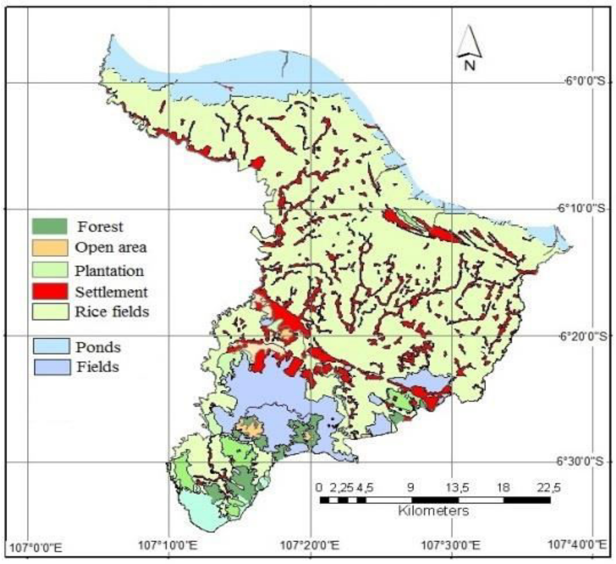

Figure-3. Tematic map in 2000.

Landsat-8 Image Record data on October 18, 2015, an enhancement process was performed by transforming the Normalized Difference Vegetation Index (NDVI) and Tasseled Cap Transformation (TCT) spectral values, NDVI giving vegetation land cover (Figure-5) and TCT giving local indication information wetland.

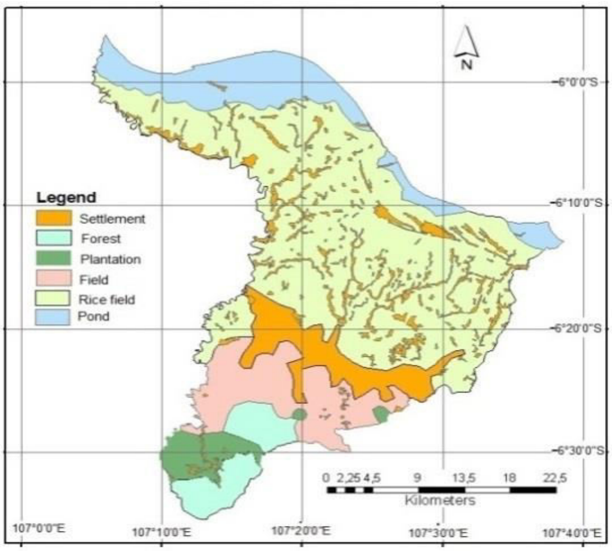

Figure-4. Tematic map in 2006.

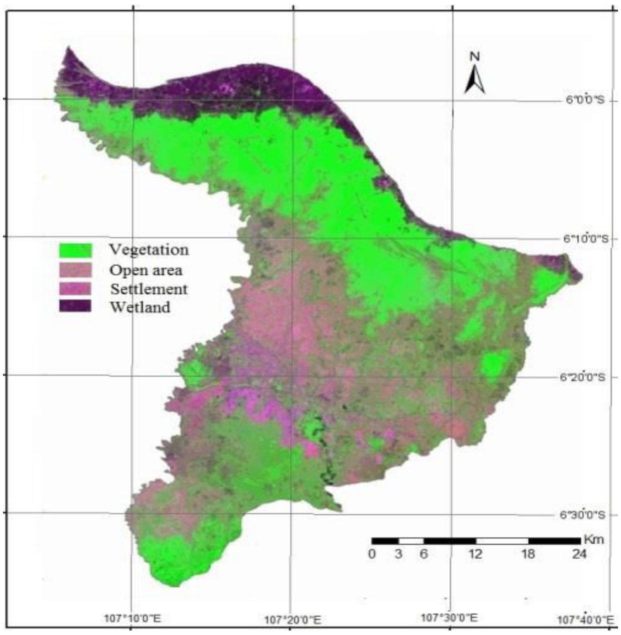

Figure-5. NDVI map in 2015.

The result of transformation process of spectral value with Tasseled Cap Transformation (TCT) gives three bands created are commonly held to represent Brightness, Greenness and Wetness. Transformation of multi-temporal color composite (RGB) values can separate the fields of rice fields with non-visible rice fields (Figure-6). Blue color associated with water, red color associated with open area, settlement, dry land, open land. For green color associated with vegetation. Table-1. Shows the results of the analysis, states that the decrease in wetland area from 2000 to 2015. Existing wetland area of 98,462 hectares (year 2015).

Table-1. Land cover for period 2000, 2006 and existing land cover of 2015.

	Land Cover 2000		Land Cover 2006		Land Cover 2015	
Land Cover	Area ha	%	Area ha	%	Area ha	%
Field, open area	18.805	9.82	15.064	7.86	22.563	11.78
Plantation	5.414	2.83	13.640	6.56	11.725	6.12
Settlement	20.301	10.60	18.757	9.79	25.611	13.37
Forest	7.038	4.11	5.218	2.72	5.814	3.03
Ponds	4.484	2.34	12.184	6.36	20.839	10.88
Water body, swamp	14.325	7.48	13.836	7.22	1.311	0.68
Rice fields	120.371	62.83	112.878	58.92	98.462	51.41
Industrial area	-	-	-	-	5.223	2.73
Total Area	191.577		191.577		191.577	

Source: Spatial analysis

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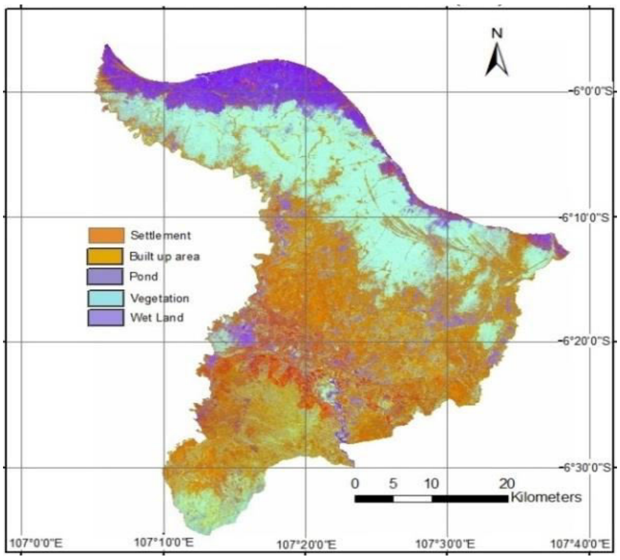

Figure-6. TCT map in 2006.

3.3 Land use/land cover modeling

To predict changes in land use/land cover in the next few years is done by modeling CA-Markov. The result of spatial modeling of land cover changes 2015 (Figure-7). Was validated by linear regression to measure whether the Markov modeling results correlated with existing land cover or not (Table-2).

Table-2. Relationship between modeling results with land cover existing.

Land Cover	Existing 2015		Result Markov 2015	
	Area ha	%	Area ha	%
Settlement, others	53,426	14.36	61.007	31.75
Plantation	11,725	6.12	4,357	2.41
Forest	5,814	3.03	8,697	4.66
Ponds	20,839	10.88	24,107	12.64
Swamp	1,311	0.68	303	0.16
Rice fields	98,462	51.41	93.107	48.38
Total	191,577		191.577	

Source: Spatial analysis

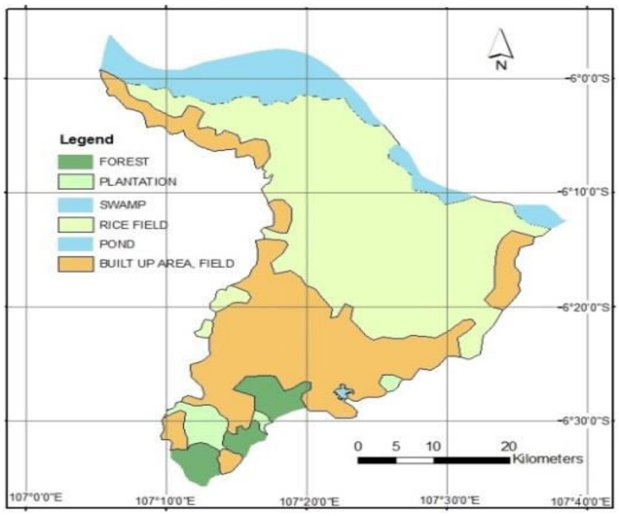

Figure-7. Modeling markov in 2015.

Markov land cover modeling correlation resulted in a R square value of 0.9772 or 97.72% (Figure-8), it states if Y significantly affects X.

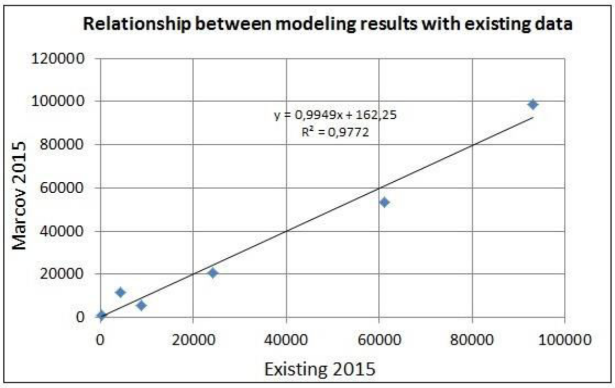

Figure-8. Linear regression of spatial modeling.

For further modeling for land cover change up to 2031 (Figure-9). The variables used in this prediction are settlement, built up area, open area and rice field, up to 2031 the remaining wetland area is 45.81% (88,007 ha) (Table-3).

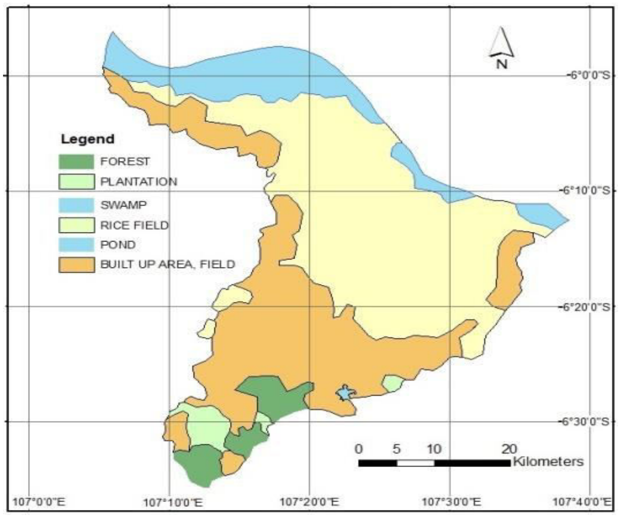

Figure-9. Projected land cover in 2031.

Table-3. Predicted land cover change up to 2031.

Land Cover	Markov 2015		Predicted Markov 2031	
	Area ha	%	Area ha	%
Settlement, others	61,007	31.75	65,807	34.28
Plantation	4,357	2.41	4,457	2.42
Forest	8,697	4.66	8,697	4.67
Ponds	24,107	12.64	24,207	12.67
Swamp	303	0.16	303	0.16
Rice fields	93,107	48.38	88,007	45.81
Total	191,577		191.577	

Source: Spatial analysis

3.4 Identification of flood hazard areas

The flood hazard area analysis is done by integrating the spatial modeling data of TWI with historical data of flood events. The historical data

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parameters of flooding in paddy fields consisting of the frequency of flood events, the average height of the puddle, and the average length of the inundation in the overlay by giving the attributes of each parameter in accordance with its influence. The TWI map is overlaid on the TCT map, indicating that the flood hazard in Karawang regency occupies the rice fields area (Figure-10).

From the analysis results, areas with high flood hazard with an area of 7,489 ha (7.61%), moderate flood hazard level 19.188 ha (19.49%) and low flood hazard with 1,689 ha (1.72%). The level of flood hazard shows that the danger of flooding in paddy fields is 71.19% of land is at non-vulnerable level. Flood incidents recorded each year result in crop failure and decreased production of rice crops in Karawang regency (Riadi *et al.* 2017).

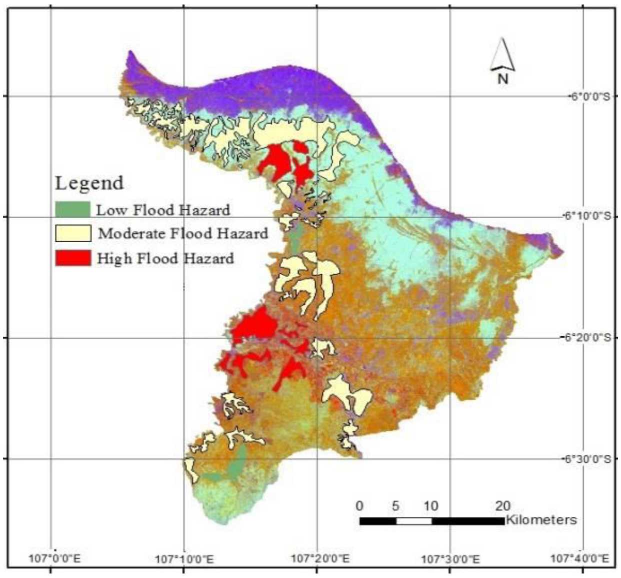

Figure-10. Flood hazard map.

Flood incidents recorded each year caused in the crop failure and a decline in rice crop production in Karawang regency (Table-4).

Table-4. Inundation area, crop failure area, productivity and loss of harvest.

Year	Inudation area (ha)	Crop failure area (ha)	Productivity ton/ha	Loss of harvest ton
2010	12.462	6.346	5,968	37.873
2011	1.722	1.952	6,042	11.794
2012	3.254	6.475	5,846	37.853
2013	7.677	4.547	6,156	27.991
2014	11.550	7.700	5,953	45.838
2015	1.374	415	6,448	2.676
2016	10.272	810	6,448	5.223

Source : DPKPP 2016; BPS 2016 and The Calculation Results

4. CONCLUSIONS

Changes in rice fields in Karawang from 2000 to 2015 decreased by 21, 909 ha. In this area there are areas with high flood hazard with an area of 7, 489 ha, medium flood hazard 19,188 ha. Every year the average loss of rice production due to floods reached 24, 178 tons. Predicted until 2031, the paddy field will experience a reduction and leave 88, 007 ha, while the population increases 2, 826, 579 people. Assuming fixed rice production, and the population continues to increase, flood harvest failure always occurs. In the next few years the need for rice for Karawang regency can still be fulfilled but the surplus of rice for the national food stock needs will decrease.

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