Strategy to Maintain Food Security in the Area of Flood Hazard in Karawang Regency

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Abstract. Rice yield in Java Island as national rice supplier in order to support food security. Java has a dense population, causing very high pressure on land use. The need for housing, roads and industrial infrastructure encourages the conversion of agricultural land for other land uses. This study aims to formulate strategies for the purpose of maintaining food security in flood-prone areas. Karawang Regency is a rice barn of West Java Province and is also a frequent area of flooding. Therefore, it is necessary to map the spread of flood-prone areas and to analyze land use linkages, rice productivity, population and food needs in the study area. Strategies for maintaining spatial food security are by mapping land cover multi years and mapping the flood hazard areas using high-resolution DEM data. Land cover mapping using RBI Map Scale 1:25,000 the Year 2000 and Citra Landsat-8 and Spot-6 Year 2015. Wetland Area Year 2000 is 120,371 (62.83%), land area Year 2015 is 98,462 ha (51.40%). The average rice field area caused by flooding reaches 219.84 ha/year, if the productivity of 6.9 tons/ha annually loses rice production on average 1,517 tons. Food security in the research area is still maintained from various pressures of land use. There is unfulfilled support for national food security with the obligation to provide 1.5 million tons of paddy stock per year. The selection of strategies in maintaining food security in the research area is to tighten supervision in licensing in favor of the protection of paddy fields. The professionalism of agricultural extension resources will be able to increase rice productivity.

Keywords: DEM, Food security, multi years, spatial

1. Introduction

In general, flooding is caused by high rainfall above normal, so water runs from river to low land by riverside. The flood caused by river water flows into the surrounding environment as a result of high rainfall. Rainfall affects the production of food of agricultural products if the rainfall is very high can cause flooding, this event can reduce the production of food crops. The area of rice farming experiencing the immersion stress due to flood is expected to increase due to increased rainfall and rising sea levels due to global warming [1]. The submerged plants are inhibited by the process of photosynthesis, and in general, the rice plants will die if all parts of the plant are flooded for seven days [2]. And in flood-prone areas, where rice cultivation is often completely submerged for several days at different age crop conditions, causing crop damage and also decreased yield [3]. Floods often occur in the lowlands which are usually rice production centers, so the impact is quite significant related to the availability of food,
especially rice. Wetland is generally located on the fluvial plains and its location is relatively lower than the road or settlement so that the paddy field is physically a flood-prone area and potentially experience deeper and longer pools in case of flooding.

The threat of flooding needs to get serious attention because this region contributes to the national rice demand on average reaching 865,000 tons of rice per year [4]. In the planting season of 2013/2014, floods caused many rice fields that failed to harvest and caused 7,700 ha of paddy fields to fail to harvest [4]. Another problem that can reduce rice production is reduced irrigated rice field, land conversion is permanent, which means after the rice field switch function cannot be returned to the original rice field again. Conversion of land that affects food production is the disappearance of effective stretches to contain excess runoff that can help reduce flooding. Increasing the area of rice fields affected by the flood is directly proportional to the area of crop failure [5], this condition is worrying because it can lead to decreased rice production.

Landform in the coastal area of Karawang regency is alluvial plain, an area with landforms from the alluvial plain land system is flood-prone area because it is low area or basin. For coastal areas with slope characteristics <2% and has an average rainfall of ≥ 200 mm included in flood-prone class [6]. The floodplain landform can be identified as a wetland area which is also a lowland form of the basin. To identify the wetland area in this study will utilize the map of the index of DEM TerraSAR-X in 2011. Food security is a multi-dimensional issue that requires analysis of production and food availability. Although there is no specific way to measure food security, the complexity of food security is simplified by focusing on the food availability dimension.

The objectives of this research are (1) to explain the factors needed to maintain food security in the region with the danger of the flood, and to collect information about the impact of flood on rice production. (2) By utilizing advances in mapping technology to identify wetland changes and flooding incidents in rice fields. (3) wetland maintenance strategy for agricultural land, with anticipatory measures in the face of flood disaster by building and strengthening the forecasting system for flooding. The results of this study are expected to be useful for researchers and local governments in preparing the improvement of spatial plans to maintain food security.

2. Method and materials
2.1. Location and time of research
The research location is Karawang Regency and lies in the north part of Province of West Java, which is geographically located between 107º02' - 107º40' East Longitude and 5º56' - 6º34' South Latitude. The research and data processing activities were conducted from October 2016 to March 2017. Data analysis was conducted at the Geospatial Information Agency. Climatologically monthly average rainfall in Karawang Regency shows that rainfall at low-intensity level [7].

2.2. Types and data sources
The data used in the implementation of this research consist of primary data and secondary data. Primary data were obtained from field surveys to check the data on flood events, cover, and documentation and analysis results. While the secondary data in the form of thematic maps, statistical data, and other data required. The basic data types used in the study were Landsat 8 imagery October 2015 recording, topographic map of scale 1: 25,000 in 2000 [8], TerraSAR-X TWI map of 2011 (analysis results), land cover map of 2000, the land cover map of 2006 and the land cover map of 2015. Average monthly rainfall data from 2010 to 2017 [9]. Map Plan of Spatial Pattern Karawang regency 2011-2031 scale 1: 50,000.
2.3. Data Analysis Procedure
This research is conducted through several stages as follows:

![Flowchart of research methods](image)

- **Administrative boundary map**
- **Topographic wetness index (TWI)**
- **Citra Landsat-8 dan Spot-6**
- **Overlay flooding in paddy fields**
- **Spatial analysis of the adequacy of food**
- **Evaluation of spatial utilization**
- **Food security in the area of flood**

**Figure 1.** Flowchart of research methods

The expected output from this research is the strategy in maintaining food security in agriculture area with the danger of flood. The software used to process spatial data is Global Mapper V.10, ER Mapper 7, Ilwis 3.85 and ArcGIS 10.2, while for processing data attribute used Ms. Office Excel 2010.

2.4. Topographic Wetness Index Analysis (TWI)
Index calculation with DEM input fill sink and flow accumulation produce wetness index. TWI analysis is arranged sequentially with the Stream Networks analysis to construct a network of streams that exist in a particular region using flow accumulation information. Flow accumulation is explained by determining the value of flow accumulation considered as a river.

In this research, the high index value (> 25) has a sloping slope so that the potential for high water puddle. The index value of 15 in this study as an indication of boundary inundation area. The wetness index < 15 indicates that a region has a steep slope and has a low TWI index value, with a low potency of water puddle. Delineation of boundary areas indicating the danger of flooding is done by converting raster to format vector format and/or through visual interpretation showing the distribution of flood hazard areas [10].

2.5. Analysis of Land Cover and Flooded Land
Land cover data extracted from topography map scale 1: 25,000 in 2000, grouped into 7 kinds of land cover (open area/fields, plantation, settlement/land woke up, forest, pond, water body, rice field). According to [11], spatial analysis of land use from satellite imagery is done by classifying, for this study using Landsat Satellite Image 2006 and Landsat-8 Image 2015. Furthermore, the classification result is detailed using a Spot-6 image with main concern on the use of wetland, changes in the use of wetland for other uses greatly affect rice production. To see the relation of existing land cover with potential flood vulnerability done by spatial analysis of overlay of hazard map of flood result of analysis with a land cover map.
Flood control programs have been widely implemented but floods (frequency, duration, intensity, the extent of inundation) continue to increase. Spatial or land use changes have more influence or contribution to flooding than the physical construction of flood controllers [12]. Production data, population data and historical data of flooding using secondary data from the Department of Agriculture and the Central Bureau of Statistics which will be dispatched and made its own attributes in the units of the district administration.

### 2.6. Spatial analysis for food sufficiency

The food adequacy analysis method used is analyzing food security policy and program done descriptively with content analysis method. This method is a method used to examine the content of food security policies and programs whose calculations use the formula (1):

$$FS = \frac{NC}{A} \left(\frac{kg}{capita/year}\right)$$

Where:
- **FS**: Food Sufficiency
- **NC**: Normative Consumption
- **A**: Availability

If the value of sufficiency is more than 1, then the area is food deficit and if the value of sufficiency is less than 1, then the area is food surplus.

Space utilization system basically contains two main components namely the component provider of space (supply), and components of space users (demand). Spatial components include natural and physical resources, while the userspace component (demand) includes people with activities, both production and consumption activities.

Supply components include agricultural land, analysis by identifying existing rice fields. This analysis begins with topographic extracts for making thematic land cover basic maps. Followed by updating the basic thematic map with a Landsat-8 image, increasing the depth of information of land cover analysis in update using Spot-6 image resolution 1,5 m and producing existing land cover map 2015. This existing map is used as the basis for calculating rice production, rice productivity 6.9 tons/ha and intensity of cropping 2 times per year [13].

The demand component includes the population with its activities, both production and consumption activities. Based on the data of population in 2010 - 2015, it can be seen that the average population growth rate (r) for 5 years (2010 - 2015) is at 1.948%. Predicted population and rice needs can be done for the coming years.

$$Pt = Po \left(1 + (r \cdot t)^n\right)$$

Explanation:
- **Pt** = Number of residents in the final year
- **Po** = Population in the base year (2010).
- **t** = Time period (e.g.: t = 2016 - 2010)
- **r** = Population growth rate (1,948 %)

To be able to know the needs of population consumption of rice per year using the formula:

$$KK = SK \cdot Pt$$

Conversion of grain to rice is 62,74% [1]

$$KG = KK \left(\frac{100}{62,74}\right)$$

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
2.7. Strategy
SWOT analysis is a strategic planning method used to evaluate the strengths, weaknesses, opportunities, and threats in a project. The four factors that form the acronym SWOT [14]. This process involves determining specific objectives and identifying internal and external factors that support and which are not in achieving that goal. SWOT analysis can be applied to analyzing and sorting things that affect the four factors. In the application is how strength is able to take advantage of existing opportunities. How to overcome the weaknesses that prevent the advantage of existing opportunities. How strengths are able to deal with existing threats. And how to overcome the weaknesses that can make the threat real or create a new threat.

3. Result and discussion
3.1. Topographic wetness index (TWI)
Topographic Wetness Index (TWI) is a wetness index that can be used as an indicator of an area that has the potential for flooding. This index is calculated from the surface variables formulated as TWI = ln (As / tan β) where As is Flow Accumulation and β is the slope. High Index values indicate sloping slopes that have a high potential for water puddles, low TWI index values, the low potency of water puddles. This index provides a wetland potential pattern in the catchment area, but the accuracy of the spatial prediction depends heavily on the quality of DEM used [15]. Delineation of boundary areas indicating the danger of flooding is done by converting the format of raster to format vector and or through a visual interpretation which shows the distribution of flood hazard areas (Figure.2.).

The study of flood hazard areas of most of the flood hazard areas is located in paddy fields (Figure.3.). From the results of the study in a certain period, it is found that the Karawang Regency with an area of 191,577 hectares in 2000 has paddy fields with an area of 120,371 ha (62.83%). In 2006 result of analysis of wetland area of 112.878 ha (58.92%), there was degradation of rice field of 7,493 ha. Results of existing land analysis of 2015 land use Landsat-8 image data and Citra Spot-6 obtained wetland area of 98,462 ha (51.41%). So in the period of 2000 to 2015 degradation of paddy fields with an area of 21,909 ha (11.42%) [16].

Based on the calculation, the amount of reduction of rice field in Karawang regency is 1.88% per year [17]. As a result, it has reduced the contribution of rice out of the region beyond the internal consumption of 59.75% of production in 2000, to 49.82% in 2011 [17]. The difference in the results of the degraded rice field counts from previous research is the use of high-resolution image data in this
The heavy pressure on land use in the research area due to geographical proximity to the national capital, the need for residential and industrial land increases the pressure on land conversion due to the low land rent of agricultural land compared to land use for industrial and residential land. Based on the plan of spatial pattern Karawang regency in 2011-2031 identified land use rice field remaining 95,556 ha or 49.88%.

To maintain food security Government of Karawang regency needs to focus on increasing aspect of productivity in food agriculture sector and preserving rice fields. The procedure for measuring food security is based on the availability category, particularly the adequacy/supply indicator. Therefore, production level becomes a very important element in maintaining food security, technological innovation is needed which can increase rice productivity by 6.9 ton/ha. Using the Formula (1) until Formula (4) can be projected for the research area of rice needs until 2031 will still be fulfilled with the remaining 95,556 ha (49.88%), but the surplus obligation of 1.5 million tons of grain for national stocks cannot be met if the level of rice productivity has not increased (Table 1.).

Flood hazard area with an area of 28,366 ha in Karawang regency mostly inundated rice fields. Overlay of the land cover map with TWI map (Figure 3.) Shows the distribution of flood hazard areas, the area of flood hazard with high flood hazard criteria with an area of 7,489 ha (7.61%), medium flood hazard level 19,188 ha (19.49%) and low flood hazard with an area of 1,689 ha (1.72%). The non-hazard level of flooding in paddy fields is 70,095 ha or 71.19% of rice area of 98,462 ha.

Areas with high flood hazard levels have characteristics close to industrial and urban areas, since there has been a lot of conversion of agricultural land to industrial land, resettlement or built up area (Figure 3.). This condition makes high surface flow and causes flooding in the area, special handling needs to be done so that in this area there is no failure of harvest so that rice production is maintained. Flood events that will result in crop failure is a flood that inundated rice fields for more than 7 days, which makes the rice cannot do photosynthesis.

| Year | Population and Projection | Rice Consumption (ton/year) | Needs of grain (ton/year) | Area of rice field (ha) | Grain production | Surplus of grain (ton) |
|------|---------------------------|----------------------------|---------------------------|-------------------------|-----------------|-----------------------|
| 2000 | 1,787,319                 | 176,051                    | 280,604                   | 120,371                 | 1,661,120       | 1,380,516             |
| 2006 | 2,009,647                 | 197,950                    | 315,509                   | 112,878                 | 1,557,716       | 1,242,208             |
| 2015 | 2,273,579                 | 223,948                    | 356,945                   | 98,462                  | 1,358,776       | 1,003,830             |
| 2020 | 2,437,497                 | 240,093                    | 382,680                   | 97,532                  | 1,346,218       | 963,538               |
| 2025 | 2,596,832                 | 255,788                    | 407,695                   | 96,642                  | 1,333,660       | 925,964               |
| 2030 | 2,766,582                 | 272,508                    | 434,345                   | 95,732                  | 1,321,102       | 886,756               |
| 2031 | 2,801,841                 | 275,981                    | 439,881                   | 95,556                  | 1,318,673       | 878,792               |

Source: Result of analysis and calculation

The average area of paddy fields that failed to harvest due to flooding reached 219.84 ha/year, the estimated value of economic losses due to flooding in paddy rice farming is a tangible loss consisting of direct and indirect. Direct losses include damage to agricultural land estimated through a cost recovery approach. The indirect losses include decreasing productivity and loss of farmer income using productivity change approach. Direct losses as a result of physical damage to farmland, are estimated from farmers’ expenditure to improve the quality of agricultural land damaged by floodwater during one
period. The cost of these improvements will be incorporated into production costs after the floods to calculate the income of farmers lost.

For the development of strategies to maintain food security, analyzed by using SWOT analysis based on the data obtained, internal and external factors owned and strategies that can be done referring to the SWOT matrix (Table.2.), Are as follows.

**Table.2.** Further arranged matrix in the following table:

| Internal factors | Strength (S)                                                                 | Weakness (W)                                                                 |
|------------------|-------------------------------------------------------------------------------|-------------------------------------------------------------------------------|
|                  | 1. Food availability:                                                         | 1. Food supply: high population growth, the difficulty of getting              |
|                  |     Agricultural land available                                               |     the means and production                                                |
|                  | 2. Access to food: Presence                                                   |     infrastructure                                                          |
|                  |     Departement of Food security                                               | 2. Food access: Lack of quality and a strength of human resources extension    |
|                  | 3. Utilization and absorbent                                                  | 3. Utilization and absorption:                                               |
|                  |     - an: Available means and agricultural infrastructure                     |     Low tech support and capital                                              |
|                  | 4. Food vulnerability: Area                                                   |     4. Food vulnerability: High                                               |
|                  |     land failure due to flooding                                                |     overland function, low                                                    |
|                  |     the minimum                                                               |     land ownership, disaster                                                  |
| External factors | Opportunity (O):                                                             | Threats (T):                                                                 |
|                  | 1. Food availability:                                                         | 1. Needs of food: Its high                                                   |
|                  |     Open marketing access                                                      |     Growth population                                                        |
|                  | 2. Access to food: means                                                      | 2. Food access: road and agricultural infrastructure                          |
|                  |     good road infrastructure                                                   | 3. Utilization and Absorption:                                               |
|                  | 3. Utilization and absorption:                                                |     low public awareness of health                                           |
|                  |     Expansion food Technology                                                  |     Rice field function transfer, floods                                       |
|                  | 4. Food vulnerability:                                                         | Strategy Strengths Treats (ST):                                              |
|                  |     Increased facilities                                                      | 1. Making a system policy licensing and supervision                           |
|                  |     agricultural production                                                   |     deep area layout                                                          |
|                  | Strategy Opportunities (SO):                                                  |     protecting farmland                                                       |
|                  | 1. Increased productivity and marketing of rice (S1, O1)                      |     (S1, T1, T4)                                                             |
|                  | 2. Prepare management                                                         | 2. Improving infrastructure                                                   |
|                  |     Effective food security (S2, O2, T2)                                      |     road and agriculture (S2, T2)                                             |
|                  | Strategy Weakness Oppor. (WO):                                                | Strategy Weakness Threats (WT):                                              |
|                  | 1. Professional human resources extension workers enhanced quality and number | 1. In cooperation with financial or agricultural institutions (BUMN)         |
|                  |     (W1, W2, O3)                                                             |     in order availability of food (W3, T3)                                   |
|                  | 2. Allocated development funding as needed (W3, O1, O3)                      | 2. Cooperate with insurance for Protection plants due to flood (W4, T4)       |
|                  | 3. Assistance, facilities supervision Production (W3, O2, T3)                | Table.3. Development of SWOT elements based on their importance              |

| Strengths (S) | Weakness (W) | Opportunities (O) | Threats (T) |
|---------------|--------------|------------------|-------------|
| Components   | Values       | Components Values| Components   |
| S1           | 3            | W1               | 3           | O1          | 2             | T1           | 3             |
| S2           | 2            | W2               | 2           | O2          | 2             | T2           | 2             |
| S3           | 3            | W3               | 2           | O3          | 3             | T3           | 2             |
| S4           | 2            | W4               | 3           | O4          | 3             | T4           | 3             |

Nilai 3 = Important     2 = Medium importance     1 = Not important
Table 4. The alternative selection strategy

| SWOT element | Linkages       | Weight | Rank |
|--------------|----------------|--------|------|
| SO1          | S1, O1         | 3+2 = 5 | 7    |
| SO2          | S2, O3, T2     | 2+3+2 = 7 | 3    |
| WO1          | W1, W2, O3     | 3+2+3 = 8 | 2    |
| WO2          | W2, O1, O3     | 2+2+3 = 7 | 4    |
| WO3          | W3, O2, T3     | 2+2+2 = 6 | 6    |
| ST1          | S1, T1, T4     | 3+3+3 = 9 | 1    |
| ST2          | S2, T2         | 2+2 = 4  | 8    |
| WT1          | W3, T3         | 2+2 = 4  | 9    |
| WT2          | W4, T4         | 3+3 = 6  | 5    |

Based on the value and weighting that has been done, the determination of food security strategy is the strategy ST1, WO1, and SO2, which include:

1. To make a policy of permit system and supervision of territorial scope in protecting agricultural land (S1/ Agricultural land available, T1/ High Growth population, T4/ Rice field degradation, floods).
2. The professionalism of extension human resources, quality improvement and a number of the productive workforces to increase food production (W1/ high population growth, the difficulty of getting the means and production infrastructure, W2/ Lack of quality and expertise of human resources agricultural extension, O3/ Expansion food Technology).
3. Preparing effective food security management (S2/ Presence Departement of Food security, O2/ Access to food: means good road infrastructure, T2/ road and agricultural infrastructure), controlling and maintaining agricultural land in order to avoid land conversion which resulted in widespread flooding in paddy fields.

4. Conclusion

Strong pressure on land use in the research area due to the geographical location close to the state capital, the need for residential land and industrial land increases the pressure on land conversion. This condition occurs due to low land rent of paddy fields compared with land use for the industrial and residential land. Wetland land use to other uses from 2000 to 2015 reached 21,909 ha (18.2%). Another pressure is the danger of flooding in paddy fields that can reduce rice production. The results of the analysis obtained the area of flood hazard with high flood hazard criteria with an area of 7,489 ha (7.61%), medium flood hazard with 19.188 ha (19.49%) and low flood hazard with 1,689 ha (1.72%). The average rice field area caused by flooding reaches 219.84 ha/year if the productivity of 6.9 tons/ha each year average loss of rice production is on average 1,517 tons.

Food security in the research area is still in good condition, but it cannot support national food security as an obligation to provide 1.5 million tons of paddy stock per year. The selection of strategies in maintaining food security in the research area is to tighten the supervision in licensing in favor of the protection of paddy fields. The professionalism of agricultural extension resources will be able to increase rice productivity from the current average rice productivity of 6.9 tons/ha.

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