The land-based paddy food sufficiency model in Cirebon Regency West Java Province, Indonesia

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Abstract. Cirebon Regency, which is one of rice production centers in West Java Province, has experienced the conversion of paddy fields to non-agricultural land. The conversion caused the decline in rice production, which automatically reduces its contribution to West Java Province. The objective of this research is to build a paddy food sufficiency model as a direction to develop food sufficiency in Cirebon Regency, West Java, Indonesia. Secondary data used were sourced from various reports and documents of relevant time series from several authorities, while primary data were obtained from research in the area. The model uses a dynamic system approach. The results of the study showed that in 2031, area of paddy fields which should be protected increase, the number of farmers decreases, food sufficiency decreases, the area of paddy fields decreases, and farmers’ income increases. The application of moderate or optimistic scenarios can reduce the area of paddy fields which should be protected, increasing food sufficiency as well as farmer’s income. The spatial analysis results in land which is suitable and available which can be defined to become sustainable food agriculture land through a review process of the official spatial land-use plan.

Keywords: dynamic systems, food sufficiency, land conversion, paddy fields,

1. Introduction
As one of the centers of rice production in West Java Province, Cirebon Regency is one of the areas for fulfilling the food needs of West Java Province. In 2015, Cirebon Regency had a paddy field area, which consists of 6% of total paddy field in West Java Province. This amount signifies the 6th largest paddy field area after Indramayu Regency (13%), Karawang Regency (10%), Subang Regency (9%), Sukabumi Regency (7%) and Cianjur Regency (7%). Along with population growth, Cirebon Regency continues to carry out development in various sectors by its regional potential. The national conversion rate of paddy field estimated 96,512 ha year⁻¹ [1]. The 8.1 million ha paddy field in 2016 will decrease to about 5.1 million ha in 2045, assuming the same conversion rate from 2000-2015. In 1994-2015 conversion of paddy fields to built area/infrastructure in Karawang is approximately 10,326.6 ha. It took up 56% of the paddy that was changed [2]. Meanwhile, a decrease in the paddy field area in Cirebon Regency with an absolute decline of -0.3% year⁻¹ [3,4,5,6,7,8,9]. This fact has an impact on the reduction

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of Cirebon Regency’s rice production during 2009-2015 which is indicated by a downward trend [4,5,6,7,8,9,10]. Although the drop is not high, this has implications for a more significant reduction in the contribution of Cirebon Regency in rice production of West Java Province [8,9,10]. If all regencies in West Java Province experience conditions such as Cirebon Regency, then it can have implications for the sufficiency of rice food nationally.

In addition to the loss of the potential for increasing rice production, conversion of paddy fields has also impact on the decreasing income of farmers and farm workers. There will be shifts in the profession of farmers to other livelihoods, which means a decrease in the number of farmers. Paddy field conversion has an impact on changes in environmental conditions. As an example, the increase in the built-up area. The protection of paddy fields in the Cirebon Regency is so necessary. Regulation for sustainable land for food farming exists, but it has not yet applicable in the area.

An overall analysis of [11] shows that there are not many lands that could be used for the expansion of agricultural land to keep pace with population growth. This result implies that in the future, land utilization should be planned more strictly, considering the strict application of existing official spatial land use plan allocation and more efficient use of land for agriculture [12].

A dynamic model system can be used to formulate, simulate, and validate land use for sustainable lowland rice. System dynamics designed for analysis of complex physical-socio-economic systems [13]. The dynamic system model approach is widely used as an analytical tool in Indonesia in various sectors including the dynamic system model approach in waste management to reduce the burden of accumulation [14], dynamic system model for estimating air pollution from motor vehicle emissions in Jakarta [15], dynamic model of national beef availability system [16], the dynamics model of the spread of dengue fever by implementing three control strategies [17], dynamics model of supply and distribution systems in PT Pertamina Padang’s fuel distribution disruption [18].

With such background, this paper has an objective to model paddy field sufficiency in Cirebon, one of the center of rice production in West Java. The model can be used to give the direction for developing land resources in Cirebon Regency so that the sufficiency of food in the Cirebon Regency is fulfilled while its contribution as a center for food production still maintained.

2. Material and Methods

2.1. Study Area
This research was conducted in the Cirebon Regency, which consists of 40 districts (Figure 1). The research location of Cirebon Regency lies at the position of 108°40’ – 108°48’ East Longitude and 6°30’ – 7°00’ South Latitude, which is bordered on the north by Indramayu Regency, in the northwest bordering with Majalengka Regency, in the south with the Kuningan Regency and in the east with Cirebon City and Brebes Regency, Central Java Province. The total area of the Cirebon Regency is 990.36 km² [10]. The research was conducted for eight months, from May 2018 to December 2018.

2.2. Data
Secondary data were obtained from agencies that are directly related to rice commodity development programs, which are Cirebon Regency Agricultural Services, Cirebon Regency Regional Development Planning Agency, and the Cirebon Regency Central Bureau of Statistics. Primary data were obtained from field study [19], such as identification of land cover and land-use change, and delineation of land suitability and land availability.
2.3. Analysis
A dynamic system approach was used in this research to model food sufficiency. Dynamic system analysis steps consist of (i) determining the objectives in the system, (ii) determining system requirements, (iii) making problem formulations, (iv) identifying systems, (v) simulating structures by using stock-flow diagrams and (vi) validation. The direction for the development of paddy rice is made based on the condition of the scenario matrix and evaluation of the Cirebon Regency’s Spatial Land-use Plan for 2011-2031.
To determine the rank of priority, protected and actual paddy field was used as a reference. Another requirement, such as land suitability, land availability, alignment, and spatial pattern of Cirebon Regency RTRW 2011-2031, were also implemented as a spatial direction. The designation of the area of the paddy field which should be protected is based on the results of the scenario on the rice food sufficiency model in The Cirebon Regency. Land with 1st and 2nd priority are categorized as land that should be protected in 2031, land with 3rd and 5th priority are the actual paddy field (business as usual scenario) in 2031 and the real conditions in 2019. Land with 4th priority is agriculture in wetlands according to the allocation of official land-use plan spatial.

3. Results and Discussion
The average mean error (AME) and the average variation error (AVE) value of each sub-model has been calculated. The results of the calculations indicated that AME and AVE values are below 10%. The model is so said to be valid [20]. The process of applying the scenario can so be carried out.

3.1. Scenario and direction matrix from dynamic sufficiency model
The scenario of business as usual conditions was built based on rice productivity. The rice productivity of land of S1 (highly suitable) class ranged between 6.22-7.10 tons ha⁻¹, for land of S2 (suitable) class were between 5.3-6.22 tons ha⁻¹ and for land of S3 (marginally suitable) classes were range from 5.30
to 1.70 tons ha\textsuperscript{-1}. In an optimistic scenario, land with S2 class can be increased to become S1 class, with improving it’s limiting factor. Again, in an optimistic scenario, land of S3 land class can be improved to become an S2 class with improving their limiting factor. The simulation model assumption in moderate as well as the optimistic scenario is presented in table 1.

| No | Scenario | Productivity (ton/ha) | Cropping index |
|----|----------|-----------------------|----------------|
| 1  | Business as usual | 7.10 | 1.70 |
| 2  | Moderate    | 6.66 | 1.95 |
| 3  | Optimistic  | 7.10 | 2.20 |

The business as usual condition is based on data sourced from CBS West Java Province in 2011-2017, which is the average productivity and cropping index in the Cirebon Regency for eight years (2010-2017). The moderate and optimistic scenario also considers the average productivity and cropping index of Indramayu, Majalengka, and Kuningan Regencies, which are regencies around Cirebon Regency in West Java Province. The results of expert judgment concerning ability to apply policy in Cirebon Regencies were also taking into account (table 2).

| No | Scenario | Protected Paddy field (ha) | Farmers (man) | Food sufficiency (ton) | Paddy field (ha) | Farmers income per capita per year (IDR/man/year) |
|----|----------|-----------------------------|---------------|-----------------------|------------------|---------------------------------------------|
| 1  | Business as usual | 21,802 | 103,162 | 94,000 | 50,249 | 18,463,086 |
| 2  | Moderate    | 22,848 | 58,174 | 46,099 | 43,619 | 30,288,948 |
| 3  | Optimistic  | 18,618 | 58,354 | 125,275 | 45,215 | 38,520,665 |

3.2. Modelling and simulation on Economic Sub-Model

The purpose of the economic sub-model is to see rice production in meeting the needs of rice in the study area, so that food sufficiency will be achieved (figure 2), an increase in average per capita income of farmers (figure 3), the need for area of rice fields that should be protected (figure 4).

A decrease in rice production and an increase in rice demand have an impact on the surplus of food availability, which is getting lower (low food sufficiency). This affects the Cirebon Regency contribution to the surrounding area. Based on this fact, it is necessary to increase productivity and cropping index on suitable and available land to achieve food sufficiency.
3.3. Modelling and simulation Social Sub-Model
The ownership of rice fields also influences the number of farmers. The decrease in rice field area of 470.6 ha annually reduces the number of farmers [14], because farmers prefer to work in other livelihoods (figure 5).
The application of moderate or optimistic scenarios can reduce the number of farmer’s downward trends until 2031 compared to business as usual conditions (figure 6). The simulation shows that in the business as usual conditions, the conversion of paddy fields will continue to occur until 2031. The application of moderate or optimistic scenarios requires more farmers so that this has an impact on the needs of the farmer more than in the business as usual condition.

**Figure 6.** Number of farmer projection to 2031 in detail

### 3.4 Modelling and Simulation Environment Sub Model

Simulation of the use of paddy fields shows that the area of paddy fields has declined from 53,536 ha in 2010 to 43,619 ha in 2031 (figure 7). The efforts to increase productivity and crop indexes through the application of moderate or optimistic scenarios in the economic sub-model also resulted in inhibiting of conversion of paddy fields to non-paddy fields. More intensive use of paddy fields than business as usual condition inhibits the conversion of paddy fields into non-paddy fields so that the conversion rate of paddy fields is under control.

**Figure 7.** Paddy field projection and simulation to 2031

### 3.5 Spatial direction to develop paddy field

One of the solutions to achieve food sufficiency for the Cirebon Regency is by establishing the regulation of Sustainable Food Agriculture Land (SFAL). Until now, the rule has not been established. Spatial directions to develop paddy fields based on suitability and availability of land can be considered
in its preparation. Priority scale is made tiered from the smallest to the most significant area. The actual area of paddy fields (business as usual condition) and paddy fields that should be protected are used as a reference. The area of paddy fields that should be protected is the minimum area used to produce rice to meet the food needs of the population of the Cirebon Regency. The actual land area of paddy fields (business as usual) is the area of land in real conditions and without the application of a scenario. The 1st and 2nd priorities were categorized as land that should be protected in 2031. The 3rd and 5th priority are the actual lands of paddy fields (business as usual conditions) in 2031 and 2019. The 4th priority is land with an allocation indicated in the Official Spatial Land-use Plan map (OSLUP Map) (table 3 and figure 8).

**Table 3. Spatial direction to develop paddy fields in Cirebon Regency**

| Space pattern in RTRW map                                      | Allocation in OSLUP map (ha) | Paddy fields (ha) | Spatial direction |
|----------------------------------------------------------------|------------------------------|-------------------|-------------------|
| Wetland agriculture                                            | 48,273                       | 18,618            | 1st Priority      |
| Protected paddy field in 2031 (Moderate)                       |                              |                   |                   |
| Protected paddy field in 2031 (Business as usual)               |                              | 4,230             | 2nd Priority      |
| Paddy field in 2031 (business as usual)                         |                              | 20,771            | 3rd Priority      |
| Paddy field according to allocation wetland agriculture         |                              | 4,654             | 4th Priority      |
| Paddy field in 2019 (business as usual)                         |                              | 1,035             | 5th Priority      |
| Total                                                           |                              | 49,308            |                   |

**Figure 8. Map of direction to develop paddy fields in Cirebon Regency**
4. Conclusion and Recommendation

4.1. Conclusion

The food sufficiency model has been built in this research, resulting in a value of AME and AVE less than 10% (valid). According to field conditions and paddy fields that should be protected, the model produces spatial directions to develop paddy fields for Cirebon Regency. The spatial delineation was obtained from land which is suitable, available, and conform with Official Spatial Land-use Plan. The 1st priority of paddy field which should be protected covers an area of 18,618 ha; the 2nd priority covers an area of 4,230 ha, lands with 3rd priority covers 20,771 ha, land with 4th priority covers an area of 4,654 ha and land with 5th priority covers an area of 1,035 ha. Such area can be proposed as Sustainable Food Agriculture Land (SFAL), which conforms with Law No. 41/2009 through a review process of Official Spatial Land-use Plan and determination of SFAL by local regulation.

4.2. Recommendation

Based on this research, government policy is needed for the establishment of Sustainable Food Agriculture Land in Cirebon Regency with a review of the Official Spatial Land-use Plan.

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