An analysis of irrigated paddy land contribution to maintain regional self-sufficiency of food (rice) at Bantul regency of the special province of Yogyakarta

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Abstract. Bantul Regency is a rice barn area for the Special Province of Yogyakarta. For a long time, this regency has been self-sufficient in rice. In the last five years, the conversion of irrigated rice fields has changed to become settlements at the rate of 81.2 ha a year as a result of the population growth rate of 2.04% a year. The study aimed to determine the contribution of irrigated land in maintaining regional rice self-sufficiency. The analytical methodology used applies the quantitative analytical description approach to estimate the rice supply-demand balance position for 2006-2015. The results were applied to predict the balance position for the next 10, 20, 30, 40 and 50 years with 10 scenarios. The results showed that this regency had surplus of rice in 2006-2015 with self-sufficiency rate of 1.08-1.28. The realistic scenario simulation results showed that the rate of population growth causes the rice deficit to be wider and faster to occur. To prevent the occurrence of the rice deficit, control of land conversion and control of the population must be carried out simultaneously. Land use change also had a high risk for irrigation activities carried out because it caused changes in the water balance, losses to irrigation network infrastructure, lack of water in Planting Season II and Planting Season III.

1. Introduction

In the Special Province Yogyakarta, area at Bantul Regency is one of the districts with the second widest rice field area after Sleman Regency, each of 13,066 ha and 21,324 ha. With the rapid development of the city, these two districts have a rapid decline of paddy fields area. In 2006-2015 at Bantul and Sleman is 81.2 and 120.5 ha per year, respectively [1]. Connected with the demand for rice, the consumption of rice is increasing as the population increases.

The population in Bantul Regency, in 2006 was 820,555, to 971,511 people in 2015, or the rate of population growth was 2.04% per year. Because there is almost no expansion of paddy fields and a significant increase in production in this district, this increase in population disrupts the availability of rice. The aim of research was to determine the contribution of irrigated land in maintaining regional rice self-sufficiency. The benefit of the research results can be used as a consideration for the competent authority to make decisions in terms of policy of local self-sufficiency of rice and legal protection of paddy fields.
2. Methodology

Research on food self-sufficiency has been carried out by several researchers, including by [2,3] with different focus and methodology. In Indonesia, the similar research was carried out by [4], focusing on landuse conversion impact on landscape provisioning service for rice sufficiency in Langkat Regency, the Province of North Sumatra. Here, an analytical methodology with quantitative and analytic description approach were used to estimate the balance of supply-demand of rice at Bantul Regency in the year of 2006-2015, continued to determine a local level of self-sufficiency of rice. Contribution of irrigated rice filed to local self-sufficiency of rice was calculated using thematic map with super imposed techniques. Then, the results were applied to predict 10 scenarios of the balance position of rice for the next 10, 20, 30, 40 and 50 years.

2.1. Population growth and decreasing of paddy field area

Population growth is calculated by the following arithmetic approach:

\[ Pt = Po (1 + r \cdot t) \]  

Where, \( Pt \) is number of population at \( t \), \( Po \) is initial population, \( r \) is population growth rate, and \( t \) is time in year.

For decreasing of paddy field area is calculated based on the following Equation 2:

\[ r = \frac{L_t - L_{t-1}}{L_{t-1}} \times 100\% \]  

Where, \( L_t \) is land area for year \( t \), \( L_{t-1} \) is land area for previous year’s, and \( r \) is rate of declining land area.

2.2. Level of local self-sufficiency

Level of local self-sufficiency at time \( t \) is used with following formula:

\[ NPK_t = \frac{NP_t}{NK_t} \]  

Where, \( NPK_t \) is level of local self-sufficiency at time \( t \), \( NP_t \) is net production at time \( t \), \( NK_t \) is consumption at time \( t \), and \( t \) is time. Prediction of rice consumption was calculated based on consumption figures in previous years, using the following formula:

\[ D = \frac{P \times RCi}{1000} \]  

Where, \( D \) is rice consumption per year (ton), \( P \) is number of population, \( RCi \) is Rice Consumption Index (kg/capita/year) and 1000 is conversion number.

To estimate rice production, following formulas is used:

\[ Lp = IP \times L \]  

Where, \( Lp \) is harvested area for one year (ha), \( IP \) is cropping index, \( L \) is planted area (ha).

\[ SI = \frac{Lp \times pr}{10} \]  

Where, \( SI \) is self-sufficiency index.
Where, $S_1$ is milled dry grain production a year (tons), $pr$ is productivity in quintal per ha (kw per ha) and 10 is conversion number.

$$S_2 = S_1 \times akg$$  \hspace{1cm} (7)

Where, $S_2$ is rice production a year (tons), $akg$ is conversion number from milled dry grain to rice.

3. Results and discussion

3.1. Research location and description

The research location is in Bantul Regency (Kabupaten), which is one of the districts in the Special Province of Yogyakarta. Administratively, the district is divided into 17 Sub-districts (Kecamatan), having total land area of 50,685 ha, which is divided into several functions. Figure 1 shows the land zoning that functions for agricultural cultivation covers around 15,206 ha or 30% of the total land area. Of that area, 13,077 ha or 86% are irrigated paddy fields, the rest is rainfed land. The area of non-paddy land occupies around 13,178 or 26% of the total land area functioning for dry land, community forests, ponds and freshwater fish ponds. Non-agricultural land occupies around 22,301 ha or 44% of the total land area, in the form of land for buildings and yards, state forests, and swamps (see Figure 1). In 2006-2016, the converted land was 812 ha from agricultural cultivated land (irrigated and rainfed rice fields) to residential and non-agricultural land in the rate of 81.2 ha per year.

![Agricultural Land Zoning at Bantul Regency, 2015](image)

**Figure 1.** Agricultural land zoning map of Bantul Regency

The climate character in this region falls into the wet tropical monsoon climate with range of yearly rainfall between 3000-3500 mm. There are two contrasting seasons, the rainy season (Oct-Apr) to the dry season (Apr-Oct). With this climate character, giving monthly potential evapotranspiration (ETo) ranged from 95 to 120 mm/month. If this monthly Eto is plotted with monthly rainfall, giving monthly surplus period in Oct-Apr and deficit in Apr-Oct, in line with two contrasting seasonal variations.
In this analysis, supply is more oriented to the total volume of rice production while demand is more emphasized in the total volume of rice consumption. During the last ten years (2006-2015), rice production in this Regency is quite high, supplying around 27% of rice for the Special Province of Yogyakarta. More than 99% of this rice production in this region is produced from irrigated rice fields and rainfed area with an average level of productivity of 64.34 kw/ha. The average rice consumption in the Regency in 2010 was 89.5 kg/cap/year, increasing to 98.1 kg/cap/year in 2011 and decreasing until in the year of 2015 to 91.2 kg/cap/year. The decreasing in rice consumption occurred due to a change in the menu from rice to cassava in some residents, especially those who live in Sub-districts (Kecamatan) where land is not available for agricultural cultivation.

By applying the available formula as mentioned above and using the basis of the population growth rate in this Regency of 2.04% per year, the average rate of rice consumption was used to estimate the total volume of rice consumption (tons). Likewise, the average production was used as a basis for calculating the volume of rice production (tons). The result is presented in Figure 2.

Figure 2. Supply-Demand of rice (2006-2015)

It is clear from the figure that rice is always surplus in this district. However, with a population growth rate of 2.4% and pressure for conversion of irrigated rice fields, it is certain that in the future this Regency will turn into a rice deficit.

3.2. Present Self-Sufficiency of Rice

Figure 3 shows the results of the calculation of the level of rice self-sufficiency (NPKt) in this Regency. During the past ten years (2005-2015) this Regency has been in a position of local self-sufficiency in rice, with the self-sufficiency rate between 1.08 to 1.28. The end year the self-sufficiency (2015) was 1.21. Role of the local government was very significant in achieving this position of this self-sufficiency. The local government encourages increased productivity by providing various types of subsidies in the form of agricultural equipment to farmer groups such as tractors, water pumps, hand sprayers, and others. This role is part of the national policy of the central government which emphasizes in infrastructure improvement, land optimization, provision of assistance for farming facilities and structuring human resources.

3.3. Prediction of Rice Availability and Needs

Table 1 shows the result of prediction of population growth using formula of arithmetic model as described above. The prediction was validated using actual data in 2006-2015.
Then the prediction was tested by ANOVA. The results show that there is no difference between real data and prediction data. Prediction of decreasing irrigated rice filed was carried out using the mathematical equation presented in the methodology. The result was validated by using actual data in 2006-2015. Then the prediction was also tested by ANOVA. Table 2 show the result that there is also no difference between actual data and prediction data. To predict the position of rice supply-demand in the future the simulation was made with several realistic scenarios based on the position of existing conditions (Scenario 0) with a decreasing irrigated land area of 81.2 ha/year and population growth of 2.04%/year (see Table 3).
For the supply scenario was carried out by considering a reduction of 60% of the irrigated land per year if the government manages to reduce the rate of land conversion and or open new rice fields, at 80% per year if the rate of change in land area does not change from the current position, and at 100% per year if large-scale land conversion occurs due to increase land requirements for housing, roads, fields, and so on. The demand scenario considers population growth at 1% per year if the government succeeds in controlling population through the Family Planning Program (Program Keluarga Berencana), at 2% per year if the population growth rate does not change and at 3% per year if there is a population explosion caused by declining mortality rates, high young age marriages, and high births that fail to control.

In simulating the 10 scenarios, the following zoning policy considerations were included, as follows: Zone 1, for irrigated rice fields that are not allowed to be converted, except in special conditions related to national and strategic interests. Zone 2, irrigated rice fields are allowed to be converted provided that these lands have to be replaced elsewhere with land capacity is not much different, and Zone 3 for irrigated rice fields is allowed to be converted with clear objectives and interests (see Figure 1 and Table 4).

Figure 4 shows the result for Scenario 0 of the existing condition of prediction of rice supply-demand for 2020-2050. It shows from the Figure 4 that starting from 2021 the Surplus (S) position ended, then changed to a Deficit (D). From these 10 Scenarios, the results of the prediction are obtained in the position of the year starting from the rice deficit between 2021 to 2030 (Table 5). Figures 5a and 5b show the two results of the longest year prediction Scenario. Scenario 1 starts the rice deficit in 2032 and Scenario 4 the rice deficit occurs in 2030.

Scenario 1 gets the year starting with the longest rice deficit, occurring in 2032. In this scenario, it was designed based on the assumption of population growth of 1% per year and the rate of decline in land area of 60 ha per year. The area decrease in this land occurs in Zone 1 estimated at 10 ha/year, Zone 2 at 20 ha/year, and Zone 3 at 30 ha/year (see Figure 5a). Scenario 4 is the second longest with a prediction of the year of rice deficit starting in 2030. In this scenario, it was designed based on the assumption of population growth of 1% per year and the rate of decline in land area of 80%. The decrease in land area that occurs in Zone 1 is estimated to be 15 ha/year, Zone 2 is 25 ha/year, and Zone 3 is 40 ha/year (see Figure 5b).
The prediction of the rice supply-demand in this area also proved that the rate of population growth causes the rice deficit to be wider and faster to occur. To prevent the occurrence of the rice deficit, control of land conversion and control of the population must be carried out simultaneously. Land use change also has a high risk for irrigation activities carried out because it causes changes in the water balance, losses to irrigation network infrastructure, lack of water in Planting Season II (March-June) and Planting Season III (July-October).

### Table 4. Area of land rice fields in each zone at the District, 2015

| Sub-district | Area Zona 1 | Area Zona 2 | Area Zona 3 |
|--------------|-------------|-------------|-------------|
|              | ha          | %           | ha          | %           | ha          | %           |
| 1. Srandakan | 185         | 1.2%        | 278         | 1.8%        | 0           | 0%          |
| 2. Sanden    | 583         | 3.8%        | 404         | 2.6%        | 0           | 0%          |
| 3. Kretek    | 486         | 3.2%        | 404         | 2.6%        | 0           | 0%          |
| 4. Pundong   | 804         | 5.3%        | 4           | 0.0%        | 0           | 0%          |
| 5. Bambanglipuro | 1061 | 6.9%            | 68          | 0.4%        | 0           | 0%          |
| 6. Pandak    | 957         | 6.3%        | 0           | 0.0%        | 0           | 0%          |
| 7. Bantul    | 708         | 4.6%        | 297         | 1.9%        | 0           | 0%          |
| 8. Jetis     | 1 116       | 7.3%        | 11          | 0.0%        | 0           | 0%          |
| 9. Imogiri   | 73          | 0.4%        | 175         | 1.1%        | 860         | 5.6%        |
| 10. Dlingo   | 0           | 0.0%        | 63          | 0.4%        | 839         | 5.5%        |
| 11. Pleret   | 333         | 2.1%        | 362         | 2.3%        | 0           | 0%          |
| 12. Piyungan | 102         | 0.6%        | 657         | 4.3%        | 451         | 2.9%        |
| 13. Banguntapan | 278    | 1.8%        | 717         | 4.7%        | 2           | 0%          |
| 14. Sewon    | 507         | 3.3%        | 670         | 4.4%        | 0           | 0%          |
| 15. Kasihan  | 76          | 0.5%        | 458         | 3.0%        | 29          | 0.1%        |
| 16. Pajangan | 0           | 0.0%        | 171         | 1.1%        | 102         | 0.6%        |
| 17. Sedayu   | 844         | 5.5%        | 60          | 0.4%        | 0           | 0%          |
| **Total Districts** | **8 113** | **53** | **4 796** | **32** | **2 284** | **15** |

The prediction of the rice supply-demand in this area also proved that the rate of population growth causes the rice deficit to be wider and faster to occur. To prevent the occurrence of the rice deficit, control of land conversion and control of the population must be carried out simultaneously. Land use change also has a high risk for irrigation activities carried out because it causes changes in the water balance, losses to irrigation network infrastructure, lack of water in Planting Season II (March-June) and Planting Season III (July-October).

### Table 5. Position of the year starts deficit for each Scenario

| No | Scenario | Position of the year starts deficit |
|----|----------|-------------------------------------|
| 1  | 0        | 2021                                |
| 2  | 1        | 2032                                |
| 3  | 2        | 2025                                |
| 4  | 3        | 2022                                |
| 5  | 4        | 2030                                |

| No | Scenario | Position of the year starts deficit |
|----|----------|-------------------------------------|
| 6  | 5        | 2024                                |
| 7  | 6        | 2022                                |
| 8  | 7        | 2029                                |
| 9  | 8        | 2024                                |
| 10 | 9        | 2022                                |

From the social aspect, with the two scenarios that produce the longest surplus time (Scenario 1 dan 4) people in this Regency should be able to get used to eating diversification with a carbohydrate menu other than rice. For the local government, there is still enough time to open new rice fields.
4. Conclusion and Recommendation

4.1. Conclusion

a) Using data from 2006-2015, Bantul Regency never Deficit (D) and even Surplus (S) of rice with variety of self sufficiency of rice ranging from 1.08-1.28. With the population growth rate of 2.04% per year and decreasing irrigated land area of 81.2 ha/year, it tends to reduce the level of sufficiency of rice. The irrigation network infrastructure rehabilitation program is able to increase the level of self-sufficiency. With the existing conditions (Scenario 0) the balance position of D and S is predicted only until 2021.

b) The simulation results with other 9 Scenarios based on population growth and changes in irrigated land area in three land use zones produced various levels of self-sufficiency of rice. There are two scenarios that produce years reaching a balance position between D and S, Scenario 1 and Scenario 4. Scenario 1 gets the year starting with the longest rice deficit, occurring in 2032. In this scenario, it is designed based on the assumption of population growth of 1% per year and the rate of decline in land area of 60 ha per year. The area decrease in this land occurs in Zone 1 is estimated at 10 ha/year, Zone 2 at 20 ha/year, and Zone 3 at 30 ha/year. Scenario 4 is the second longest with a prediction of the year of rice deficit starting in 2030. In this scenario, it is designed based on the assumption of population growth of 1% per year and the rate of decline in land area of 80%. The decrease in land area that occurs in Zone 1 is estimated to be 15 ha/year, Zone 2 is 25 ha/year, and Zone 3 is 40 ha/year.

4.2. Recommendation

To prevent the occurrence of the rice deficit, control of land conversion and control of the population must be carried out simultaneously. From the social aspect, with the two scenarios that produce the longest surplus time (Scenario 1 dan 4) people in this Regency should be able to get used to eating diversification with a carbohydrate menu other than rice. For the local government, there is still enough time to open new rice fields.

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