Climate stresses and its impact towards food sufficiency: a case in Bantul regency Yogyakarta-Indonesia

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Abstract. Biomass production is influenced by climate, soil, and water. The most uncontrolled factor is climate. Climate change increases the hazard of hydrometeorological disasters such as floods and drought which influences harvest area an agricultural commodity. This study was purposed to identify and analyze the impact of climate stress on food sufficiency in Bantul Regency, at Special Region of Yogyakarta. Later, it was applied to recommend a strategy in achieving food sufficiency in Bantul. Here, dynamic modeling was applied to simulate the supply and demand for food. Rice is staple food in Indonesia, so it was selected in the simulation of food sufficiency in this study. The modeling used rice production, population, urbanization, and rice field area data released by the Statistic Agency of Bantul. The range of data was 10 (ten) years i.e 2010 to 2019. MAPE (Mean Absolute Percentage Error) was used to validate the model. The MAPE of rice production was 8.36%, so the modelling of climate stresses and its impact towards food sufficiency was accepted. This study identified that food sufficiency in Bantul would finish in 2026. The increasing crop index from 2.34 to 3.00 could extend the period of food sufficiency up to 10 years.

1. Introduction
Rice is not only a staple food for nearly half of the world's population as a major daily source of calories and protein, but also a major source of employment and income for rural communities. Rice ranks second in agricultural production in most Asian countries [1]. As a country located in the disaster-prone ring of the fire region, Indonesia must continue to increase preparedness for possible disasters as well as potential food insecurity that is transient as a disaster impact. It is for the anticipation of increasingly unpredictable climate change anomalies that can lead to crop failure. Research on the factors affecting the rice availability ratio shows that rice stock, rice harvested area, land productivity, total rice consumption, and rice price affect the ratio of rice availability individually and as a whole [2].

Climate change is a global phenomenon that is a serious challenge to development in agriculture at this time and in the future [3]. Climate change affects productivity, widespread planting, and harvesting of food crops. Rising air temperature, changes in pattern and amount of rainfall, increase in salinity of groundwater, decrease plant productivity. Increasing frequency and intensity of extreme
climate (floods, droughts, and high winds), explosions of pests/diseases, and rising sea levels affect planting patterns, harvest indices, reducing the area of harvest area and area of agriculture [4–8].

The Bantul Regency is part of the Province of Special Region of Yogyakarta (DIY) with the second largest rice field area after Sleman Regency, covering 13,066 ha and 21,324 ha. The existence of rice fields supported by irrigation infrastructure in the Bantul Regency, Yogyakarta Province, has become an important role in the needs of rice, both for the Bantul regency itself and for provincial areas. Bantul Regency is also one of the granaries of rice production that contributes significantly to supporting the sustainability of regional rice self-sufficiency [9]. This study was purposed to identify and analyze the impact of climate stress on food sufficiency in Bantul regency, the Special Region of Yogyakarta.

2. Materials and methods
To identify and analyze the impact of climate stress on food sufficiency in the Bantul Regency, Special Region Yogyakarta. The impacts of climate change (La Nina and El Nino) in this study used a dynamic model approach built with two subsystems of supply and demand. Rice availability analysis based on productive rice fields in Bantul Regency. The data used is data on rice production, population, urbanization, and rice field area starting from 2010-2019. The data obtained from the Central Bureau of Statistics (BPS) and the Department of Agriculture and Food Crops Bantul Regency.

Validation of the model used the MAPE test (Mean Absolute Percentage Error) for comparing the behavior of the model and the real system. The MAPE test is one of the relative measures concerning percentage errors. The test was used to determine the suitability of the prediction result and the actual data [10].

The assumptions used in this study:
a. Due to the availability of data, the modeling of rice availability in The Bantul Regency focused on rice fields, production, and population.
b. The area of rice fields as a baseline used rice field area data in 2010 is 15,465 hectares [11].
c. Conversion of land function to non-agricultural land (processed data) in The Bantul Regency amounted to 391 hectares for ten years (2010-2019) with a land conversion rate of 0.28 %/year [11,12].
d. Reduce 2.43 % for each El Nino and 0.61 % increase in rice production for each La Nina event [13,14].
e. Changes of an El Nino event once every three years and La Nina once every five years [13, 14].
f. Crop index is the average ratio of harvest area with an area of irrigation planting in 2010-2019 of 2.34 [11,12].
g. Rice productivity is the production of dried grain rice harvest per hectare 60.18 quintals/hectare [12].
h. Rice for non-consumption needs namely rice for processed industry 0.56%, rice diluted 5.4%, need for seeds 0.9%, feed needs 0.44% [15].
i. Rice conversion 64.27% [12].
j. The Consumption of rice per capita per year in the Bantul Regency is 91.58 kg [12].
k. The baseline population used was 909,539 in 2010 [11].
l. The population growth rate from 2010 to 2019 was 1.3% [12].

3. Results and discussions
Yogyakarta Special Region Province has five districts and one municipality, one of which is the Bantul Regency. When viewed from the landscape, Bantul regency consists of a plain area located in the middle and hilly area located in the east and west, as well as the coastal area to the south. The condition of the landscape is relatively longitudinal from north to south. Geographically, Bantul Regency is located between 07°44’04” 08°00’27” South Latitude and 110°12’34” - 110°31’08” East Longitude. To the east, it is bordered by Gunungkidul Regency, to the north bordering Yogyakarta
City and Sleman Regency, to the west bordering Kulon Progo Regency, and to the south bordering the Indonesian Ocean. Bantul regency consists of 17 sub-districts and 75 villages [12].

3.1. Model

Based on the results of the study, the conceptual model of rice supply in the Bantul Regency present in Figure 1. In the conceptual model, there are two main loops, namely the production loop and the consumption loop.

![Figure 1. Causal Loop Diagram of rice availability model in Bantul Regency.](image1)

![Figure 2. Flow chart simulation of rice availability in The Bantul Regency.](image2)

The availability of rice in Bantul regency is influenced by production and consumption level. Rice production is influenced by the rice field area and productivity level. Rice fields are affected by the impact of La Nina and El Nino as well as conversion. Causal Loop Diagram of rice supply system in Bantul Regency developed into a dynamic system-based model that more complex in the form of Stock and Flow Diagram (SFD). The results of the development of the rice supply model in the Bantul Regency present in Figure 1 and Figure 2.

3.2. Model validation

The validation used the MAPE test on the simulation. The validation results are shown on Table 1. Table 1 shows that validation tests for land conversion, population, and consumption are very high accuracy levels with MAPE values 3.87, 0.18, and 1.81%. The accuracy rate of production is quite good (right) levels with a MAPE value of 8.36%. Based on this, the model that formed can be used to perform scenarios and produce simulation values that are close to real circumstances.

3.3. Scenario 1: no government policy implementation

In this scenario, there was no policy applied to the rice production system in Bantul regency. It assumed that there is no increase in the rice field area, no addition of agricultural land conversion, no increase in crop index, and rice productivity. The results of the simulation of scenario without policy implementation show in Table 2. The trend of rice availability present in Figure 3.

Furthermore, in the picture, it is also seen that the availability of rice in Bantul can still meet the needs of the people consumption until 2026 (surplus conditions). However, from 2027 to 2050, Bantul will have a shortage of rice (deficit). The decline in the rice balance sheet will affect the performance of rice self-reliance in Bantul. In the period 2020 to 2026 (six years) The Bantul rice self-sufficiency index will decrease drastically to 1.46%. This shows that rice production in Bantul Regency in 2027 will no longer be able to meet the needs of people’s consumption.
The effort that should be made by the policymakers is to immediately create a policy to maintain the balance between the production sub-system (supply) and the consumption sub-system (demand). In the production sub-system, the government can carry out the policy through the intervention of the addition of rice fields, the implementation of decreasing land conversion, increasing crop index, and increasing crop productivity. In the consumption sub-system, the government can carry out the policy of suppressing population growth with a decrease in the birth rate through family planning programs and delays in the marriage age. Another policy that can reduce rice consumption is diversifying the consumption of staple foods through a decrease in the per capita rice consumption.

Table 1. Validation of rice availability model in Bantul Regency due to climate stress.

| Year | Rice field Data | Rice field Simulation | Production Data | Production Simulation | Population Data | Population Simulation | Consumption Data | Consumption Simulation |
|------|-----------------|-----------------------|----------------|-----------------------|-----------------|-----------------------|----------------|-----------------------|
| 2010 | 15,465.00       | 15,465.00             | 113,327.07     | 129,749.59            | 909,539         | 909,539.00            | 83,295.58      | 84,194.70             |
| 2011 | 15,453.00       | 15,516.12             | 118,088.29     | 130,178.47            | 922,104         | 921,635.87            | 84,446.28      | 85,395.06             |
| 2012 | 15,482.00       | 15,567.40             | 122,472.38     | 130,608.76            | 934,674         | 933,893.63            | 85,597.44      | 86,623.27             |
| 2013 | 15,471.00       | 15,151.14             | 124,863.32     | 127,116.32            | 947,072         | 946,314.41            | 86,732.85      | 87,881.17             |
| 2014 | 15,191.00       | 15,108.77             | 115,012.69     | 126,760.89            | 959,445         | 958,900.39            | 87,865.97      | 89,170.85             |
| 2015 | 15,225.00       | 14,311.57             | 118,766.39     | 123,371.35            | 971,511         | 971,653.77            | 88,970.98      | 90,494.58             |
| 2016 | 15,332.00       | 14,318.73             | 107,704.49     | 120,072.44            | 983,527         | 984,576.76            | 90,071.40      | 91,854.93             |
| 2017 | 15,160.00       | 14,278.69             | 108,902.64     | 120,469.32            | 995,264         | 997,671.63            | 91,146.28      | 93,254.78             |
| 2018 | 15,205.00       | 13,896.88             | 111,746.10     | 120,132.48            | 1,006,692       | 1,010,940.67          | 92,192.85      | 94,697.24             |
| 2019 | 15,074.00       | 13,858.02             | 111,984.80     | 119,796.57            | 1,018,402       | 1,024,386.18          | 93,265.26      | 96,185.93             |

MAPE (%) 3.87 8.36 0.18 1.81

Source: BPS Bantul Regency and the data is processed

Table 2. Rice availability with no policies.

| Year | Rice Field | Production | Consumption | Balance |
|------|------------|------------|-------------|---------|
| 2020 | 13,896.88  | 116,593.25 | 97,724.77   | 18,868.47 |
| 2025 | 13,456.48  | 112,898.32 | 106,346.19  | 6,552.13  |
| 2030 | 12,717.17  | 106,695.62 | 117,163.58  | -10,467.96|
| 2035 | 12,314.15  | 103,314.35 | 131,594.50  | -28,280.15 |
| 2040 | 11,637.61  | 97,638.19  | 152,149.25  | -54,511.06 |
| 2045 | 11,268.80  | 94,543.96  | 183,287.77  | -88,743.81 |
| 2050 | 10,649.69  | 89,349.66  | 232,949.54  | -143,599.88 |

Source: Dynamic model analysis with Powersim 10 (2020).

The effort that should be made by the policymakers is to immediately create a policy to maintain the balance between the production sub-system (supply) and the consumption sub-system (demand). In the production sub-system, the government can carry out the policy through the intervention of the addition of rice fields, the implementation of decreasing land conversion, increasing crop index, and increasing crop productivity. In the consumption sub-system, the government can carry out the policy of suppressing population growth with a decrease in the birth rate through family planning programs and delays in the marriage age. Another policy that can reduce rice consumption is diversifying the consumption of staple foods through a decrease in the per capita rice consumption.

Figure 3. Rice availability and Rice Needs without no government policies.

Figure 4. Rice availability and Rice Needs with decreasing land conversion.
needs with technology, irrigation networks, availability of rice production and the increase of rice reached 89,349.66 tons. It strengthened the rice self-sufficiency by conducting simulations through the scenario of increasing the planting area by an average of 39.1 hectares per year, the plan of cultivation technology, and the empowerment of farmers groups. The rice production improvement reached 6.8 tons/ha. In the period 2010 to 2050, the implementation of productivity improvement policy was able to strengthen the rice self-sufficiency index. The rice production increased from 1.46% to 2.56%. It affected the achievement of the rice self-sufficiency index increased from 1.46% to 2.56%. Changes and shifts in trend patterns show in Figure 4.

This policy will be successful if implemented with adequate guidelines and instructions. It has to have to be accompanied by support for the provision of agricultural facilities and infrastructure such as fertilizer availability, improvement of cultivation technology, irrigation networks, availability of superior seed, machinery technologies, and the empowerment of farmers groups.

### 3.4. Scenario 2: land resource utilization policy

Interventions in the model by conducting simulations through the scenario of increasing the planting area can be implemented through the addition of the rice field area as well as an increase in the cropping index. This model explains that land conversion affects the availability of rice in the future. Without any intervention and breakthrough through scenario changes, with the land conversion that occur with an average of 39.1 hectares per year, the planting area has decreased dynamically. The condition of decreasing rice supply due to pressure from lowland conversion is by the results of previous studies [9,16].

#### Table 3. Rice availability with decreasing land conversion

| Year | Rice Fields | Production | Consumption | Balance |
|------|-------------|------------|-------------|---------|
| 2020 | 13,896.88   | 116,593.25 | 97,724.78   | 18,868.47 |
| 2025 | 13,578.14   | 113,919.04 | 106,346.19  | 7,572.86 |
| 2030 | 12,948.17   | 108,633.68 | 117,163.58  | -8,529.90 |
| 2035 | 12,651.19   | 106,142.04 | 131,594.50  | -25,452.47 |
| 2040 | 12,064.23   | 101,217.50 | 152,149.25  | -50,931.75 |
| 2045 | 11,787.52   | 98,895.95  | 183,287.77  | -84,391.82 |
| 2050 | 11,240.63   | 94,307.60  | 232,949.54  | -138,641.94 |

Source: Dynamic model analysis with Powersim 10 (2020)

Based on Table 3, it shows in 2050 rice production 94,307.60 tons. An increase of 4,957.94 tons compared to without an increased rice production scenario that only reached 89,349.66 tons. It indicated that the implementation of increased rice production by 5.55%. It affected the achievement of the rice self-sufficiency index increased from 1.46% to 2.56%. Changes and shifts in trend patterns show in Figure 4.

3.5. Scenario 3: productivity improvement policy

In the period 2010-2019, the average rice production reached 6.34 tons/ha while the highest productivity reached 6.8 tons/ha. In the period 2020 to 2050, the implementation of a productivity improvement policy of 6.8 tons/hares will increase rice production and the rice self-sufficiency index. The rice production increase and the ability of rice supply in the next 50 years show in Table 4.

Based on Table 4, the production of rice in 2050 increases to 100,960.08 tons or up 13% compared to without the policy. Furthermore, the increasing productivity policy was able to strengthen the rice
self-sufficiency index by 8.8% (from the previous -61.6%, if without increase productivity policy). Thus, the condition of surplus rice increases over five years from the scenario without it. The trend pattern of the rice supply of Bantul Regency is present in Figure 5. Efforts for policymakers that can be made related to the increase of rice in Bantul Regency are the use of superior seeds, the use of balanced fertilizers, the use of supporting production facilities, and the application of a post-harvest handling system.

Table 4. Rice availability with the implementation of productivity improvement policy

| Year | Production | Consumption | Balanced |
|------|------------|-------------|----------|
| 2010 | 129,749.59 | 84,194.70   | 45,554.89|
| 2015 | 123,371.35 | 90,494.58   | 32,876.77|
| 2020 | 131,743.79 | 97,724.78   | 34,019.01|
| 2025 | 127,568.72 | 106,346.19  | 21,222.53|
| 2030 | 120,560.02 | 117,163.58  | 3,396.44 |
| 2035 | 116,739.37 | 131,594.50  | -14,855.13|
| 2040 | 110,325.64 | 152,149.25  | -41,823.60|
| 2045 | 106,829.33 | 183,287.77  | -76,458.43|
| 2050 | 100,960.08 | 232,949.54  | -131,989.45|

Source: Dynamic model analysis with Powersim 10 (2020).

3.6. Scenario 4: increasing crop index
Based on BPS data from 2010 to 2019, the average crop index was 2.34. In the same period, there was an increase in the crop index by an average of 1.2% per year. Assuming optimistically that in 2020 and beyond, policies can be implemented that can increase the crop index by 3, the ability to supply rice will increase as shown in Table 5.

Table 5. Rice availability with the implementation of increasing crop index.

| Year | Production | Consumption | Balance |
|------|------------|-------------|---------|
| 2010 | 129,749.59 | 84,194.70   | 45,554.89|
| 2015 | 123,371.35 | 90,494.58   | 32,876.77|
| 2020 | 156,952.46 | 97,724.78   | 59,227.68|
| 2025 | 151,978.50 | 106,346.19  | 45,632.32|
| 2030 | 143,628.72 | 117,163.58  | 26,465.13|
| 2035 | 139,077.00 | 131,594.50  | 7,482.50 |
| 2040 | 131,436.03 | 152,149.25  | -20,713.21|
| 2045 | 127,270.72 | 183,287.77  | -56,017.05|
| 2050 | 120,278.39 | 232,949.54  | -112,671.12|

Source: Dynamic model analysis with Powersim 10 (2020).

Efforts for policymakers that can be made related to the improvement of rice supply capability in the Bantul Regency are by increasing rice production through the use of superior seeds, the use of balanced fertilizers, the use of supporting production facilities, and the application of post-harvest handling system.

4. Conclusion and remarks
The dynamic rice availability model in Bantul Regency taking into account changes in land area and potential crop failure due to climate stresses (La Nina and el Nino). The model proved a good level of accuracy to predict the availability of rice in Bantul district. From several single scenarios used, the
scenario of increasing the crop index 3.00 has a significant influence on the ability of Bantul district to provide rice until 2036. For further research, several combined scenarios should be considered to get the most fit of it.

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