Spatial Analysis of Sustainable Management Strategy in Bedog Sub-watershed Based on Carrying Capacity of Agricultural Land

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Abstract. Over the last ten years, the Bedog Sub-watershed area has continued to develop into an urban area. Along with these developments, land-use change processes occurred in the Bedog Sub-watershed area, especially the reduction in agricultural land, which was depressed by population growth. For this reason, the purpose of this study is to identify population pressure on agricultural land, identify the carrying capacity of agricultural land, and develop sustainable management strategies based on the carrying capacity of agricultural land in the Bedog Sub-watershed. The calculation method utilized was the measurement of population pressure on agricultural land and the carrying capacity of agricultural land, analyzed spatially with distribution maps. The sustainable management strategy was then formulated through the SWOT method. Overall, in the Bedog Sub-watershed, the carrying capacity of agricultural land was low, while population pressure on agricultural land was high. Thus, sustainable management strategies in the Bedog Sub-watershed can be carried out by increasing land productivity, diversifying non-agricultural jobs, empowering farmers, optimizing land use, and innovating environmentally friendly agricultural technology.

Keywords: Strategy, Sustainable, Carrying Capacity of Agricultural Land

1. Introduction

The Bedog Sub-watershed has developed, which tends to have more urban characteristics over time. At least, for the last ten years, the Bedog Sub-watershed area has continued to experience urban development [1]. These developments involve not only urban activities but also other activities that have long developed in the area, such as agricultural activities. Along with these developments, land-use change processes continue to occur in the Bedog Sub-watershed area, especially the decreased amount of agricultural land [2]. The decrease in the area took place due to conversion into residential and residential land [1]. This conversion happened since the middle part of the Bedog Sub-watershed is part of the Yogyakarta urban agglomeration, one of the growth centers in the Special Region of Yogyakarta.
and the Java Island [3]. In other words, the continued urbanization in the region has led to massive land-use changes.

On the other hand, population pressure is the urge to clear land or/and go to the cities [4]. Along with urban developments in the Bedog Sub-watershed, the studies on population pressure are becoming increasingly relevant. In addition, the Bedog Sub-watershed itself is one of the areas in the growth center, developing into an increasingly densely populated and built-up area. Thus, the need for non-agricultural land is increasing, causing a lot of land conversion, especially rice fields [5]. The problem of converting agricultural land becomes widely related when studied together with the concept of population pressure and the phenomenon of urban development. It is because the conversion of agricultural land to non-agriculture will have a negative impact on the environment, which will have a long-lasting impact on reducing the level of food security [6]. Therefore, the problems in the Bedog Sub-watershed so far require the right strategy for realizing sustainable regional management. The strategy accommodates social problems, such as urbanization and population pressure. For this reason, this study aims to identify the level of carrying capacity of agricultural land in the Bedog Sub-watershed and then develop a management strategy in the Bedog Sub-watershed to achieve sustainability.

2. Methods

2.1. Population Pressure on Agricultural Land

Measurement of population pressure on agricultural land is an activity to compare the population in an area to the minimum area of agricultural land to achieve a decent life [4]. The calculation of population pressure on agricultural land Model I began with measuring land area for a decent living for farmers (Z), calculated by the following formula:

\[
Z = (0.25 \times \text{LSI2}) + (0.5 \times \text{LSI1}) + (0.5 \times \text{LST}) + (0.76 \times \text{LLK})
\]

\[
\text{TK} = Z \times f \times \frac{\text{Po} (1+r)^t}{L}
\]

Information:

- Z = Minimum land area for a decent living (ha/person)
- LSI2 = Area of irrigated rice fields harvested two times a year (ha)
- LSI1 = Area of irrigated rice fields harvested once a year (ha)
- LST = Area of rainfed rice fields (ha)
- LLK = Dry land area (ha)

This study employed the technique of measuring population pressure on agricultural land with the assumption that the population in the study area only lived from the production of cultivated agricultural land, so that the formula for calculating population pressure on agricultural land was Model I [4].
The variables used in measuring population pressure on agricultural land in the Bedog Sub-watershed are presented in Table 1.

| Sub-district | Z value | f value | Po value | R value | L value |
|--------------|---------|---------|----------|---------|---------|
| Pakem        | 0.53    | 0.11    | 511      | 1.25    | 27.38   |
| Turi         | 0.71    | 0.10    | 22042    | 0.41    | 1687.17 |
| Slemang      | 0.43    | 0.08    | 31533    | 0.98    | 921.83  |
| Mlati        | 0.48    | 0.05    | 35928    | 1.56    | 602.81  |
| Gamping      | 0.44    | 0.03    | 67307    | 1.52    | 802.53  |
| Godean       | 0.43    | 0.07    | 3994     | 1.14    | 100.04  |
| Kasihan      | 0.44    | 0.03    | 77480    | 1.9     | 445.38  |
| Pajangan     | 0.54    | 0.10    | 13004    | 1.23    | 120.15  |
| Bantul       | 0.40    | 0.07    | 3295     | 0.89    | 65.84   |
| Sewon        | 0.41    | 0.05    | 7984     | 1.44    | 120.54  |
| Pandak       | 0.40    | 0.11    | 5654     | 0.48    | 129.14  |
| Bedog Sub-watershed | 0.49    | 0.05    | 255234   | 1.16    | 5421.42 |

Source: Data processed, 2021

2.2. Agricultural Land Carrying Capacity

Furthermore, it is also necessary to take into account the amount of land carrying capacity (LCC/DDL) of agriculture, which is a ratio of one per of the value of population pressure on agriculture with the following formula.

$$DDL = \frac{1}{TK}$$

**Figure 3.** The formula for calculating the land carrying capacity of agriculture

**Information:**

$$DDL = \text{Land Carrying Capacity}$$

$$TK = \text{Population Pressure on Agricultural Land}$$

The results of the score calculation of the land carrying capacity (DDL) of agriculture are classified into three:

- DDL > 1 : High carrying capacity of agricultural land
- DDL = 1 : Optimum agricultural land carrying capacity
- DDL < 1 : Low carrying capacity of agricultural land

Descriptive analysis of the calculation results for population pressure (TK) and land carrying capacity (DDL) of agriculture was then analyzed spatially and presented in the form of a map.

3. Results and Discussions

Integrated watershed management requires comprehensive management by various stakeholders, encompassing the population, business community, and local government, with the integration, equality, and commitment principles to managing fair, effective, efficient, and sustainable natural resources. In this regard, the population is one of the stakeholders since population growth and economic development are factors causing the acceleration of watershed damage due to the use of natural resources resulting from population growth. The low carrying capacity of the watershed as an ecosystem causes the potential
for natural disasters to occur [7]. Therefore, the assessment of the carrying capacity of agricultural land in the Bedog sub-watershed obtained from the measurement of population pressure on agricultural land and land area for decent living is important to analyze the level of carrying capacity of the Bedog sub-watershed. By analyzing the carrying capacity of agricultural land in the Bedog sub-watershed, a priority strategy for managing the sub-watershed can be drawn up.

3.1. Minimum land area for decent living

Land area for a decent living for farmers is one of the variables measuring population pressure on agricultural land [4]. There are four types of rice fields that need to be known for their land area to measure the land area for a decent living for farmers, including the area of once a year harvested rice field, the area of twice a year harvested rice fields, the area of rainfed rice fields, and the area of dry land (moor). In addition, the existing agricultural land area is one of the important variables for the criteria for determining and changing the function of sustainable food agricultural land. The first criterion is to have a certain area of land, and the second is to produce staple food whose production is sufficient for the local community, in this case, the sub-district level in the sub-watershed [8]. Thus, it is crucial to know the area of agricultural land in the Bedog Sub-watershed for consideration of determining policies, especially regarding sustainable food-agricultural land, which also supports the research objective of achieving a sustainable Bedog Sub-watershed. Besides, various parties need agricultural land, especially farmers who produce food as a livelihood and survival. Therefore, it is necessary to know the land area for a decent living for farmers to measure population pressure on agricultural land.

| Sub-district | LSI 2 (Ha) | LSI 1 (Ha) | LST (Ha) | LLK (Ha) | Zt |
|--------------|------------|------------|----------|----------|----|
| Pakem        | 12.58      | 0.00       | 0.00     | 14.80    | 0.53 |
| Turi         | 157.89     | 2.96       | 0.00     | 1526.32  | 0.71 |
| Sleman       | 581.55     | 15.75      | 0.00     | 324.53   | 0.43 |
| Mlati        | 334.37     | 0.00       | 0.00     | 268.43   | 0.48 |
| Gamping      | 496.92     | 0.00       | 0.00     | 305.61   | 0.44 |
| Godean       | 65.04      | 0.00       | 0.00     | 35.00    | 0.43 |
| Kasihan      | 275.41     | 0.00       | 7.57     | 110.76   | 0.40 |
| Pajangan     | 24.54      | 26.70      | 25.26    | 181.49   | 0.66 |
| Bantul       | 46.59      | 0.00       | 0.00     | 0.15     | 0.25 |
| Sewon        | 80.73      | 3.26       | 0.00     | 0.00     | 0.26 |
| Pandak       | 90.01      | 0.00       | 1.41     | 4.67     | 0.28 |
| Bedog Sub-watershed | 2797.47 | 51.04 | 30.66 | 2271.23 | 0.48 |

Source: Sleman and Bantul District Agriculture Office, 2021

In the Bedog Sub-watershed, the area of twice a year harvested rice fields is 2,797.47 hectares, the area of once a year harvested rice fields is 51.04 hectares, the area of rainfed rice fields is 30.66 hectares, and the area of dry land is 2,271.23 hectares. In Table 2, the data on the area of rice fields based on the irrigation type was used to measure the area of land for a decent living for farmers (Z). The Z-value in the Bedog Sub-watershed was 0.48 ha/person, while for the 11 sub-districts in the Bedog Sub-watershed, there was a variation in the Z-value. The Z-value owned by the Bedog Sub-watershed belonged to medium, meaning that it is not too big or small. The highest Z-value of 0.71 ha/person was in Turi Sub-district. In this case, the higher the Z-value, the higher the land area for a decent living for farmers, closely related to population pressure on agricultural land, which will also have a high number. [4]. Areas with high Z-value, such as in Turi, need to increase their rice production or introduce plant species with high values to reduce the Z-value.
This study also compares with previous research at [9], which states that there are three main aspects of food security, namely availability, food access, and food absorption. Urban Area Determination Yogyakarta resulted in Bantul Regency experiencing a shortage of land to establish as Sustainable Food Agricultural Land. The existing area of KPY’s agricultural land ± 3,600 hectares, while Agricultural Land Sustainable Food to be established 13,000 hectares of the total land area agriculture in Bantul Regency ± 15,000 hectares. This means that Bantul Regency has experienced lack of agricultural land area of ± 1,600 hectares, not including the area of land reserves or buffer that must also be allocated when there is a transfer of function to the land Sustainable Food Agriculture as a result natural disasters or land acquisition for development in the public interest. So that the results of these two studies require a regulation regarding the direction and policy of protecting sustainable food agricultural land in a holistic and integrated manner, involving all relevant parties, both the government, capital owners and the community.

3.2. Population Pressure on Agricultural Land

An area, whether it is sub-watershed coverage or certain administrative boundaries in which the availability of regional resources is insufficient to meet the population's needs, shows the occurrence of population pressure, which is a symptom of the occurrence of overpopulation [10]. This phenomenon is the result of a situation where the population growth rate continues to increase. The measurement of population pressure on agricultural land can ultimately be used for further analysis, namely the land’s carrying capacity or ability to meet the population's need for food [11]. In addition, as the inability of the regions to meet their needs indicates the occurrence of population pressure on agricultural land, the residents will look for new jobs outside the agricultural sector or even move to other areas that can support the sufficiency of the population's food needs.

The measurement results of population pressure on agricultural land in the Bedog Sub-watershed in 2020 showed that the Bedog Sub-watershed experienced a high population pressure level. It was because almost every sub-district experienced high population pressure on agricultural land, except in Turi Sub-district, Bantul Sub-district, and Pandak Sub-district, which experienced population pressure in the moderate class (Table 3). Concerning this, the increasing population growth rate causes a decrease in the ratio of land to population (mainland ratio) [4] since the high population presses the land due to the conversion of agricultural land to non-agriculture, especially settlements. Population pressure can also result in reduced farmers due to shifting jobs outside the agricultural sector. If exacerbated by agricultural land that no longer supports the population, this condition can cause structural unemployment due to farmers moving to new jobs but are not ready to adapt to new job opportunities.

| Sub-district | Population Pressure value | Classification of Population Pressure | Class |
|--------------|---------------------------|--------------------------------------|-------|
| Pakem        | 2.46                      | TP > 2                               | High  |
| Turi         | 1.35                      | 1 < TP < 2                           | Moderate |
| Sleman       | 2.35                      | TP > 2                               | High  |
| Mlati        | 3.65                      | TP > 2                               | High  |
| Gamping      | 3.00                      | TP > 2                               | High  |
| Godean       | 2.65                      | TP > 2                               | High  |
| Kasihan      | 6.04                      | TP > 2                               | High  |
| Pajangan     | 16.42                     | TP > 2                               | High  |
| Bantul       | 1.60                      | 1 < TP < 2                           | Moderate |
| Sewon        | 2.07                      | TP > 2                               | High  |
| Pandak       | 1.97                      | 1 < TP < 2                           | Moderate |
| Bedog Sub-watershed | 2.67                  | TP > 2                               | High  |

Source: Data processed, 2021
In this case, spatial analysis can describe the distribution of population pressure on agricultural land in the Bedog Sub-watershed. The pattern formed from observations of the population pressure distribution map on agricultural land in the Bedog Sub-watershed in 2020 depicted that the upstream (north) and downstream (southern) areas had moderate population pressure (Figure 4). The analysis results also showed that the sub-districts that experienced moderate-class population pressure were only in Turi, Bantul, and Pandak Sub-districts, while the rest experienced high-class population pressure. This result aligns with previous research, which found the increased number of houses included in the medium class in Pandak, Bantul, Jetis, Imogiri and Sedayu Sub-districts [12]. It further strengthens that the population pressure in the Bantul and Pandak Sub-districts was in the medium class since the population growth by the increased number of houses approach was also in the moderate increase class. Based on previous research at [9], the level of land fertility in the area is at a moderate to high level, and is known as a rice-producing center in Bantul Regency. This cannot be separated from the level of land conversion which is quite low when compared to the sub-districts designated as Yogyakarta Urban Areas and the land in these sub-districts is suitable for wetland agricultural cultivation. Regional spatial planning regulations in Bantul Regency also have a hand in turning these sub-districts into rice granaries.

Figure 4. Map of the Distribution of Population Pressure on Agricultural Land in Bedog Sub-watershed 2020

Source: Data processed, 2021
Further analysis of population pressure on agricultural land needs to be related to the carrying capacity of agricultural land where population pressure occurs because the population has exceeded the land's carrying capacity [14]. As long as the area of agricultural land remains the same and its productivity does not increase even though population growth continues to increase in absolute terms, population pressure on agricultural land will continue to occur. The long-term impact is that there is a shock to the existence of people's lives due to very high dependence on land and pushes farmers out of their profession to earn income from other sectors. In this study, the condition of population pressure, which was dominated by high levels of population pressure in the sub-districts and the entire Bedog Sub-watershed, posed a threat to achieving a sustainable Bedog Sub-watershed. It was because the availability of food could no longer meet the population's food needs. Thus, strategies that can be taken to maintain population pressure on agricultural land according to [4] include increasing production to reduce land requirements, increasing income outside the agricultural sector, reducing the number of farmers, increasing benefits for farmers through cheap credit and cooperatives, expanding agricultural land, and reducing population growth rates.

3.3. Agricultural Land Carrying Capacity

Population pressure on agricultural land in the Bedog Sub-watershed, which has been known from previous measurements, was further utilized to measure the carrying capacity of agricultural land in the Bedog Sub-watershed. Regarding this, there is an inversely proportional pattern between population pressure and land carrying capacity, where the higher the level of population pressure, the lower the level of land carrying capacity [15]. The high population pressures the land because increasing humans will add to the burden of consumption per capita, while the development of technological innovation could only increase the efficiency of the use of natural resources but does not increase the carrying capacity of agricultural land [16]. Besides, the analysis of the land's carrying capacity is related to the assessment of the land compared to the existing population pressure, whether agricultural land is still able to support the lives of people who depend on agricultural land.

However, the quality of land in each area is different, which affects the level of land suitability for certain uses, which can be a limiting factor for management to achieve optimal production. Therefore, the management of the Bedog Sub-watershed also needs to pay attention to the carrying capacity of the agricultural land to achieve a sustainable balance of the Bedog Sub-watershed pattern. The commodity used as one of the benchmarks is rice. An area is categorized as good if the ratio of rice production per capita is above 0.13 tons of rice/person/year, the assumption is that the average consumption value is 130 kg/capita/year [9].

| Sub-district | Carrying Capacity value | Classification of Carrying Capacity |
|--------------|-------------------------|-------------------------------------|
| Pakem        | 0.41                    | DDL < 1 (Low land carrying capacity) |
| Turi         | 0.74                    | DDL < 1 (Low land carrying capacity) |
| Sleman       | 0.43                    | DDL < 1 (Low land carrying capacity) |
| Mlati        | 0.27                    | DDL < 1 (Low land carrying capacity) |
| Gamping      | 0.33                    | DDL < 1 (Low land carrying capacity) |
| Godean       | 0.38                    | DDL < 1 (Low land carrying capacity) |
| Kasihan      | 0.17                    | DDL < 1 (Low land carrying capacity) |
| Pajangan     | 0.06                    | DDL < 1 (Low land carrying capacity) |
| Bantul       | 0.63                    | DDL < 1 (Low land carrying capacity) |
| Sewon        | 0.48                    | DDL < 1 (Low land carrying capacity) |
| Pandak       | 0.51                    | DDL < 1 (Low land carrying capacity) |
| Bedog Sub-watershed | 0.37 | DDL < 1 (Low land carrying capacity) |

Source: Data processed, 2021
In this study, the measurement results of the land's carrying capacity in the Bedog Sub-watershed revealed that overall, the Bedog Sub-watershed had a low agricultural land carrying capacity (DDL < 1). This condition also occurred in the analysis by sub-districts in the Bedog Sub-watershed, which uncovered that DDL of agriculture was low class (Table 4). However, the sub-district with the highest DDL value was Turi Sub-district with 0.74 DDL, closest to 1 (Table 4). Thus, the Turi sub-district is considered to have the highest land carrying capacity compared to the DDL value. Meanwhile, agriculture in other sub-districts in the Bedog sub-watershed indicates that the land was still quite available.

Further, all Bedog Sub-watersheds had a low carrying capacity of agricultural land, so spatial analysis of distribution per sub-district was in the same class, namely, low DDL of agriculture, as presented in the distribution map of land carrying capacity of agricultural land in the Bedog Sub-watershed in 2020 (Figure 5). Low land carrying capacity indicates that there is a use that exceeds the land's carrying capacity, resulting in inefficiency. It can have a long-term impact on land damage, especially in this case, the potential for degradation of agricultural land in the Bedog Sub-watershed due to overexploitation of the population that continues to suppress. In terms of the carrying capacity of land in an area, the ability and suitability of land are assessed by comparing the carrying capacity of the land (supply) and the value of benefits (demand) to assess its feasibility [16]. Thus, the low value of DDL of agriculture in the Bedog Sub-watershed has not been able to conclude the feasibility of using land in the Bedog Sub-watershed for management to realize a sustainable Bedog Sub-watershed.

![Figure 5. Map of the Distribution of Carrying Capacity of Agricultural Land in Bedog Sub-watershed 2020](source: Data processed, 2021)

In this case, the land's carrying capacity, which includes describing the characteristics and quality of the land, is not used directly for the evaluation of land resources but requires a comprehensive analysis to develop sustainable management policies [17]. It is because land use that changes irregularly causes a decrease in the function of biological productivity and the diversity of ecosystems on land [18]. In Indonesia, the area of agricultural land and productivity on the growth of lowland rice production tends to decrease so that the planting intensity factor plays a vital role in agricultural management strategies [19]. Hence, the management of the Bedog sub-watershed should be sustainable to overcome the low carrying capacity of the land by optimizing the cropping pattern, where planting intensity is the key to increasing the carrying capacity of agricultural land.
3.4. *Bedog Sub-watershed Management Strategy Related to the Carrying Capacity of Agricultural Land*

The analysis of the Bedog Sub-watershed management requires the right strategy with the cooperation of various stakeholders. To formulate a strategy, it is necessary to understand the general condition of population and agricultural land in the Bedog Sub-watershed. To meet the needs and potential of agriculture in the Bedog sub-watershed, it must also be assessed based on the area of land and the number of farmers available. It can be used as a step to take a strategy to create a food surplus. Without farmers, food production will decline as the population increases. Based on the graph (Figure 6), it can be seen that the Turi and Gamping Sub-districts had extensive agricultural land, but the number of residents who became farmers was still very low. It could be a threat in Turi and Gamping Sub-districts as they could not use the land properly for their residents. In fact, it also happens because the younger generation does not want to continue working in the agricultural sector. Then, for the Godean, Pakem, Sewon, Bantul, Pajangan and Pandak Sub-district, although they did not have large agricultural land, many residents worked as farmers. Interestingly, the Sewon Sub-district had the highest population of farmers among the 11 sub-districts in the Bedog Sub-watershed. It can be an advantage for sub-districts that experience a surplus in agriculture since they can work in other sub-districts with wider land.

![Graph of Comparison of Total Agricultural Land Area with Availability of Bedog Sub-watershed Farmers in 2019](image)

*Figure 6. Graph of Comparison of Total Agricultural Land Area with Availability of Bedog Sub-watershed Farmers in 2019*

The provision of incentives is one of the instruments used to control the transfer of functions to Sustainable Food Agricultural Land. Therefore, the Bantul Regency Government needs to immediately complete the formulation of incentives for Sustainable Food Agricultural Land to gather farmers' willingness by considering land type, soil fertility, land area, irrigation, land fragmentation level, farming productivity, location, collectivity of agricultural businesses, and/or environmentally friendly farming practices [9]. Based on the analysis results of the number of farmers with agricultural land area, the strengths and weaknesses of the conditions in the Bedog Sub-watershed could be seen. Thus, a strategy could be drawn up using the SWOT method. The SWOT analysis resulted in a strategic design, as presented in Table 5. To achieve sustainability, the management strategy in the Bedog Sub-watershed can be carried out by increasing land productivity, empowering farmers through increasing farmer capacity and farmer regeneration, diversifying non-agricultural work, optimizing land use, and encouraging environmentally-friendly agricultural technology innovation.
Table 5. SWOT Analysis of Sustainable Bedog Sub-watershed Management Strategy

| Strength | Weakness |
|----------|----------|
| 1. There are still many people who work as farmers 2. Has a large potential agricultural land 3. Envy resources in the upstream area are abundant | 1. Population pressure is high 2. Low land carrying capacity 3. The area of agricultural land is narrowing |
| Opportunity | Strategy (S-O) |
| 1. Optimizing cropping patterns 2. Farm management system optimization 3. Use of modern equipment and technology | Increasing land productivity |
| Opportunity | Strategy (W-O) |
| 1. Optimizing cropping patterns 2. Farm management system optimization 3. Use of modern equipment and technology | Optimizing land use, and encouraging environmentally-friendly agricultural technology innovation |
| Threat | Strategy (S-T) |
| 1. Low knowledge and expertise of farmers 2. Low human resources for young farmers 3. Is part of an urban agglomeration | Empowering farmers through increasing farmer capacity and farmer regeneration |
| Threat | Strategy (W-T) |
| 1. Low knowledge and expertise of farmers 2. Low human resources for young farmers 3. Is part of an urban agglomeration | Diversifying non-agricultural work |

4. Conclusion

1. The entire Bedog Sub-watershed had a low carrying capacity of agricultural land. Low land carrying capacity indicates that there is a use that exceeds the carrying capacity of the land.
2. To achieve sustainability, the management strategy in the Bedog Sub-watershed can be carried out by increasing land productivity, empowering farmers through increasing farmer capacity and farmer regeneration, diversifying non-agricultural work, optimizing land use and encouraging innovation in environmentally-friendly agricultural technology.

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