Carrying Capacity of Grompol Watershed Settlements, Central Java

Nasrudin¹, C Muryani², Y Yusuf³

¹Master Program of Geography Education of Studies Sebelas Maret University, Surakarta, Indonesia
²Departement of Geography Education, Sebelas Maret University, Surakarta, Indonesia
³Departement of Geography Education, Sebelas Maret University, Surakarta, Indonesia

*Email: nazruroeddy33@gmail.com

Abstract. Settlements within the watershed will be damaged by natural disasters if the carrying capacity has been exceeded, so research is needed to determine the limits of the carrying capacity of settlements in the watershed so that natural disasters can be minimized. The purpose of this study is to determine the limit of the carrying capacity for settlements in the Grompol watershed. Data on rainfall, soil type, and contours were collected from the BPDAS Solo and BIG. The data obtained were then analyzed into rainfall intensity using the Spline method, erodibility based on BPN soil types and slope classes using the Surface Analysis with Slope method, then the three criteria were overlaid based on Decree of Minister of Agriculture Number 837 / KPTS / UM / II / 1980, so that the region use of the settlement area can be obtained. After that, the settlement suited region will be analysed based on disaster-prone areas. Settlement carrying capacity is calculated from the settlement suited region divided by population and space / capita needs. The result of calculation of settlement carrying capacity is obtained \( DDP_m = 1.23 \). This condition shows that the carrying capacity for settlements is still high and can support the growth of settlements.

1. Introduction

Watershed is an ecosystem unit where organisms and their environment interact dynamically and have a dependence on each other in their composition [1]. Watershed becomes an area whose spatial activities must be managed thoroughly in accordance with the principle of sustainable development based on environmental carrying capacity, so as not to experience land degradation. The problem of watershed land management starts from land use that is not in accordance with the carrying capacity of the land and is followed by the application of cultivation techniques that are not in accordance with conservation rules, thus causing degradation of watershed land.

Development must be carried out optimally according to the carrying capacity of the environment, namely by processing land that is comparable to environmental capabilities. The ability of the environment to support human life, living things, and balance between them are called environmental carrying capacity. Regional development and spatial planning need to examine the carrying capacity of the environment [2]. Study of environmental carrying capacity is very important to do to avoid environmental damage.
1.1 Literature Review
Carrying capacity has a great value as a concept around which to organize development. The very nature of carrying capacity requires long-range planning, a feature so notably lacking from most of the development plans laid for rainforest areas [3]. Development of settlements must indeed be done, but there is a need for spatial planning that is able to manage the environment so that it goes hand in hand. Spatial planning is done to get the benefits of available resources- optimally by not ignoring environmental sustainability and the intended use does not exceed the carrying capacity of the environment [4].

The quality of the environment must be maintained properly. A settlement must take into account the existence of nature, 1/3 - 2/3 of all spatial plans to be managed or changed, must be allowed to develop naturally [4].

2. Methods

2.1. Region Use Analysis
This analysis was conducted to find out how much the area functions to be able to support efforts to utilize settlements. The analysis begins analyzing the limiting aspects of regional functions based on the Decree of Minister of Agriculture Number 837 / KPTS / UM / II / 1980, namely slope class, soil sensitivity, and rain intensity.

The three criteria above are slope class, soil sensitivity, and rainfall intensity overlay analysis and total score scoring using GIS. A total score of more than 175 is a protected area, the total score between 125-17 has a buffer zone function, a total score of less than 125 with a slope of less than 15% is an area of annual crop cultivation, and a total score of less than 125 with a slope of less than 8% is a function of seasonal crop cultivation and settlement areas. Thus, the distribution of regional functions in the research area is obtained.

2.1.1. Slope Class Analysis. Analysis was carried out by means of contour map processing obtained from Geospasial Information Agency (Badan Informasi Gespasial) or (BIG) using Topo to Raster extensions, and it was then analyzed using the Surface Analysis with Slope in ArcGIS.

2.1.2. Erodibility Analysis. The analysis was carried out by determining soil sensitivity based on BPN soil type data obtained from Solo BPDAS.

2.1.3. Rainfall Intensity Analysis. The analysis was carried out by processing rainfall data obtained from Water and Human Resources Agency Karanganyar and Sragen using the Interpolation Spline extension in ArcGIS.

2.2. Settlement Suited Region Analysis
This analysis shows the ability of land in the study area for settlements, taking into account the criteria of the function of the area and being prone to disasters. The analysis is carried out by overlaying the two criteria and calculations using the formula:

\[
LP_m = LW - (LKL + LKP + LKBTT + LKBTS + LKRB)
\]

Note:
LPm = Settlement suited region
LW = Area of the watershed
LKL = Protected area
LKP = Buffer zone
LKBTT = Annual crop cultivation area
LKBTS = Seasonal crop cultivation area
LKRB = Disaster-prone area
2.3. Settlement Carrying Capacity Analysis

This analysis is intended to find out or provide information on the size of land resource capacity that is still available and can be utilized for settlements. The analysis is done by the formula:

\[ DDPm = \frac{LPm}{\alpha} - Jp \]

Note:
- \( DDPm \) = Settlement carrying capacity
- \( LPm \) = Settlement suited region
- \( Jp \) = Total population
- \( \alpha \) = Coefficient of space need per capita (m\(^2\)/ capita)

3. Result

Slope class classification based on the Decree of The Minister of Agriculture Number 837 / KPTS / UM / II / 1980 and the following results are obtained:

**Table 1.** Slope Class of Grompol Watershed

| No | Slope Class Classification | Information | Area (ha) | %  |
|----|---------------------------|-------------|-----------|----|
| 1. | 0-8 Flat                   |             | 15,123.56 | 84.80 |
| 2. | 8-15 Sloping              |             | 1,376.88  | 7.72  |
| 3. | 15-25 Slightly Steep      |             | 540.52    | 3.03  |
| 4. | 25-40 Steep               |             | 596.18    | 3.34  |
| 5. | >40 Very Steep            |             | 197.78    | 1.11  |
|    | Total                     |             | 17,834.90 | 100   |

Soil sensitivity classification in the study area consisted of insensitivity, a little sensitive, insensitive, sensitive and very sensitive:

**Table 2.** Soil Type of Grompol Watershed

| No | Soil Type Group | Information          | Area (ha) | %  |
|----|-----------------|----------------------|-----------|----|
| 1. | Alluvial        | Insensitivity        | 3,176.26  | 17.81 |
| 2. | Latosol         | a Little Sensitive   | 4,851.13  | 27.20 |
| 3. | Mediteran       | Insensitive          | 4,936.07  | 27.67 |
| 4. | Grumosol + Andosol | Sensitive     | 4,870.36  | 27.30 |
| 5. | Andosol + Litosol | Very Sensitive    | 2.97      | 0.02  |
|    | Total           |                      | 17,834.90 | 100   |

Based on the recording of rainfall observation stations, Grompol watershed can be divided into five rainfall intensity classifications:

**Table 3.** Rainfall Intensity of Grompol Watershed

| No | Classification of Rainfall Intensity (mm / rainy day) | Information | Area (ha) | %  |
|----|-------------------------------------------------------|-------------|-----------|----|
| 1. | 0 – 13.6                                              | Very Low    | 1,817.94  | 10 |
| 2. | 13.6 – 20.7                                           | Low         | 2,504.41  | 14 |
| 3. | 20.7 – 27.7                                           | Medium      | 8,866.13  | 50 |
| 4. | 27.7 – 34.8                                           | High        | 3,904.06  | 22 |
| 5. | > 34.8                                                | Very High   | 742.36    | 4  |
|    | Total                                                 |             | 17,834.90 | 100 |
Based on the above criteria, the region use of Grompol watershed area can be determined:

| No | Region Use                             | Area (ha) | %      |
|----|----------------------------------------|-----------|--------|
| 1. | Protected                              | 402.92    | 2.26%  |
| 2. | Buffer                                 | 1,096.79  | 6.15%  |
| 3. | Annual Plant Cultivation               | 1,409.06  | 7.90%  |
| 4. | Seasonal Cultivation                   | 9,599.05  | 53.59% |
| 5. | Settlements                            | 5,326.41  | 30.10% |
|    | Total                                  | 17,834.90 | 100%   |

Further analysis is carried out by looking for the area of disaster-prone settlement cultivation areas (LKBRB). The analysis was carried out by overlaying the map of settlement cultivation areas with disaster-prone maps so that LKBRB obtained 1,851.94 ha.

Based on the results of the overlay analysis and the results of calculations using the formula, the ability of the study area for settlements can be determined by the ability of the land in the form of settlement suited region.

\[ LPm = LW - (LKL + LKP + LKBTT + LKBTS + LKRB) \]

\[ LPm = 17,834.90 - (402.92 + 1,096.79 + 1,409.06 + 9,599.05 + 1,851.94) \]

\[ LPm = 3,474.47 \text{ ha} \]

The analysis of the population of Grompol watershed is done by finding the percentage of the area of village settlements that enter the watershed, after that it is multiplied by the total population per village. The results of the analysis of the population of Grompol watershed were 211,961.

Based on the Regulation of the Minister of Public Housing No. 11 / PERMEN / M / 2008 concerning Guidelines for Harmony of Housing and Settlement Areas, the needs of the maximum space of the population vary more according to the zone of the region. Determination of the coefficient value (α) of the total space requirements per capita can be determined by looking over the density of the population of Grompol watershed. The value of population density in Grompol watershed is calculated by means of the population entering the watershed divided by the watershed area.

\[ PD = \frac{211,961}{17,834.90} \]

\[ PD = 11.88 \text{ inhabitants/ hectare} \]

The results of the calculation of population density amounted to 11.88 inhabitants per hectare, so based on Regulation of the Minister of Public Housing No. II / PERMEN / M / 2008, the area coefficient of space needs per capita in Grompol watershed is α = 133 m² / capita.

Finally, the analysis of settlement carrying capacity is obtained from, the area of settlement suited region per total population of the watershed divided by the coefficient of space/capita needs (m² / capita), so the carrying capacity of the environment for settlements in Grompol watershed is:

\[ DDPm = \frac{Lpm \text{(m²)}}{\alpha / Jp} \]

\[ DDPm = \frac{34,744,663.82 / 211,961}{133} \]
Based on the results of the analysis, Grompol watershed has a total carrying capacity of settlements of 1.23 which mean high and residential development can still be carried out based on the optimal total population (\(J\text{Po}\)) with the formula:

\[J\text{Po} = DDPm \times \text{Total Population}\]
\[J\text{Po} = 1.23 \times 211,961\]
\[J\text{Po} = 261,238\]

and the optimal area of suitable for settlement (\(LP\text{mo}\)) with the formula:

\[LP\text{mo} = \frac{1}{DDPm} \times LPm\]
\[LP\text{mo} = \frac{1}{1.23} \times 3,474.47 \text{ ha}\]
\[LP\text{mo} = 2,819.08 \text{ ha}\]

4. Conclusion

Based on the analysis using the Settlement Carrying Capacity (DDPm) formula above, the environmental carrying capacity for settlements in the study area is 1.23. Therefore, Grompol watershed has a high carrying capacity of settlements. \(J\text{Po}\) value = 261,238, means that the current population can still accommodate 49,277 people to get the optimal population. Whereas \(LP\text{mo}\) = 2,819.08 ha, means that the size of residential settlements can still be added to 655.38 ha in order to be eligible for optimal settlements. The calculation is based on the Decree of Minister of State of Population/ Head of National Population and Family Planning Board (BKKBN) Number: Kep-03 / MEN / MENEG. K / 2/1998 which states that environmental quality will be well maintained if humans manage to carry capacity based on the minimum and optimum limits (30-70%). If the land is used more than 70%, it will result in decreased environmental quality [5].

The ideal direction for settlements based on the analysis of environmental carrying capacity is to place the location of the settlement according to its designation. Settlement areas should be developed as much as possible on land with settlement suited region- according to several criteria above. However, with the limited number of ideal location, priority is needed in the plan for utilizing further settlements- along with efforts to improve the quality of land in less ideal areas.

References

[1] Asdak, C. 2010. *Hidrologi dan Pengelolaan Daerah Aliran Sungai.* (Yogyakarta : Gadjah Mada University Press)
[2] Muta’ali, L. 2011. Environmental Carrying Capacity Based on Spatial Planning. *Indonesian Journal of Geography* 43(2): 142-155.
[3] Fearnside, P.M. 1984. Brazil’s Amazon Settlement Schemes: Conflicting Objectives and Human Carrying Capacity (Habitat International 8(1): 45-61.
[4] Riyanto, A. 2003. Kajian Kemampuan Lahan untuk Arahan Kegiatan Permukiman Berdasarkan Aspek Fisik Dasar. Unpublished thesis. Diponegoro University, Semarang.
[5] Muta’ali, L. 2012. *Daya Dukung Lingkungan untuk Perencanaan Pengembangan Wilayah.* (Yogyakarta : Badan Penerbit Fakultas Geografi (BPFG) Universitas Gadjah Mada)