Land, Water, and Development in Marioriwawo District

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Abstract. This research was conducted to determine carrying capacity of the environment in Marioriwawo District, Soppeng Regency, Sulawesi Selatan Province. The carrying capacities of land for buildings and water were used for analysis in this study, referring to the Regulation of the Minister of Environment No. 17 of 2009. The results showed that the environmental carrying capacity was 78.15, which was more than 3, thus categorized safe/good based on the calculation results that 70% of the carrying capacity of land for buildings was 108.30 hectares and 40% of the carrying capacity of water was 5.86 m³/year.

Keywords: Carrying capacity; Land; Water; Environment

1. Introduction

Carrying capacity of the environment (CCE) is the ability of the environment to support human life, other living things, and the balance between the two [1]. The carrying capacity of the environment of a region is strongly influenced by the increase in the population with all its activities which causes the need for land and water to increase [2]. Regulation of the Minister of Environment Number 17 of 2009 concerning Guidelines for Determination of Carrying Capacity of the Environment in Regional Spatial Planning states that the determination of carrying capacity of the environment is carried out by knowing the capacity of the natural environment and resources to support human/population activities that use space for survival. So, carrying capacity of the environment must obtain special attention to maintain a balance between the needs and the limitations of the environment [3].

Marioriwawo is District in Soppeng Regency, Sulawesi Selatan, Indonesia. Most of the area of this district is a mountainous region and is famous for its cool temperatures, with natural views that are very soothing. Most of the residents' livelihoods in this region are farming, both garden farmers and rice farmers. The most widely produced agricultural products are cocoa and rice. In addition, many residents of this district are traders and employees. This area has the potential to be used as a tourist destination [4]: there are many places that are truly unspoiled, plus views of rice fields that are not less beautiful than Ubud Bali [5].

However, its diverse natural resources make an increase in population which will have an impact on increasing the rate of use of natural resources [6-7], such as reduced availability of natural resources from the forestry sector [8-9] and agriculture, including the use of space for human life and other living things [10-11].

The results of the determination of carrying capacity of the environment can be used as a reference in the preparation of a sustainable spatial plan (RTRW) [12-13] in the Marioriwawo District of Soppeng Regency. The relationship between carrying capacity of the environment and the RTRW

can be determined by the KLHS (Strategic Environmental Assessment as a tool that can provide a review or evaluation of the RTRW prepared.

The determination of carrying capacity of the environment is carried out using a spatial data-based approach, in which spatial information about the characteristics of an area [14], a spatial picture of the designation, and detailed land cover and optimization of environmental-based development efforts can be obtained through Geographic Information Systems (GIS) [15-16]. This study aimed to determine the carrying capacity of the environment of Mariorowawo District, Soppeng Regency.

2. Research Method

This research was located in Mariorowawo District, Soppeng Regency, with an area of 59,515 Ha.

Analysis of the data used in this study was the analysis of the carrying capacities of building/residential land and water [17-18].

Analysis of Carrying Capacity of Land for Buildings (Residential Area)

Calculation of land carrying capacity with an approach to building (DDLb) uses an equation that refers to the Regulation of the Minister of Environment No. 17 of 2009 as follows:

$$DDLb = \frac{(\alpha \times LW)}{LTb} \quad (1)$$

$$LTb = LB + LTp \quad (2)$$

Keterangan:

DDLb = carrying capacity of land for buildings

LW = area (ha)

LTb = built up area (ha)

LB = building area (ha)

LTp = land area for infrastructure (such as roads, rivers, drainage and others (ha); if it cannot be identified, assume 20% of the building area).

α = coefficient of the maximum land area developed (ha) (70% if agriculture <50%, 50% if agriculture >50%).

The calculation results were analyzed with the following categories:

DDLb < 1: The carrying capacity of residential land is exceeded or poor

DDLb 1 - 3: The carrying capacity of residential land is conditional or moderate

DDLb > 3: The carrying capacity of residential land is safe or good

Analysis of Water Resources Carrying Capacity

Based on the Regulation of the Minister of Environment No. 17/2009, the calculation of carrying capacity of water is carried out by comparing the availability of water (SA) and the demand for water (DA) with the following formula:

$$DDA = SA/DA \quad (3)$$

where

SA : water availability (m³/year)

DA : the demand for water (m³/tahun)

Analysis of Water Availability

The equation for calculating water availability is as follows:

$$SA = 10 \times C \times R \times A \quad (4)$$

$$C = \sum(C_i \times A_i) / \sum A_i \quad (5)$$

$$R = \sum R_i / m \quad (6)$$

Note:

SA : water availability (m³/year)

C : weighted runoff coefficient

C_i : land use runoff coefficient

R : average annual algebraic rainfall in the region (mm/year)

R_i : annual rainfall

m : number of rainfall observation stations

A : area (ha)

A_i : land use area (ha)

Analysis of the demand for water

Calculation of the demand for water was calculated using the following equation:

$$DA = N \times KHL \quad (7)$$

Note:

DA : the demand for water (m³/year)

N : total population (soul)

KHL : the demand for water to live properly (1600 m³/capita/year)

The calculation results were analyzed with the following categories:

DDA < 1 : Water resources carrying capacity is exceeded or poor

DDA 1 - 3 : Water resources carrying capacity is conditional or moderate

DDA > 3 : Water resources carrying capacity is safe or good

Analysis of Carrying Capacity of the Environment

The carrying capacity of the environmental is determined by weighting DDLB 70% and DDA 40% [19]. The following is the DDL calculation:

$$DDL = (70\% \times DDLB) + (40\% \times DDA)$$

DDL < 1 : The carrying capacity of the environment is exceeded or poor

DDL 1 - 3 : The carrying capacity of the environment is conditional or moderate

DDL > 3 : The carrying capacity of the environment is safe or good

3. Results and Discussion

3.1. Carrying Capacity of Land for Building

Calculation of the carrying capacity of land for buildings (residential land) was done by calculating the area of land for buildings in the study area. To find out the area of land for buildings in Marioriwawo District, image interpretation was performed (Table 1)

Table 1. Data of Land Use in Marioriwawo District

No.	Land Use	Area (ha)
1	Forest	34178.43
2	Diversified Gardens	86952.43
3	Farm/field	13556.25
4	Open field	5605.25
5	Housing	632.03
6	Rice field	3086.09
7	Shrubs	1830.97
8	Water body/river	4744.86
Total area		
Region (LW)		150586.30

Based on the interpretation of the land for buildings (housing), the area of the land for buildings (housing) in Mariorowawo District is 632.03 Ha from the total area of 150586.30 Ha. From the calculation of land use, it can be concluded that:

Total population (JP)	= 45100 souls
Kepadatan Penduduk	= 0.299 soul/ha
Area (LW)	= 150586.30 ha
Building area (LB)	= 632.03 ha
Land for infrastructure (LTp)	= 63.203 ha
Coefficient of developed land area (α)	= 50% ha/capita
Coefficient of required land area/capita (α)	= 0.0133 ha/capita

$$LTb = LB + LTp$$

$$LTb = 695.24 \text{ ha}$$

$$DDLb = \frac{(\alpha \times LW)}{LTb}$$

$$DDLb = 108.30 \text{ ha}$$

Based on the above calculation, the carrying capacity of land for buildings in Marioriwawo District was 108.30 ha, namely $DDLb > 3$. The carrying capacity of land for buildings was categorized as safe/good category, so that Marioriwawo District is still able to provide land for buildings/settlements to accommodate a number of residents to live properly.

3.2. Water Resources Carrying Capacity

Water resources carrying capacity is the ability of water resources to meet a need by reviewing the water availability [20-21]. Water resources carrying capacity is calculated based on the calculation of water availability and the demand for water.

3.3. Analysis of Water Availability

Calculation of water availability is based on the Regulation of the Minister of Environment No. 17 of 2009 concerning Guidelines for Determination of Carrying Capacity of the Environment in Regional Spatial Planning [22]. Based on this, the data needed in the calculation are land availability, weighted runoff coefficient, average algebraic annual rainfall, and area.

3.3.1 Calculation of Weighted Runoff Coefficient

Calculation of the weighted runoff coefficient is presented in the following table:

Table 2. Data of Weighted Runoff Coefficient

No.	Land Use	Area/Ai (ha)	Runoff Coefficient/Ci	Ci x Ai
1	Forest	34178.43	0.18	6152.12
2	Diversified Gardens	86952.43	0.10	8695.24
3	Farm/field	13556.25	0.35	4744.69
4	Open farm	5605.25	0.35	1961.84
5	Housing	632.03	0.65	410.82
6	Rice field	3086.09	0.30	925.83
7	Shrubs	1830.97	0.35	640.84
8	Water body/river	4744.86	0.00	0.00
Total		150586.30		23531.37

Source: Deliniation of Soppeng Regency Image Map

$$C = \frac{\sum(C_i \times A_i)}{\sum A_i}$$

$$C = 0.16$$

3.3.2 Calculation of Average Rainfall

Calculation of average annual rainfall is obtained based on the comparison of annual rainfall to the number of rainfall observation stations [23], as calculated based on the following equation:

$$R = \frac{\sum R_i}{m}$$

$$R = 1756 \text{ mm/year}$$

The value of water availability in the Marioriwawo District was obtained based on the following equation:

$$SA = 10 \times C \times R \times A$$

$$SA = 10 \times 0.16 \times 1756 \times 150586.30$$

$$SA = 423087268.48 \text{ m}^3/\text{year}$$

3.4. Analysis of the demand for Water

Based on the Regulation of the Minister of Environment No. 17 of 2009 concerning Guidelines for Determination of Carrying Capacity of the Environment in Regional Spatial Planning, the calculation of the demand for water can be obtained by multiplying the number of population (N) with the demand for water to live properly (KHL) [24-25]. The number of population based on data from the Central Statistics Agency of Soppeng Regency Marioriwawo District was 45100 people while the demand for water to live properly was 1600 m³/person/year. Thus, the calculation of water demand:

$$DA = N \times KHL$$

$$DA = 45100 \times 1600$$

$$DA = 72160000 \text{ m}^3/\text{year}$$

So, the demand for water in Marioriwawo District was 72160000 m³/year. The calculation results were analyzed with the following equation:

$$DDA = \frac{SA}{DA}$$

$$DDA = \frac{423087268.48}{72160000}$$

$$DDA = 5.86 \text{ m}^3/\text{year}$$

Based on the calculation between the availability of water and the demand of water, the carrying capacity of water resources Marioriwawo District was 5.86 m³/year, namely DDA > 3. The carrying capacity of water was categorized as safe/good because of the large availability of water to meet the needs of the population in Marioriwawo District.

3.5. The Carrying Capacity of the Environment

The condition of carrying capacity of the environment in Marioriwawo District can be determined by adding up 70% of the carrying capacity of the land for buildings and 40% of the carrying capacity of water resources. So, the results of calculations between the carrying capacity the land for buildings, water resources carrying capacity and environmental carrying capacity of 78.15 was DDLP > 3. The environmental carrying capacity was categorized as safe/good because there were several supporting indicators, namely the carrying capacity of land for buildings that was safe/good [26] so that there were land for buildings available to accommodate the population to live properly and the carrying capacity of water resources in Marioriwawo District also had greater water availability, compared to the residents' demand for water.

4. Conclusions

Based on the aims and results of the study, it can be concluded that the carrying capacity of land for buildings (housing) in Marioriwawo District was 108.30 ha, namely DDLB > 3, which was categorized as safe/good, so that Marioriwawo District was still able to provide land for buildings/housing to accommodate a certain number of residents to live properly. Meanwhile, the water resources carrying capacity of Marioriwawo District was 5.86 m³/year, namely DDA > 3, which was categorized as safe/good. This was due to the water availability for the population in Marioriwawo District. Therefore, based on the results, the environmental carrying capacity of the district was 78.15, namely

DDLP> 3. So, it can be concluded that the environmental carrying capacity in Marioriwawo District, Soppeng Regency, was categorized as safe/good.

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