



# Water Carrying Capacity in Buol Urban Area Based on Ecosystem Services

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## Abstract

*The environmental carrying capacity of water is a factor that contributes to community welfare. Determining the carrying capacity is generally done by the ecosystem services approach. In this case, the provision of water by the environment is considered an ecosystem service. The environmental carrying capacity of water is a factor that participates in the formation of community welfare. Determining the carrying capacity is generally completed by the ecosystem services approach. The higher the value of ecosystem services, the higher the environment is carrying capacity. The environmental carrying capacity is calculated as the water carrying capacity based on ecosystem services in Buol urban area, consisted of (i) classification of landscape characteristics, vegetation types, and land cover characteristics; and (ii) calculation and creation of service maps of environmental services as an indicative carrying capacity status of water supply in the Buol urban area. The results showed that the carrying capacity of water based on the performance of water supply ecosystem services in Buol urban area covers the very low to the high category. The water carrying capacity in Buol area is generally dominated by high and moderate water carrying capacities, which are 4507.53 ha and 1415.21 ha, respectively, or 68.71% and 21.57% of the total urban area. Areas with low and very low water carrying capacity or performance of ecosystem services cover an area of 514.85 Ha and 122.40 Ha, respectively, or only about 7.85% and 1.87% of the total urban area of Buol.*

*Keyword: carrying capacity, water, ecosystem services.*

## I. Introduction

Water, especially for human needs in an area, besides being used for drinking and household needs, water is also used in other aspects of life, for agriculture, plantations, housing, industry, and tourism [1], [2]. This condition requires an area to be able to maintain the availability of adequate water resources. Buol City, the capital of Buol Regency, is one of the urban area developments in Central Sulawesi province,

and the consequences of population growth every year will follow. The increasing population in Buol City will trigger various activities and needs that affect water use patterns, which in turn will impact the carrying capacity of the Buol City area. The status of water carrying capacity indicates a condition of regional water availability with existing needs. Improper water management can harm water availability. This can also cause environmental disasters (floods) if the carrying capacity of the environment for water is exceeded [3].

According to the Regulation of the State Minister for the Environment Number 17 of 2009 article 1, the environment's carrying capacity is the environment's ability to support human life and other living things. The carrying capacity of the environment that comes from nature, such as the carrying capacity of water, is a factor that participates in the formation of community welfare. Determining the amount of environmental carrying capacity is done by knowing the capacity of the environment to meet and support the activities of human space users to ensure their survival [4].

One approach that can be used in determining the environment's carrying capacity is the ecosystem services approach [5], [6]. In this case, the provision of water by the natural environment is considered a form of ecosystem services, and with the assumption that the higher the value of ecosystem services in an area, the higher the carrying capacity of the environment in that area.

The form of presenting information on ecosystem services is often done in the form of a map. Ecosystem service maps are a tool for policymakers to identify the spatial distribution of ecosystem services and the linkages or relationships between one ecosystem service and other ecosystem services [7]. This map can be used for various needs, especially in environmental management and spatial planning, based on the carrying capacity of the environment. The output in the form of a map is one of the advantages of determining the environment's carrying capacity based on ecosystem services. By presenting a map of ecosystem services, the output will be produced to display the status of the environment's carrying capacity spatially so that the distribution of carrying capacity status can be adjusted according to the unit analysis and spatial scale used. This study aimed to assess and map the status of water carrying

capacity based on the ecosystem services of water supply in Buol City.

## II. MATERIALS AND METHODS

### 2.1. Data acquisition

The tool used in this research activity was a computer/laptop equipped with software for spatial analysis (Arc GIS 10.8) and numerical data processing software (Microsoft Excel).

The materials used in processing the water-carrying capacity data in the Buol City Region consist of spatial and non-spatial data materials as follows:

1. Landscape Map (ecoregion) of Buol City with an information scale of 1:250,000, source from the Ministry of Environment and Forestry.
2. Map of Natural Vegetation Types for the City of Buol information scale of 1:250,000, source from the Directorate of Environmental Impact Prevention for Regional and Sector Policy, Directorate General of Forestry Planning and Environmental Management, Ministry of Environment and Forestry, 2017 [8].
3. Land Cover Map for the City of Buol, information scale 1:50,000 in 2018, sourced from updating land cover data, the thematic land cover map for RDTR City of Buol.
4. Map of Buol City Administrative Boundary Information scale 1:50,000 source from Buol City RDTR.
5. Scoring types of landscape classification, vegetation type and land cover in each environmental service, source: Directorate General of Forestry Planning and Environmental Management, Ministry of Environment and Forestry, 2017 [8]
6. Landscape weight, vegetation type and land cover for each environmental service, source: Directorate General of Forestry Planning and Environmental Management, Ministry of Environment and Forestry, 2017 [8].

### 2.2. Calculation of Ecosystem Services Index and Water Carrying Capacity

The environmental services approach can be used in an indicative way to calculate the performance of ecosystem functions to measure the carrying capacity. Carrying capacity of an area's environment by calculating the index of ecosystem services based on the performance of ecosystem services to determine supply (availability) from nature. Environmental service performance calculation uses three parameters: landscape, vegetation type and land cover. The Simple Additive Weighting method uses the mathematical model used in spatial analysis to determine the performance of these environmental services [9]–[11].

The following equation calculates the ecosystem services index;

$$\text{Ecosystem Service Performance Index} = f \{ \text{Landscape, Vegetation, Land Cover} \}$$

$$= (wbl \times sbl) + (wveg \times sveg) + (wpl \times spl)$$

where wbl = landscape weight, sbl = landform score, wveg = vegetation weight, sveg = vegetation score, wpl = land cover weight, spl = land cover score.

The water carrying capacity is represented as an index, which results from calculating the performance of ecosystem services based on the three parameters mentioned above. The environmental services index calculation results will have a value range of one to five: very high = 4.21 - 5.00, height = 3.41 - 4.20, moderate = 2.61 - 3.40, low = 1.81 - 2.60, very low = 1.00 - 1.80.

## III. RESULTS AND DISCUSSION

Based on the weighting and spatial analysis results, Buol only consists of four categories or classes of ecosystem service performance: Very Low category, Low category, Moderate category, and High category.

The distribution of water carrying capacity with indicators of ecosystem services providing water with deficient performance in Buol City is spatially presented in map form in Figure 1. In contrast, data on ecosystem services providing water with shallow performance categories are presented in Figure 6.

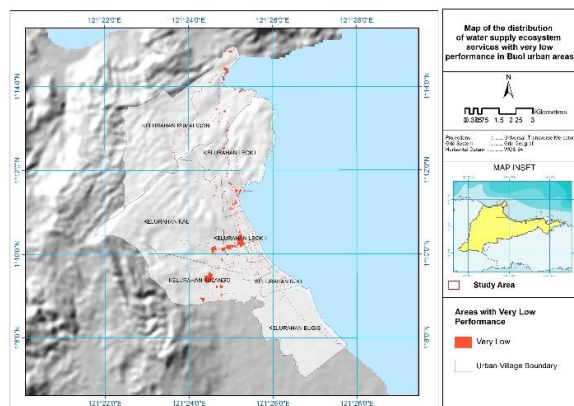


Figure 1. Map of water carrying capacity indicators based on ecosystem services providing water with deficient performance

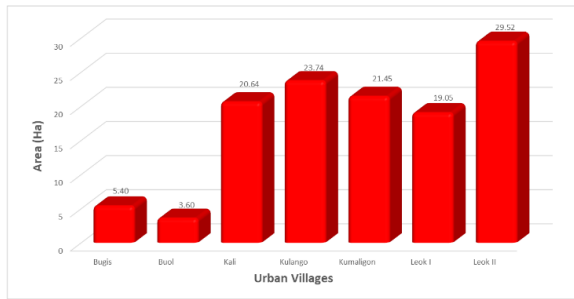


Figure 2. Environmental area with very low water supply ecosystem service performance in each urban villages (sub-district) environment in the urban area of Buol.

The distribution of water carrying capacity with indicators of ecosystem services providing water with low performance in Buol City is spatially presented in Figure 3. In contrast, the data on the area of ecosystem services providing water with low-performance categories is presented graphically in Figure 4.

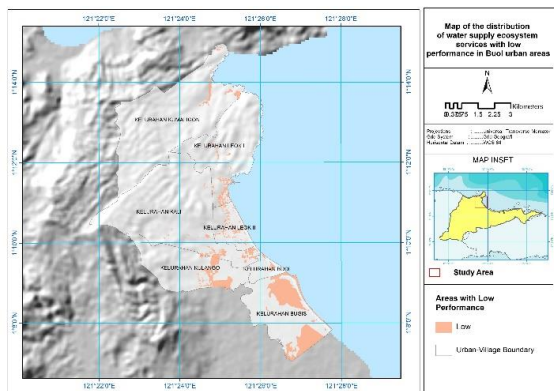


Figure 3. Map of water carrying capacity indicators based on low-performance water supply ecosystem services

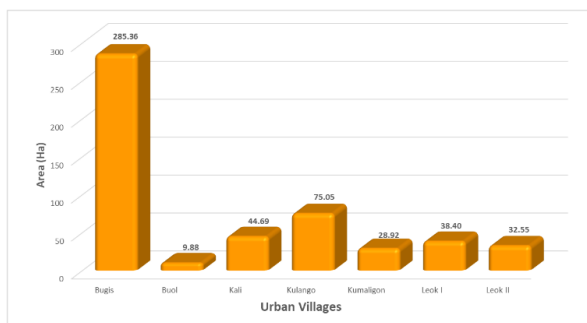


Figure 4. Areas with low water supply ecosystem service performance in each urban villages (sub-district) environment in the urban area of Buol.

The distribution of water carrying capacity with indicators of ecosystem services providing water with Moderate performance in Buol City is spatially presented in map form in Figure 5. In contrast, the area data of ecosystem services providing water with a high-performance category are presented in graphical form in Figure 8.

providing water with Moderate performance categories are presented graphically in Figure 6.

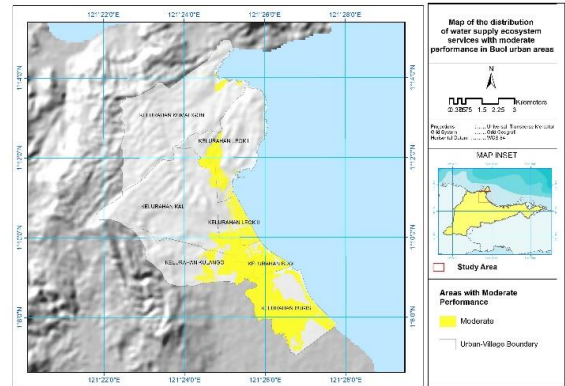


Figure 5. Map of indicators of water carrying capacity based on water supply ecosystem services with Moderate performance

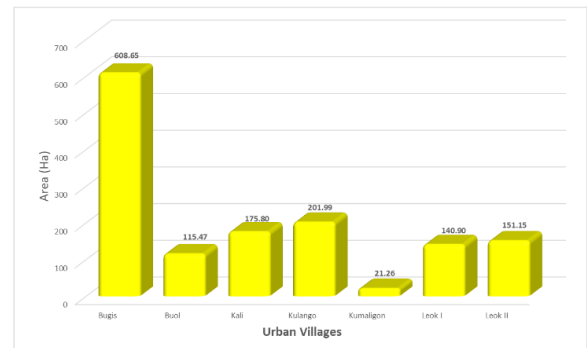


Figure 6. Area with Moderate water supply ecosystem service performance in each urban villages (sub-district) environment in the urban area of Buol.

The area with a moderate performance of ecosystem services providing water is mainly found in the Bugis sub-district area, which is 608.65 Ha or 43.01% of the total area of the environment, which is categorized as having ecosystem services providing water performance is currently. In general, it can be seen that in each of the seven kelurahan areas, the area distribution with a moderate performance of water supply ecosystem services is mainly spread over land cover types of gardens, mixed gardens, paddy fields, settlements and swamps.

The distribution of water carrying capacity with indicators of ecosystem services providing water with high performance in Buol City is spatially presented in a map in Figure 7. In contrast, the area data of ecosystem services providing water with a high-performance category are presented in graphical form in Figure 8.

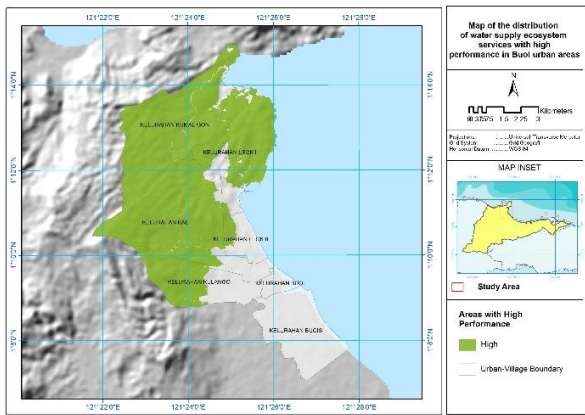


Figure 7. Map of water carrying capacity indicators based on high-performance water supply ecosystem services.

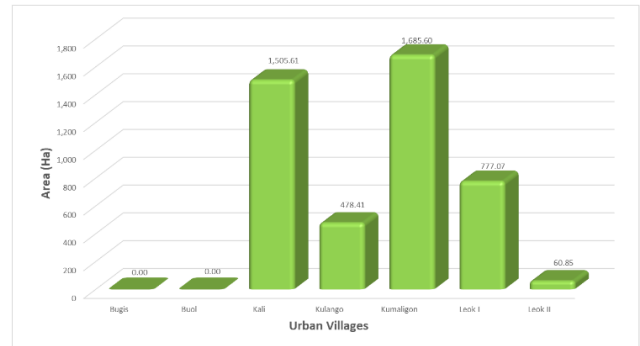


Figure 8. Area with a high performance of water supply ecosystem services in each urban villages (sub-district) environment in the urban area of Buol.

Based on the previous description, it can be seen that the water carrying capacity in Buol City is generally dominated by areas that fall into the category of water carrying capacity with high and medium performance, namely 4507.53 ha (69%) and 1415.21 ha (21%), respectively. In Figure 9 it is clear that for areas that have deficient ecosystem service performance, with a coverage area of 122.40 Ha or only about 2% of the total urban area of Buol, and spread over an area of less than 30 Ha, especially in the Leok II area and Kulango. Likewise, those with low performance cover an area of 514.85 Ha or only 8% of the total urban area of Buol. In environments with low performance of ecosystem services providing water, it can be seen that the distribution is dominant in the Kulango and Bugis sub-districts. In contrast, the other sub-districts only cover an area of less than 50 Ha.

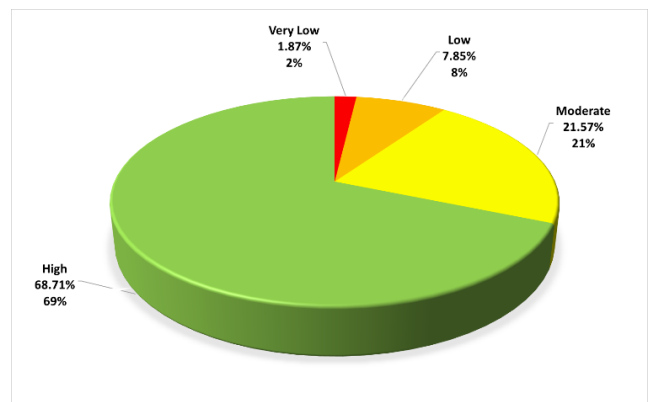


Figure 9. Percentage of Area Status of water carrying capacity based on Water Supply Ecosystem Services in the urban area of Buol.

The distribution profile of the water supply carrying capacity based on the performance of water supply ecosystem services in the urban area of Buol based on the spatial data presented graphically can be seen in map form in Figure 10 below.

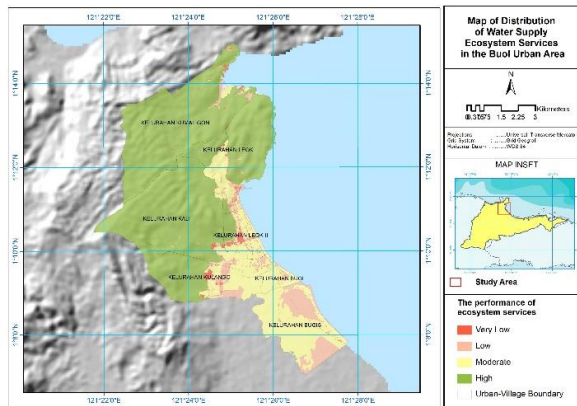


Figure 10. Composite map of the distribution of water carrying capacity based on ecosystem services providing water in the Buol City area.

To look more closely at the phenomenon of high or low performance of water supply ecosystem services in Buol City by overlaying each ecosystem service performance map with a landscape map, land cover map and original vegetation map. Then, it is possible to see the components or factors that are thought to influence service performance. Water supply ecosystem in the urban area of Buol.

In areas with the most significant area, i.e. areas with high water carrying capacity or have high performance of ecosystem services providing water. Those areas are located in solutionary karst hills made of sedimentary carbonate rock and fluvial plains made of alluvium material. This type of land cover is dominated by forest cover. Based on the types of land cover units and land cover in this typology, it is suspected that the capacity of the natural environment to maintain the hydrological cycle process is better than areas with a moderate performance of water supply ecosystem services. The environmental conditions of the ecosystem in the urban area of Buol can still function properly in carrying out the hydrological cycle function and provide high water supply ecosystem services. Based on that profile, areas with high water supply ecosystem services need to be maintained and preserved. Those areas have essential roles in maintaining the environment's capacity to supply water for various activities in the Buol urban area.

Meanwhile, areas with the status of water supply ecosystem services with deficient and low performance if the total area is only 637.24 hectares or only 9.71% of the total urban area of Buol. The typology of this area is in an environment that is a transitional ecosystem or ecotone. For example, brackish or swamp areas around a river that crosses the urban area of Buol, which, if not properly maintained and managed, can also affect and worsen the quality of the existing environment, mainly due to land conversion activities for settlements or ponds. Moreover, it is known that the area is generally located in a landscape of karst solutionary hills made of sedimentary carbonate rock. Therefore, this landscape with native vegetation cover in the

form of lowland limestone forests in karst landscapes is classified as very vulnerable to activities that can damage the environment. The type of landscape formed from limestone and karst has a low capacity to maintain and maintain water availability in the rock layers. However, it is vital to filter water flow in an environment that functions as a natural water catchment. This is further clarified by data on the types of land cover found in the upper layers of the landscape with low ecosystem services as a water provider, seen in areas that are dominant in built environments such as roads and residential areas. This type of land cover is generally known to have a shallow capacity to hold and capture rainfall so that it can be retained and available as groundwater in the hydrological cycle process.

## CONCLUSIONS AND RECOMMENDATIONS

From the results of this study, several conclusions were drawn as follows:

1. Water carrying capacity based on the performance of water supply ecosystem services in the urban area of Buol covers the very low to high category.
2. Based on the calculation of the performance of water supply ecosystem services, Buol is generally dominated by areas of high and medium water carrying capacities, 4507.53 ha each (69%) and 1415.21 ha (21 %) of the total urban area.
3. Areas that have water carrying capacity with low and deficient ecosystem service performance, covering an area of 514.85 Ha (8% of the total urban area) and 122.40 Ha (2% of the total urban area), respectively

### ii. Suggestion

Utilization of areas that indicatively have low and very low water carrying capacity needs to emphasize environmental preservation activities such as land conservation efforts and environmentally friendly technologies. This study also needs to be followed up by taking into account the need for water so that the threshold of water carrying capacity can be identified quantitatively and it can be seen that the carrying capacity has been exceeded or not exceeded.

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