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A Rapid Projection of Water Carrying Capacity in Areas with Community-Based Clean Water Supply System in Semarang City

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Abstract

This study analyzes community-based water supply in RT (Neighborhood Unit) 4 / RW (Community Unit) 3, Bulusan Sub-district, Semarang City, Central Java. Bulusan Village covers an area of 304.072 hectares with a population of 6,632 people (2,048 households) in 2022, while the research location itself has 108 households (±490 inhabitants). The study employs a quantitative descriptive methodology. Calculation results indicate that water availability (432,000 liters/day) exceeds water demand (58,800 liters/day), classifying the water carrying capacity as good. However, these calculations do not account for transient populations that may increase water demand, particularly given the area's high educational and economic activities. The study emphasizes the importance of continuous evaluation of water supply-demand balance, especially in regions with dynamic population mobility.

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INTRODUCTION

Water is a vital basic need for human. Water is not only beneficial for health, but also in human socio-economic activities, thus achieving one of the goals of the Sustainable Development Goal (SDG) (Pratiwi & Heriyanti, 2024; Maryati et al., 2018). However, the availability of clean water is facing challenges such as population growth and climate change (Mishra, 2023; Abedin et al, 2019). Many big cities are facing a water crisis, with inadequate water distribution, including in Indonesia (Luo et al, 2021; Triweko, 2021). One of them is Semarang City as a metropolitan city, facing serious challenges in meeting water needs due to population growth that is not balanced with the availability of water resources (Syafitri, 2022; Trihadianta et al, 2024).

In Indonesia, clean water provision is primarily managed by Regional Public Drinking Water Companies (Perumda), but service levels remain suboptimal (Rifai, 2014; Yuliani & Rahdriawan, 2014). For instance, Perumda Tirta Moedal in Semarang City served only 60% of clean water needs in 2023, leaving many unserved (Perumda Air Minum Tirta Moedal, 2023). To address this, communities have developed individual and communal clean water systems, especially in underserved areas (Maryati et al., 2018). An example is Bulusan Sub-district in Semarang City, which faces a clean water crisis due to rapid population growth and high educational activity (Subiyanto et al., 2021).

In 2018, the Semarang City Government built an artesian well in Bulusan Sub-district to meet clean water needs (Wandari et al., 2023). However, water carrying capacity has become a critical issue, as overexploitation risks depleting or degrading water sources (Dirawan & Jannah, 2023). This study evaluates the carrying capacity of Bulusan Sub-district's clean water system, operational since 2018, to ensure its sustainability.

Studying water carrying capacity in community-based systems is vital for water resource sustainability, as overexploitation without considering natural recovery can lead to quality decline or source depletion (Dirawan & Jannah, 2023). In Bulusan Sub-district, the community-based system faces challenges from rapid population growth and high educational activities (Subiyanto et al., 2021; Wandari et al., 2023). Without assessing carrying capacity, the system risks failing to meet long-term needs, exacerbating the water crisis. Previous studies on water carrying capacity, such as those by Sudipa (2020) and Sukwika et al (2022), have generally focused on larger scales. However, detailed studies on water sources from Community-Based Clean Water Supply Systems remain scarce. This study evaluates Bulusan's system using a rapid approach to project its sustainability by identifying capacity limits, the findings can guide policies to balance demand with ecological recovery (Hope, 2015).

METHOD

The method used in this study is quantitative descriptive. Quantitative descriptive analysis is a statistical technique that describes, summarizes, and analyzes numerical data in a simple and systematic manner. The primary goal of quantitative descriptive analysis is to provide a general overview of the data's characteristics, data distribution, and the shape of its distribution. Examples of techniques used in quantitative descriptive analysis include frequency calculations, percentages, frequency distribution tables, and graphs such as histograms or bar charts (Sugiyono, 2018).

Location and Time

The study location is situated on Street Timoho Timur III, RT (Neighborhood Unit) 4 / RW (Community Unit) 3, Bulusan Sub-district, Semarang City, Central Java. The study will be conducted in stages, starting from October 2024 to March 2025. The study process includes the stages of planning, preparation, data collection, and reporting of results. The study location can be seen in Figure 1.

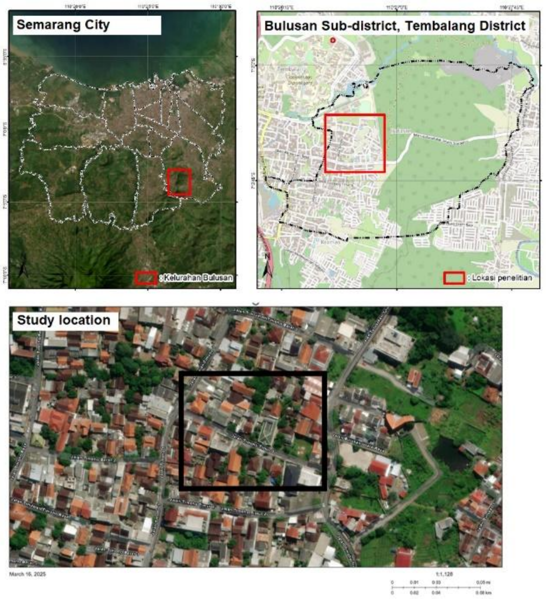

Figure 1. Study Location

Data Collection Method

The determination of surplus and deficit status is based on a comparison between water availability and water demand. The data used includes:

1. Water availability (supply) : average water discharge
2. Water demand : population size water requirements for a decent standard of living

The data used in this study consists of primary data, such as water discharge obtained from interviews, and secondary data, such as population data in study location.

Secondary data refer to information by someone other than the researcher conducting the current study (Skaran & Bougie, 2016). Primary data are those which are collected afresh and for the first time, and thus happen to be original in character (Kothari, 2004).

Research procedure

1. **Projecting Population Growth in Bulusan Sub-distric**
    1. collect population data for Buluan Sub-distric from 2013 to 2024 using the document 'Kota Semarang Dalam Angka'.
    2. Calculate population projections using linear regression analysis.
    3. Determine the population growth rate.
    4. Estimate the 2030 population for Neighborhood Unit (RT) 4 / Community Unit (RW) 3 in Bulusan Sub-district, Semarang City, Central Java.
2. **Assessing Clean Water Carrying Capacity**
    1. Gather data on the number of water system users and raw water discharge.
    2. Mutiply the number of users by the standard criteria for domestic water demand (120 liters/person/day)
    3. Procet the water carrying for 2030.

Data Analysis

Water carrying capacity is the comparison between the condition of water availability in a specific area and the water demand in that area. By comparing water availability and demand, the status of water carrying capacity can be determined (Nurfatimah, 2023). Below is the calculation of water carrying capacity in RT (Neighborhood Unit) 4 / RW (Community Unit) 3, Bulusan Sub-district.

A. Water Availability (Supply)

Water availability is derived from the water supply approach based on water discharge measurement data (Parahita et al., 2022).

B. Water Demand (demand)

Water demand is calculated by comparing the population size and the water requirement for a decent standard of living, which is set at 120 liters/day/capita. Water demand is calculated using the following formula:

$$DA = N \times KHL_A$$

Where:

DA : Water demand
N : Population size
KHLA : Water requirement for a decent standard of living (120 liters/day/capita)

C. Projection of water demand

The projection of water demand in this study is primarily focused on the future population projection. The target year for the population projection is 2030. This study can only identify the population within the area served by the Community-Based Clean Water Supply System, which is approximately 490 people. Therefore, the projection system will use the population growth rate of Bulusan Sub-district, considering that the population data for Bulusan Sub-district is more readily available from the statistical data of Tembalang District in figures. The population growth in Bulusan Sub-district is projected using linear regression analysis, and the projected population is then calculated based on this growth. The population growth rate of Bulusan Sub-district is applied to the population in the study area. The formula for linear regression analysis is as follows (Gujarati, 2003) :

$$Y = a + bX$$

Y : The predicted variable (population in a specific year).
X : The independent variable (e.g., time in years).
a : The constant or intercept, representing the value of Y when X = 0.
b : The regression coefficient, representing the average change in Y for every one-unit increase in X.

The formula for population growth rate (PGR) / (LPP) is as follows :

$$\text{PGR} = \frac{(population\ in\ year - n) - (population\ in\ final\ yar\ )}{population\ in\ final\ year}\ x\ 100\%$$

Population growth over a specific period is calculated as the ratio of the final to initial population in natural logarithmic form (ln), multiplied by 100 (United Nations, 2019:Preston et al., 2000).

D. Determination of water carrying capacity status

The concept outlined in the Minister of Environment Regulation No. 17 of 2009 is used to determine the water carrying capacity status of a region by considering the availability of and demand for water resources for the population living in that area. The calculation of water carrying capacity is done by comparing water availability (SA) or supply with water demand (DA) or demand. Below are the criteria for water carrying capacity:

- Supply < Demand : Water carrying capacity is exceeded or poor.
- Supply = Demand : Water carrying capacity is conditionally safe or moderate.
- Supply > Demand : Water carrying capacity is safe or good.

RESULT AND DISCUSSION

This study on community-based water supply is conducted on Street Timoho Timur III, RT (Neighborhood Unit) 4 / RW (Community Unit) 3, Bulusan Sub-district, Semarang City, Central Java. The boundaries of Bulusan Sub-district are as follows:

North : Mangunharjo Sub-district
East : Meteseh Sub-district
South : Kramas Sub-district
West : Tembalang Sub-district

Bulusan Sub-district covers an area of 304.072 hectares. As of January 2023, the Sub-district is divided into 8 neighborhood units and 43 community units. Based on 2022 data, the Sub-district is inhabited by 2,048 households (KK) with a total population of 6,632 people. At the study location, there are 108 households with a total permanent population of approximately 490 people. The population in Bulusan Sub-district continues to increase, in line with the growing number of student accommodations in the Tembalang area. The primary livelihoods of the productive-age population in Bulusan Sub-district are in the informal sector, particularly activities supporting higher education, such as laundry services, photocopying, online motorcycle taxis, and driving (Dewi et al., 2022).

Analysis of water availability

Water carrying capacity is calculated based on the water supply approach, referring to data from water discharge measurements (Parahita et al., 2022; Junaidi et al, 2019). Based on interviews with key respondents, the average discharge of bore wells at the study location is 5 liters per second (lps). If the raw water unit operates for 24 hours, the optimal discharge produced reaches 432,000 liters per day.

Figure 2. interviews and observations of research locations

Analysis of water demand

The demand for household and urban water (domestic and municipal) is often referred to as raw water if the water has not been treated, and clean water if the water has been treated. Meeting water demand is crucial, as failure to fulfill water needs can lead to diseases and public unrest. The amount of water demand depends on the population size, consumption patterns, and the size of the city or Sub-district, which can be assumed to correlate with the population. Below is the standard for domestic water demand:

Tabel 1. Standard criteria for domestic water demand

Source	Criteria	Requisite
NSDAS (Neraca Sumber Daya Alam Spasial)	Urban	120 liters/person/day 43800 liters/person/year
	Rural	60 liters/person/day 21900 liters/person/year
Standard WHO	General	1000 - 2000 m^3/year
KLH	General	1600 m^3/kapita/year (domestic and foreign) or 2 x 800 m^3/kapita/year
SNI Compilation of Resource Balance sheet 2002	Urban	120 liters/day/kapita
	Rural	60 liters/day/kapita

According to the Minister of Environment Regulation No. 17 of 2009, the water demand is 800 m^3/capita/year for domestic and food production purposes, while the water demand for a decent standard of living, including domestic and food needs, is 1,600 m^3/capita/year. In this study, the criteria of 120 liters/day/capita were used to determine the cumulative water demand in the study area.

Water demand is calculated by comparing the population and the standard water requirement for a decent standard of living. In study location, there are 490 people served by clean water services. Referring to the 2002 SNI (Indonesian National Standard) on the preparation of resource balance, the standard water demand for urban areas is 120 liters per day per capita. Therefore, the total water demand in the area is:

DA =N×KHLA
DA =490×120liters/person/day
DA =58,800 liters/day

calculation of water demand in 2030 :

DA =N×KHLA
DA =532×120
DA =63,840 liters/day

Where:

DA = Total water demand
N = Population
KHLA = Standard water demand for a decent standard of living (120 liters/day/capita).

Population Growth Projection

The population projection in this study is derived from scientific calculations based on hypotheses using population growth rate indicators. The projection for Bulusan Sub-district shows a continuously increasing population growth trend (Figure 3).

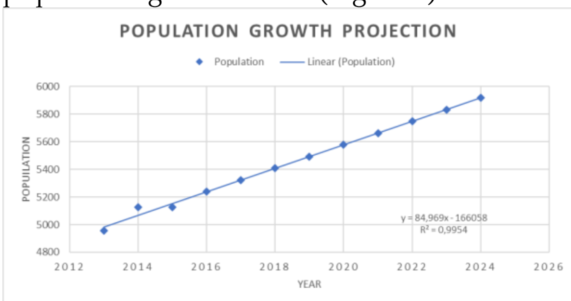

Figure 3. Population Growth Projection

From the linear regression calculation above, the equation **y = 84.969x - 166,098** is obtained. The calculation of population growth for the year 2030 is as follows:

$y = 84.969x-166098$

$y = 84.969(2030)-166098$

From these results, the population growth rate (PGR) can be calculated using the following equation:

$$PGR = \frac{(population\ in\ year - n) - (population\ in\ final\ yar\ )}{population\ in\ final\ year}\ x\ 100\%$$

$$PGR = \frac{(6429) - (5322)}{5322} x\ 100\%$$

$$PGR = 8.6\%$$

From the results of the population growth rate (PGR), the population growth projection of the study location in Bulusan District in 2030 was obtained at 532 people. This population is the result of a quick projection, which assumes that the growth rate of the study location is similar to the population growth rate in Bulusan Sub-district. The quick projection results do not consider population migration and mortality factors.

Determination of water carrying capacity status

From the calculations above, it is evident that water availability (432,000 liters/day) far exceeds water demand (58,800 liters/day). Based on these calculations, the water carrying capacity in RT (Neighborhood Unit) 4 / RW (Community Unit) 3, Bulusan Sub-district, Bulusan Sub-district, Semarang City, Central Java, is classified as safe or good. However, it is important to consider the limitations of this study. Water demand was calculated only based on the number of registered households, without considering temporary residents or visitors. In reality, the study location has high educational and economic activities, which attract many visitors. Where Bulusan Sub-district is a temporary residence for students at several universities such as Diponegoro University (Pidora & Pigawati, 2014; Prastiwi & Dewi, 2021). This could affect the accuracy of the overall water demand calculations.

Additionally, this study is still a rapid projection, which, among other things, does not take into account supply. Ideally, carrying capacity projections should also consider future supply projections and utilize integrated modeling, given that water carrying capacity is influenced not only by supply but also by factors such as climate change, as demonstrated in studies like that of Touch et al. (2020). Representative projection results are highly valuable for community-based water resource management policies.

To maintain the water carrying capacity status, sustainable water management is required, such as restricting groundwater extraction, conserving and recharging groundwater through reforestation, efficient water use, monitoring water quality and quantity, and active community and institutional involvement (UNESCO, 2012).

CONCLUSION

The water availability in RT (Neighborhood Unit) 4 / RW (Community Unit) 3, Bulusan Sub-district, Semarang City, is abundant and considered safe, with water discharge far exceeding the local residents' water demand. The daily water availability reaches 432,000 liters, while the total water demand for 118 households (KK) is only 58.800 liters per day. Based on these calculations, the water carrying capacity falls into the safe or good category. However, it is important to note that the water demand calculation is based solely on the number of registered households, without accounting for transient populations, which may affect the overall accuracy of the water demand assessment. While RT (Neighborhood Unit) 4 / RW (Community Unit) 3 currently enjoys high water security, policy and research must address dynamic populations, climate risks, and equitable management to sustain this status. Regular data updates and adaptive governance will be key to long-term resilience.

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