Indonesian Journal of Earth and Human

Water Availability Based on Seasons in Tembalang District, Semarang City

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ABSTRACT

Natural resources are a vital component of life, essential for the survival of humans and other living beings around them. One of the most crucial natural resources needed to support human life is water. The increasing population in large cities will inevitably lead to a higher demand for life-supporting natural resources such as clean water. The study is conducted in Tembalang District, one of the areas in Semarang City experiencing a clean water crisis due to rapid growth. Therefore, an analysis of the projected clean water demand in Tembalang District is necessary to determine the water demand in 2033. The future volume of water demand can be projected using the geometric method This method is applied through an analytical calculation based on population growth projections from year to year. The increase in water demand every ten-year period is almost 50% more than the previous ten-year period. Moreover, certain urban villages with extensive built-up areas have higher water demand. For instance, Tembalang Village has higher water needs than Rowosari Village.

Keywords: Water; natural resource needs; population growth

Received: August 19, 2024; revised: November 26, 2024; accepted: Desember 1, 2024.

Citation: Trihadianta, M.R., Gunawan, M., Shabrina, D., Mustikawati, L.H., Purwadi, C.E., Kholil, P.A., Fariz, T.R., Haris, A., Jabbar, A. (2024). Water Availability Based on Seasons in Tembalang District. Indonesian Journal of Earth and Human, 1(2), 84-93.

1. INTRODUCTION

Natural resources are an essential component of life, crucial for the survival of humans and other living beings around them. In an environmental ecosystem, the higher the population of living beings, the greater the demand for resources needed for survival (Febriata & Oktama, 2020). One of the vital natural resources required to support human life is water, which cannot be replaced by any other commodity (Febriata & Oktama, 2020; Efendy & Syamsul, 2019).

The increase in population in large cities due to urbanization and birth rates will inevitably lead to a rise in the demand for clean water, where the clean water needs in Semarang are supplied by the Regional Waterwork. Prabowo (2017) stated that by the end of 2017, only about 60% of Semarang's population received water from the Regional

Waterwork network, while around 40% of the population still relied on groundwater. The rapid population growth has the potential to result in some segments of society being unable to access clean water (Alihar, 2018). As a result, many of them resort to using groundwater and river water to meet their household drinking needs, despite the fact that this water may not be safe for use, especially for consumption (Rohmawati & Kustomo, 2020; Rosyidah, 2017).

Semarang City ranks among the top ten cities in disaster risk and is also vulnerable to clean water scarcity. This was revealed by the team responsible for Semarang City's climate change strategy for 2010-2020 (BLH Semarang, 2013). Water is considered a basic human need that cannot be replaced, and clean water must meet health standards and be treated before drinking. One source of water that can be used is groundwater. The Central Java Energy and Mineral Resources Agency in 2012 reported that the number of boreholes used reached 4,259 wells, with an average groundwater extraction of 15,300,000 m3 per month. Prasetya (2017) reported that land subsidence occurred at a rate of 1.33-34.9 cm per year in 2016.

Tembalang District is one of the areas experiencing a clean water crisis, due to rapid growth and its role as a hub for residential, economic, business, service, and educational activities in Semarang City (Subiyanto et al., 2021; Waskito & Pigawati, 2017). This area has become a center for various activities. The population in Tembalang District has grown rapidly due to local migration from outside the district, especially with the presence of Diponegoro University. This population growth has inevitably been accompanied by changes in land use from other uses to residential areas. In other words, Tembalang District is currently facing urban spatial planning and land management challenges. The population growth in Tembalang District, coupled with economic growth and the expansion of residential areas, leads to increased water use and reduces the availability of groundwater. This situation is exacerbated by economic and residential activities that pollute water sources due to poorly managed waste disposal, further reducing the availability of clean water for consumption (Sedyowati et al., 2017). Therefore, this study will discuss the rate of clean water demand in Tembalang District for the years 2013, 2023, and 2033.

2. METHODS

The research location for this study is in Tembalang District, which is administratively situated in Semarang City, Central Java Province. Tembalang District is one of the most densely populated areas because it serves as a hub for educational functions. This has led to rapid growth in Tembalang District as a center for residential, economic, business, and service activities. This condition contributes to the high utilization of natural resources, particularly clean water, in Tembalang District.

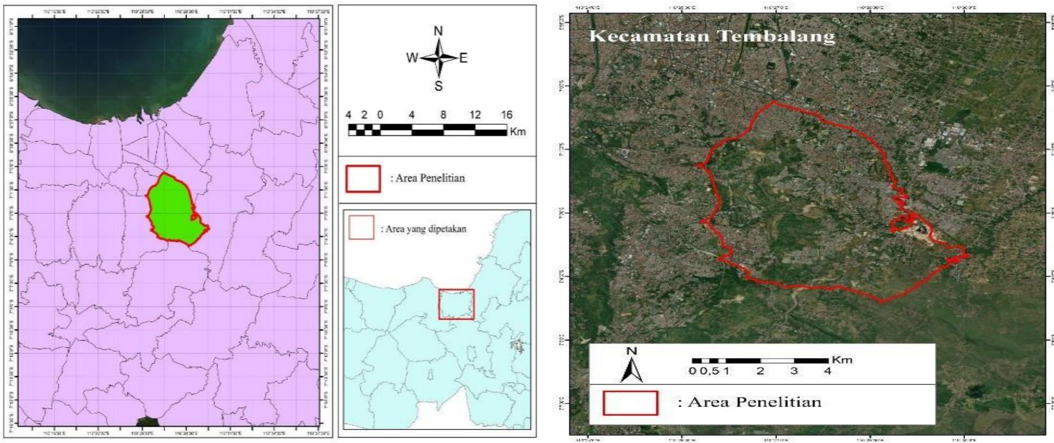

Figure 1. Map of Tembalang District Location

Population Projection Formula

Herdiansyah and Putra (2019) stated that the future water volume demand can be projected using the geometric method. This method is applied through analytical calculations based on population growth projections year by year. The calculation is performed by considering the average annual population growth rate percentage derived from the previous census data. The calculation is as follows:

$$p_n = p_o (1+r)^n$$

Where

p_n = Population at the end of the year (Number of people)

p_o = Population at the beginning of the year

r = Average annual population growth rate (%)

^{n} = Projection time in years

The geometric method is chosen because it represents the pattern of increasing population growth. Tembalang District has experienced rapid population growth over time due to urbanization, driven by its designation as one of the educational centers in Semarang City. Therefore, in the calculation method used in this study, the author includes the number of Diponegoro University students as a representation of the student population in the Tembalang area. The number of Diponegoro University students is added to the population projection obtained from the geometric method to obtain the total projected population for that year.

Water Demand Calculation Formula

Water demand is influenced by domestic usage within a community. Population and economic growth are the most significant factors affecting water demand in a specific area. High water usage by a community is driven by several factors, such as the level of economic activity, standard of living, education level, and social conditions. Regional water demand fluctuates daily based on residents' activities, community customs, individual habits, and urban patterns. These factors affect the amount of clean water used per hour. Other factors influencing water availability include planned water losses, unplanned water losses, and accidental water losses.

Water Demand Fluctuations

According to Kalensun (2016), fluctuations in basic water demand and water losses occur over time, on an hourly, daily, monthly scale, throughout the year. Based on reference average water demand, maximum daily and hourly water demands can be determined.

Table 1. Calculation of clean water demand during the dry season

Factors in calculating clean water use	Analysis	Water use
Household water use	0.8 × Population × 78	KbRt
Social and commercial facilities (30%)	0.3 × KbRt	KbF
Water needs in the region	1.25 × (KbRt + KbF)	KbW
Leakage of 10% of regional needs	10% × KbW	cKC
Fire reserves amount to 10% of total regional needs	10% × KbW	CKb
Total water demand for the region	KbW + CKc+ CKb	KbTot
Average water requirements daily in liters/second	KbTOt ÷ (24 × 60 × 60)	Kb1=dt
Maximum water requirements daily (l/s)	1.25 × Kb1 / dt	KbHMaks
Water requirement by the hour busy (l/s)	1.75 × Kb1 / dt	KbJPc

Table 2. Calculation of Freshwater During the Rainy Season

Factors in calculating clean water use	Analysis	Water use
Household water use	0.8 × Population × 152	KbRt
Social and commercial facilities (30%)	0.3 × KbRt	KbF
Water needs in the region	1.25 × (KbRt + KbF)	KbW
Leakage of 10% of regional needs	10% × KbW	cKC
Fire reserves amount to 10% of total regional needs	10% × KbW	CKb
Total water demand for the region	KbW + CKc+ CKb	KbTot
Average water requirements daily in liters/second	KbTOt ÷ (24 × 60 × 60)	Kb1=dt
Maximum water requirements daily (l/s)	1.25 × Kb1 / dt	KbHMaks
Water requirement by the hour busy (l/s)	1.75 × Kb1 / dt	KbJPc

3. RESULTS AND DISCUSSION

Water Demand Projection for Tembalang District

In this study, the first step in predicting water demand in Tembalang District for the years 2013, 2023, and 2033 is to calculate the population projection for these three periods. The population projection process in Tembalang District involves summing up the local population and the number of Diponegoro University students during the specified periods. The projected population results are then used as a reference for calculating water demand in Tembalang District for the years 2013, 2023, and 2033.

Table 3. Projected Water Demand During the Dry Season in Tembalang District

Factor in calculations use of clean water	Dry Season		
	2013	2023	2033
Domestic Needs	11.624.995,2	13.718.954,57	20.354.861,3
Social and Commercial	3.487.498,56	4.115.686,37	6.106.458,39
Regional water needs	18.890.617,2	22.293.301,17	33.076.649,61
Lack of regional needs	1.889.061,72	2.229.330,117	3.307.664,961
Reserve regional needs for fire extinguishing	1.889.061,72	2.229.330,117	3.307.664,961
Total regional water needs	22.668.740,64	26.751.961,4	39.691.979,53
Average daily requirement (l/s)	262,3696833	309,6291829	459,3979113
Max daily requirement (l/s)	327,9621042	387,0364786	574,2473891
Water demand during peak hours (l/s)	459,1469458	541,8510701	803,9463447

Table 4. Projected Water Demand During the Rainy Season in Tembalang District

Factor in calculations use of clean water	Rainy Season		
	2013	2023	2033
Domestic Needs	22.653.836,8	26.734.373	39.665.883,56
Social and Commercial	6.796.151,04	8.020.311,9	11.899.765,07
Regional water needs	36.812.484,8	43.443.356,12	64.457.060,78
Lack of regional needs	3.681.248,48	4.344.335,612	6.445.706,07
Reserve regional needs for fire extinguishing	3.681.248,48	4.344.335,612	6.445.706,078
Total regional water needs	44.174.981,76	52.132.027,35	77.348.472,94
Average daily requirement (l/s)	511,2845111	603,3799462	895,2369553
Max daily requirement (l/s)	639,1056389	754,2249327	1.119,046194
Water demand during peak hours (l/s)	894,7478944	1055,914906	1.566,664672

Based on the calculations, the water demand in Tembalang District continues to increase as the population in the area grows. In 2013, the population of Tembalang District, consisting of local residents and Diponegoro University students, was 186,298 people, with a total water demand of 22,668,740.64 liters during the dry season and 44,174,981.76 liters during the rainy season. By 2023, the population had increased to 219,855, with a total water demand of 26,751,961.4 liters during the dry season and 52,132,027.35 liters during the rainy season. Comparing these two periods, 2013 and 2023, demonstrates that as time progresses and the population grows, water demand also increases.

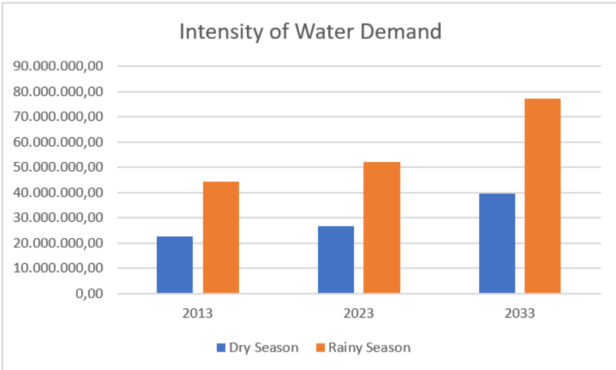

Figure 2. Bar Chart of Water Demand in Tembalang District in 2013, 2023, and 2033

The projected water demand in Tembalang District shows an increase from 2013 to 2023 and 2033. Within the same period, water demand is predominantly higher during the rainy season. For example, in 2023, the maximum daily water demand during the rainy season was almost twice as high as during the dry season. This is because, during the rainy season, people tend to use more water for activities not required during the dry season, such as agricultural needs and increased domestic activities like washing vehicles and clothes due to rain. The abundant water availability during the rainy season leads to less concern about daily water usage, resulting in more wasteful water consumption.

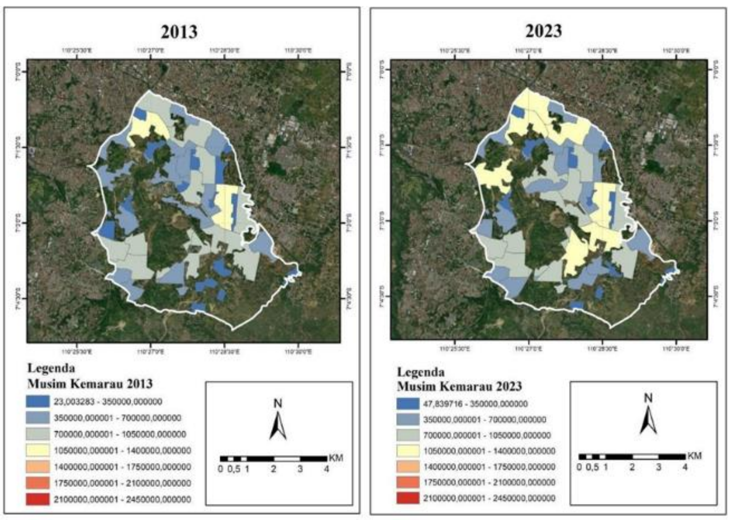

Figure 3. Map of Water Demand Changes During the Dry Season in Tembalang District in 2013 and 2023

The map of projected water demand during the dry season in Tembalang District shows a significant increase in some areas. The increase in water demand in 2023 was particularly notable in densely populated areas such as Sendangguwo, Tembalang, Tandang, Jangli, Kedungmundu, and Sendangmulyo sub-districts. For example, Tembalang Sub-district saw a significant increase in water demand between 2013 and 2023. In 2023, Tembalang Sub-district's dry season water demand was 3,332,122.16 liters, compared to just 1,778,461.99 liters in 2013. Significant increases were also seen in Jangli Sub-district, where water demand rose from 1,237,390.89 liters in 2013 to 1,800,690.88 liters in 2023, and in Meteseh Sub-district, where dry season water demand increased from 2,739,511.91 liters in 2013 to 3,377,970.14 liters in 2023. Additionally, Sendangmulyo Sub-district saw an increase from 4,195,110.51 liters in 2013 to 4,477,062.24 liters in 2023. From this comparison, it is evident that sub-districts near Diponegoro University have seen a more significant increase in water demand compared to sub-districts farther away, such as Rowosari, which has relatively lower water demand compared to other sub-districts in Tembalang District.

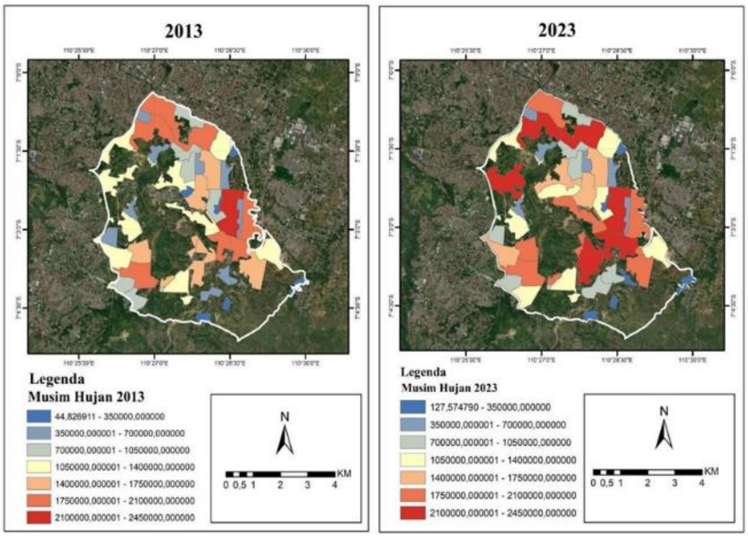

Figure 4. Map of Water Demand Changes During the Rainy Season in Tembalang District in 2013 and 2023

Unlike the dry season, the water demand map in Tembalang District during the rainy season tends to be more intense, indicating higher water usage compared to the dry season map. This is because, during the rainy season, people tend to be more wasteful in their water use. One reason for this is the abundance of water during the rainy season, while during the dry season, people are more inclined to conserve water due to its limited availability. Data processing using ArcMap shows significant changes in some sub-districts in Tembalang District from 2013 to 2023. These sub-districts include Tandang, Kedungmundu, Jangli, Tembalang, Meteseh, and Kedungmundu. The results are similar to the increase in water demand in Tembalang District during the dry season. Sub-districts with large areas of developed land tend to have higher water demand compared to sub-districts like Rowosari, which is dominated by plantations and open land. However, between 2013 and 2023, all sub-districts in Tembalang District experienced an increase in water demand during both the dry and rainy seasons.

The increasing water demand in Tembalang District raises concerns about the potential decline in groundwater supply in the area. According to observations, most residents in Tembalang already have access to Regional Waterwork water sources, with many combining Regional Waterwork water with dug wells to meet their water needs. However, some eastern sub-districts, such as Rowosari, still lack Regional Waterwork water access due to their remote location. In Rowosari Sub-district, most residents rely on dug wells, which are dug to a depth of about 10-14 meters from the surface to obtain clean water, although the water yield remains relatively low. According to the head of RW 6 in Rowosari Sub-district, the water yield from these wells has decreased over time due to the increasing use of groundwater without accompanying groundwater conservation efforts.

The impact of clean water scarcity is often felt by residents during the dry season. Although water usage is lower during the dry season, even half of that during the rainy season, the water supply is relatively abundant during the rainy season. This scarcity often leads to social, economic, and environmental problems. The limited supply of clean water in some areas results in competition among families to meet their water needs, which can sometimes lead to conflicts between individuals or even regions. Social conflicts due to water scarcity typically occur in densely populated areas. Water scarcity also significantly increases the cost of clean water services in some areas. Additionally, water scarcity forces residents to dig deeper wells to obtain larger water sources, leading to a decrease in water yield from shallower wells.

One solution to address water scarcity is to implement water usage management (Susanti & Hamdani, 2016). Water usage management can be applied by reducing water usage during both the rainy and dry seasons. This can be achieved by providing education to the public on the limitations of clean water resources and the importance of proper water management. Water conservation programs can include increasing water catchment areas, such as expanding green spaces and creating infiltration wells. Infiltration wells help water filter into the ground, increasing groundwater levels. Infiltration wells are particularly suitable for areas with low land development, typically rural areas. In densely built urban areas, water conservation efforts can be implemented through the creation of biopores. Biopores, similar in concept to infiltration wells, are smaller and shallower but can be created in large numbers, making them more cost-effective and space-efficient.

A limitation of this article lies in the method used, which only considers the local population and Diponegoro University students in the water demand analysis for Tembalang District. As a result, the findings may not be fully representative, as Tembalang District is also home to other campuses and students from other institutions who reside in the area. Future research should expand this study to include water demand projections that encompass not only the local community and Diponegoro University students but also other relevant populations, ensuring more valid and diverse data. Direct observations should also be conducted in areas experiencing significant increases in water demand to verify data and obtain more representative results.

4. CONCLUSIONS

The water demand in Tembalang District underwent significant changes between 2013, 2023, and 2033. This conclusion is based on population projections that include both the local population and Diponegoro University students. The increase in water demand every ten-year period almost reached 50% compared to the previous decade. Certain sub-districts with large developed land areas also exhibited higher water demand. For example, Tembalang Sub-district had higher water demand than Rowosari Sub-district. In other words, the increase in water demand every ten years occurred uniformly across almost the entire Tembalang District, with no drastic increases in water demand in any particular area.

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