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ANALYSIS OF SURFACE WATER POTENTIAL FOR DOMESTIC WATER USE IN GUNUNGKIDUL ECOREGION

Husnul Khotimah Setiacahyandari[1], Alfina Ayu Rachmawati[2], Alvin Anindita Katon Sumunar[3], Atina Tsabita Khairunnisa[4], Lupiya Cintantya Anindita[5], Nabila Laili Udzkhiyati[6], Slamet Suprayogi[7]

[1,2,3,4,5,6,7]Department of Environmental Geography, Faculty of Geography, Universitas Gadjah Mada Yogyakarta

[1]husnulks123@mail.ugm.ac.id

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ABSTRACT

Gunungkidul is characterized by its high rainfall intensity, high population, and various ecoregions predominated by karst, all of which can affect the availability of surface water. Therefore, this study aimed to analyze the surface water potential for domestic use in the Gunungkidul ecoregion. This analysis is carried out by calculating the water use index through a comparison of domestic water demand and surface water availability in Gunungkidul. The results show that the availability of surface water in Gunungkidul was not able to fulfill the population's domestic water needs throughout the year. It is proved by the fact that some ecoregions in July and all ecoregions in August have a surface water use index of more than 0,2 and are classified as poor and very poor classes. The ecoregion with the highest surplus of surface water is Gunung Sewu Karst Hills which is reflected by the lowest surface water use index. In contrast, Wonosari Karst Basin has the lowest surface water potential shown by the high value of its surface water use index. Based on these results, it is known that the main factors that affect the water use index are the area of each ecoregion, population, rainfall, and geological and geomorphological conditions.

Keywords: *Surface Water, Domestic Water Demand, Water Use Index, Ecoregion*

INTRODUCTION

Water is one of the most vital resources of life on earth, especially for humans to sustain their existence. Humans depend on water for domestic needs like drinking, bathing, cooking, and washing, also other needs such as production, industry, agriculture, fisheries, and sanitation (Amalia and Sugiri, 2014). Water demand is highly dependent on water availability. Water availability comes from three sources, namely rainwater, groundwater, and surface water which are influenced by seasons (Sari et al., 2012). The rainy and dry seasons have different levels of water availability. Water deficits can cause physical and social disasters. In contrast, surplus water adds value to water availability.

Annual population growth, especially in developing countries, is always the population's main problem that has a big impact. Population growth can increase the dependence ratio in a region. This condition may have an impact on employment growth, but it's also possible that a region may have not adequate employment (Arsyad, 2004). The rising population will increase water demands (Akhirul et al., 2020). In order to fulfill food demands, humans also need water. Food demands and human activities are closely related to water demands (Sitompul and Efrida,

2018). The demand for water is unavoidable, so it is crucial to study and plan the use of water resources. Therefore, the availability of sufficient water is an important priority to fulfill water demands.

Landforms have constituent aspects such as morphology, processes (structural and lithology), and chronology. Zeffitni (2010) mentions aspects of landforms that can be used as a reference in making hydromorphology. Gunungkidul has a landscape with a dominant solution or dissolution process. Not only solutional processes and karst landforms but there are other geomorphic processes in Gunungkidul's formation landforms, such as denudational and structural processes. Karst hills are composed of easily soluble rocks such as limestone, gypsum, and marble, with the characteristics of having a distinctive water flow system (Ford and Williams, 2007). Thornbury (1958) mentions that one of the characteristics of karst areas is high rainfall, where rainwater is a weathering agent. The dissolution process will result in unique hydrological conditions in the karst area, namely dry conditions on the surface inversely proportional to the subsurface, which has abundant water resources (Cahyadi, 2010). Subsurface water resources are characterized by the presence of underground rivers and springs, while on the surface there are rarely found rivers but there are dolines.

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RESEARCH METHOD

Study Area

This research was conducted in Gunungkidul Regency, based on an ecological approach. Based on law number 32 of 2009, an ecoregion is a geographical area with similar characteristics in climate, soil, water, flora, native fauna, and patterns of human interaction with nature that describe the integrity of natural systems and the environment. Gunungkidul area was chosen as the research area because it has a variety of ecoregional conditions, which are divided into five areas; Baturagung Structure Fault Hills, Baturagung Structure Inter-Hills Valley, Baturagung Denudation Hills, Gunung Sewu Karst Hills, and Wonosari Karst Basin (Figure 1). Each area has different geological, geomorphological, and potential water resources. In general, the Baturagung Hills area is controlled by tectonic structures resulting from marine subduction and active faults which include Opak and Dengkeng faults (Mulyasari et al., 2017). This area has a trellis river flow type with volcanic rock and soil types. Meanwhile, the karst area is controlled by the dissolution process, which causes the emergence of a hydrological system with secondary porosity that gives rise to underground flows (Haryono et al., 2017).

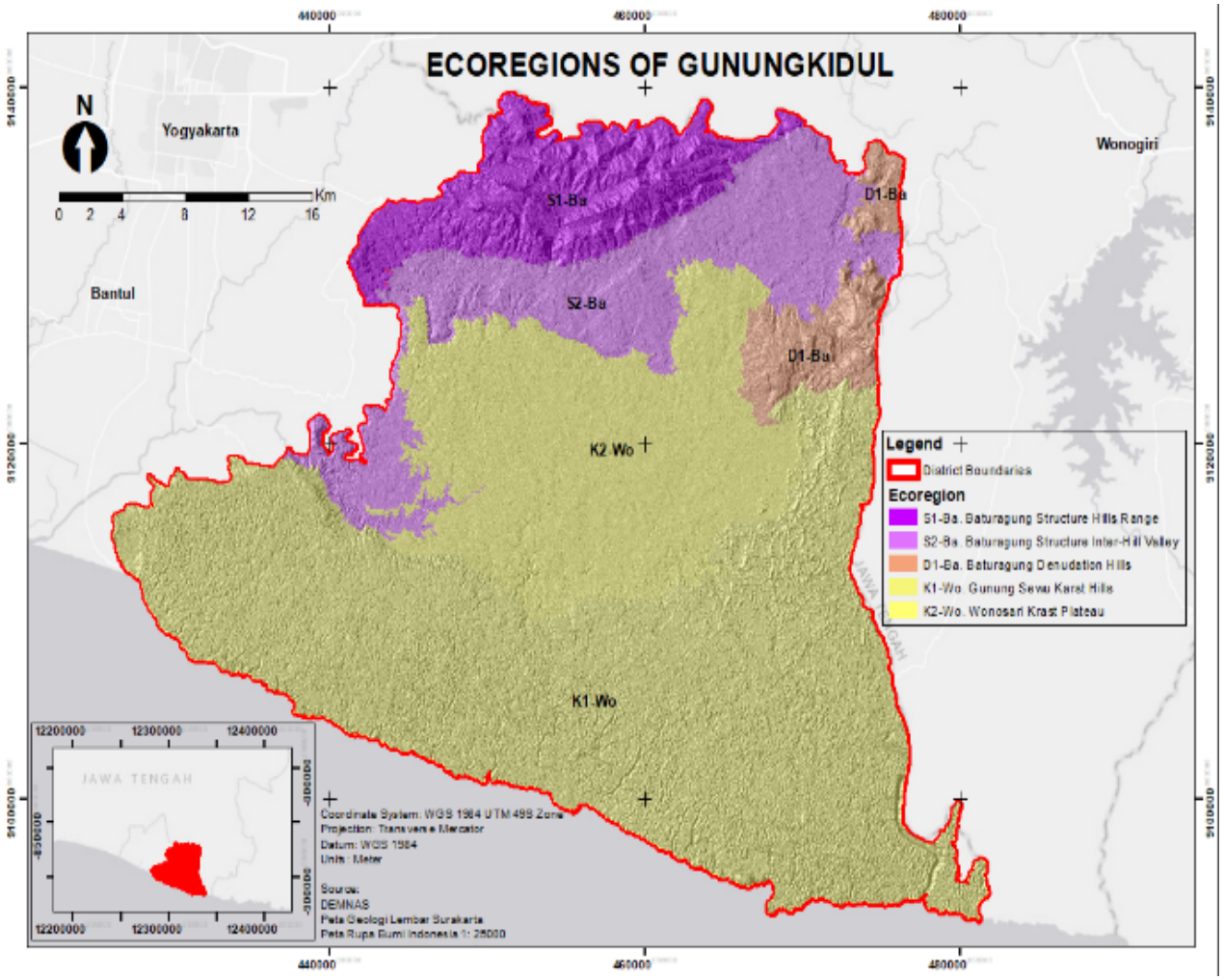

Figure 1. Ecoregions of Gunungkidul

Data Collecting

In this study, there are three main data consisting of rainfall, population, and ecoregion maps. Rainfall data from 2010 to 2020 originated from Balai Besar Wilayah Sungai (BBWS) and was used to calculate regional rainfall intensity. Rainfall data is also used to find out the rainfall distribution in the study area (Setiawan, et al., 2020). To calculate the water domestic demand in this study used population data in 2020 was obtained from Badan Pusat Statistik (BPS). Ecoregion maps originated from the overlay process between DEM data, geological maps, and geomorphological maps of Surakarta sheets which were derived from Inageoportal. Those three main data were processed to be able to calculate the water use index.

Data Processing

The potential of runoff volume provides an overview of the potential water resource availability and can be utilized in a watershed. The calculation of potential annual flow volume uses rainfall data, runoff coefficient data, and area. This calculation uses the following formula.

$$V = CH \times C \times A \ldots\ldots\ldots (1)$$

V = Runoff volume potential (m^3/month)
CH = Rainfall (m/month)
C = Runoff coefficient
A = Area (m^2)

Domestic water demand describes the water needs that are used by the population, and for the calculation, it needs total population data in each ecoregion. Calculation

of this water requirement can be done by the following calculation formula based on SNI (2015).

$$KAd=30\times((qu1000)\times Pk)\ldots\ldots\ldots(2)$$

Kad = Domestic water demand (m^3/month)
qu = Average water consumption (80-120 liters/person/day)
Pk = Total population

The water use index describes the comparison between water demand and water availability in an area. The greater demand for water, the greater value of the water use index will be. Calculation of this water use index is only for domestic water use that can be done with the following calculation formula from SNI (2015).

$$IPA=KAdV\ldots\ldots\ldots(3)$$

IPA = Water Use Index
KAd = Domestic water demand (m^3/month)
V = Runoff volume potential (m^3/month)

The calculation of this water use index generates an index value with a classification from SNI (2015) as shown in Table 1.

Table 1. Water Use Index Classification

Water Use Index	Classification	Category
> 0.4	I	Very Poor
0.2 - 0.4	II	Poor
0.1 - 0.2	III	Good
< 0.1	IV	Excellent

Source: SNI (2015)

Data Analysis

The results of this study are analyzed using the descriptive quantitative method. This method focuses on an analysis of numerical data to describe and explain the results of the research (Metler, 2021). The results are divided into three sections consisting of surface water potential, domestic water demand, and water use index, each of which will be further analyzed. In general, the surface water potential section describes the condition of surface water availability in each Gunungkidul ecoregion from rainfall intensity data. The domestic water demand section describes the population's needs for domestic water using total population data in each ecoregion. The water use index section, as the main result of this study, describes the fulfillment of domestic water demand using surface water potential and its influence factors. The results are visualized using graphs and tables. Graphs are used to illustrate the comparison between surface water potential and domestic water demand. Furthermore, a table is used to show the calculation result of the water use index.

RESULTS AND DISCUSSION

Surface Water Potential

Surface water potential in Gunungkidul is influenced by the availability of surface water and rainfall. Dependable flow is used as the reference for analyzing the availability of surface water. Dependable flow is a combination of direct runoff and base flow which can be identified in a river's observation point. This combination reflects discharge value which can be expected to occur at the observation point in terms of time and reliability values (Mahdum, 2015).

Surface water potential in Gunungkidul is classified by ecoregions. The highest surface water availability is located in Gunung Sewu Karst Hills with a water potential of 568,516,882.90 m3/year, however, Baturagung Denudation Hills has the lowest potential which is 43,306,780.39 m3/year. The other ecoregions; Wonosari Karst Basin, Baturagung Fault Structure Hills, and Baturagung Structure Inter-Hill Valley, have a surface water potential of 243,306,859.71 m3, 112,868,269.69 m3, and 162,592,319.33 m3 in one year.

Dependable flow has an impact on the surface water potential. Sriwati (2014) mentions that meteorology factor such as precipitation (i.e rainfall intensity and duration of rainfall) influences it. Furthermore, there are

several drainage areas' elements which consist of land use, land cover, drainage density, topography, and soil type (Febryanto, 2016). Besides the hydrology characteristics, the large area in an ecoregion influences the surface water potential as well. For instance, Gunung Sewu Karst Hills which has the highest surface water potential in Gunungkidul also has the largest coverage area which is 717 km2. Despite the characteristics that have a high permeability soil, karst area also has high rainfall intensity characteristics (Thornbury, 1958). Therefore, rainfall intensity which is the main source of surface water availability takes an important part in the high surface water potential in Gunung Sewu Karst Hills.

Domestic Water Demand

. Water demand is the amount of water used for various purposes or community activities in the area (Admadhani, et al., 2014). The amount of water requirement is determined by the Directorate General of Cipta Karya (2000) by setting standards for raw water needs, both domestic and non-domestic water needs. The water demand used in this analysis of water availability is domestic water demand. In addition, the calculation of domestic water needs is divided into the water needs of the population in rural and urban areas, with rural areas' range of 60-90 liters/day/person, while in urban areas of 90-110 liters/day/person (SNI, 2015).

Each ecoregion in Gunugkidul has a different amount of domestic water demand, depending on the population. Baturagung Denudation Hills is the smallest ecoregion in Gunungkidul and tends to have a small population. Hence, this area has only had 91,699 m3 of domestic water demand per month. Besides that, Gunung Sewu Karst Hills which is the largest ecoregion area in Gunungkidul produces domestic water needs of 766,401 m3 per month. Its high domestic water demand is influenced by the high population in this area. Wonosari Karst Basin has the highest population density due to its area which includes the capital city of Gunungkidul. This area produces 751,083 m3 of domestic water demand per month.

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Baturagung Structure Fault Hills cover 4 sub-districts and have hilly land conditions. Therefore, the population in this area is not quite high and only produces 202,439 m3 of domestic water demand per month. Meanwhile, in Baturagung Structure Inter-Hill Valley, which has many settlements, produces 314,885 m3/month. Based on the results of domestic water demand, it is known that if a large area has a large number of settlements and populations, the domestic water demand's value will be greater. This is aligned with Alihar's research (2018) that domestic water needs are influenced by the large population density in an area and will subsequently affect access to clean water.

Water Use Index

The water use index can be used to evaluate the usage of surface water to be more rational and efficient (Onishi, et al., 2012 Ichinose, et al., 2019). The efficiency of surface water in supplying domestic water demands is essential, especially in Karst landscapes where it is more affordable for using surface water than groundwater. Table 2 shows the pattern of water use index in Gunungkidul ecoregions. In general, Gunungkidul's domestic water demand can be fulfilled in January-June and September-

December, yet, in July the Baturagung Denudation Hills and Wonosari Karst Basin's water demand can't be fulfilled. Those areas have a water use index of more than 0.2 and are classified as poor and very poor. In contrast, Baturagung Fault Structure Hills and Baturagung Structure Inter-Hill Valley are classified as good, and the Gunung Sewu Karst Hills are excellent, in July. Those conditions are influenced by the area which impacts the population in each ecoregion. The water use index in Gunungkidul is getting worse in August, all ecoregions have values higher than 0.2, showing that surface water availability in these months is insufficient to fulfill domestic water demand. The extremely low rainfall intensity in August has an impact on this occurrence. It is aligned with Muliranti and Hadi's research (2013) which said that low rainfall intensity influences the criticality of domestic water use. Hence, this dry season affects the surface water scarcity in Gunungkidul, especially in August.

Wonosari Karst Basin ecoregion has the lowest surface water potential to supply domestic water demand. Figure 2 shows the comparison between surface water potential and domestic water demand in this ecoregion. The graph illustrates that the lowest potential of surface water occurred in August. Therefore, the surface water potential of Wonosari Karst Basin is very limited to fulfill domestic water demand which has an impact on the water use index.

The Wonosari Karst Basin's limited surface water potential to supply domestic water demand is further illustrated by the high value of the surface water index. The supply of surface water from January to June and September to December is sufficient to fulfill the ecoregion's domestic water needs. In contrast, the water use index is classified as poor (0.25) in July and very poor (0.54) in August, due to the dry season. It is similar to Purwantara, et al. (2012) and Haryono, et al. (2017) that seasons have a significant impact on the river in the Wonosari Karst Basin, which causes dry conditions during the dry season. The other factor is its geomorphological characteristics which include in karst area. The water resources in karst areas are located below the rock surface, where carbonate rocks are the predominant material (Adji and Haryono, 2004). According to Hardinasari (2018) and Harriyadi (2020), underground river flows are predominant in karst areas, hence its surface water is limited. Wonosari Karst Basin's population also takes a part in the high value of its water use index. This ecoregion includes Wonosari District, the capital and economic center of Gunungkidul Regency, which has an impact on the region's high population. Population growth in a city is quite high due to urbanization (Mardiansjah and Rahayu, 2020). Pratiwi and Hizbaron (2016) said that a region's high population causes a high demand for domestic water. This condition is also not sufficiently balanced by an adequate area, thus, the Wonosari Karst Basin has a higher water use index value than other ecoregions.

Gunung Sewu Karst Hills ecoregion has the lowest water use index. Based on the result of data processing in Table 2, Gunung Sewu Karst Hills has the highest potential for surface water compared to other ecoregions. This result is in contrast to the karst conditions which generally have a small surface flow. The karst area is characterized by the least surface rivers and the development of underground river channels (Adji, 2009). Surface water in karst areas is found in small quantities in lakes and surface rivers. Surface water in karst areas can be found in lakes or reservoirs which were originally in the form of a Dolina valley with the base covered by a layer of impermeable terrazzo soil so that it can collect rainwater (Sunarto, 1997). The existence of water resources in karst areas has an uneven distribution, both surface water and groundwater, both in quality and quantity, this is the cause of karst areas often experiencing water shortages (Sulastoro, 2013).

The river in Gunung Sewu Karst Hills has a unique drainage system. Surface rivers can be found on the surface, but disappear into grooves to the underground drainage system, then reappear to the surface (resurgence), and disappear into holes again, and so on until they

end up on a beach (Santosa, 2015). The dominant material in carbonate rock's form which has many crevices and is easily soluble in water has an impact on the development of underground drainage systems instead of surface drainage systems. The large porosity of rocks in the form of secondary porosity causes water to enter the underground drainage system and has an impact on the drying of surface water (Cahyadi, 2010 Cahyadi et al. 2017). These theories show that karst areas generally have the least surface river and surface drainage system.

The results of the water use index in Gunung Sewu Karst Hills are influenced by factors from the ecoregion. Gunung Sewu Karst Hills is an ecoregion with the largest area compared to other ecoregions in Gunungkidul. The area of Gunung Sewu Karst Hills reaches 49.3% of the total area in Gunungkidul. The population in this area reaches 286,137 people. This number shows that Gunung Sewu Karst Hills has the highest population compared to other ecoregions. Domestic water demand reaches 766,401 m3/month, which is also the highest domestic water demand compared to other ecoregions. The high demand for domestic water is influenced by the high population in this area.

Based on Figure 3, Gunung Sewu Karst Hills has a high potential for surface water every month. The comparison between surface water potential with water demand is quite far, except in August. Although the water demand in August is sufficient, the calculation of water demand is only based on the domestic sector. The results in Figure 3 show that surface water potential in August is sufficient to fulfill the water demand of the domestic sector. However, the surface water potential in August will experience a deficit if it's calculated with the water demand of other sectors. Based on the water use index, Gunung Sewu Karst Hills has the "Excellent" category, except for August which has the "Poor" category. These results indicate that Gunung Sewu karst Hills has sufficient surface water potential to fulfill domestic water demand.

All of the ecoregions in October - May have an "Excellent" water use index. This shows that the surface water potential can fulfill domestic water demand and leaves a lot of supply to be used in other sectors. Gunung Sewu Karst Hills ecoregion in July and September was the only ecoregion with an "Excellent" category. This was influenced by the area of the ecoregion, geomorphological and geological conditions, rainfall, and population. The water use index in July - September varies in each ecoregion and tends to be lower in August. In this month, surface water potential tends to be more prone to experiencing a deficit. This is because the surface water potential is sufficient to fulfill the domestic water demand, but does not leave much supply for the water demand of other sectors.

Baturagung Denudation Hills in July has a "Poor" water use index. To reduce the potential of water deficits, areas in other ecoregions with surplus water can distribute some of their surface water supply. This solution can be applied to the other ecoregions that have the potential to experience water deficits. In contrast with surface water conditions in August, Batuagung Denudation Hills, Gunung Sewu Karst Hills, Baturagung Fault Structure Hills, and Baturagung Structure Inter-Hill Valley has the "Poor" water use index, while the Wonosari Karst Basin has "Very Poor" water use index. In August under these conditions, it will be difficult to distribute surface water surplus to other ecoregions. Another way that can be done is to store surface water surplus in certain months so that it can be used and distributed during certain conditions, such as water deficits in dry months during the dry season.

Table 2. Water Use Index for Domestic Water Demand in each Gunungkidul Ecoregion

Ecoregion	Water Use Index											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baturagung Denudation Hills	0.01	0.01	0.01	0.02	0.04	0.08	0.21	0.35	0.12	0.07	0.02	0.01
	IV	IV	IV	IV	IV	IV	II	II	III	IV	I V	IV
Gunung Sewu Karst Hills	0.01	0.01	0.01	0.02	0.03	0.04	0.08	0.29	0.06	0.03	0.01	0.01
	IV	IV	IV	IV	IV	IV	IV	II	IV	IV	IV	IV
Wonosari Karst Basin	0.02	0.02	0.02	0.04	0.06	0.11	0.25	0.54	0.12	0.09	0.03	0.02
	IV	IV	IV	IV	IV	III	III	I	III	IV	IV	IV
Baturagung Fault Structure Hills	0.01	0.01	0.01	0.02	0.04	0.05	0.15	0.24	0.08	0.05	0.01	0.01
	IV	IV	IV	IV	IV	IV	III	II	IV	IV	IV	IV
Baturagung Structure Inter-Hill Valley	0.01	0.01	0.01	0.02	0.04	0.06	0.14	0.31	0.07	0.05	0.02	0.01
	IV	IV	IV	IV	IV	IV	III	II	IV	IV	IV	IV

Source: Data analysis (2021)

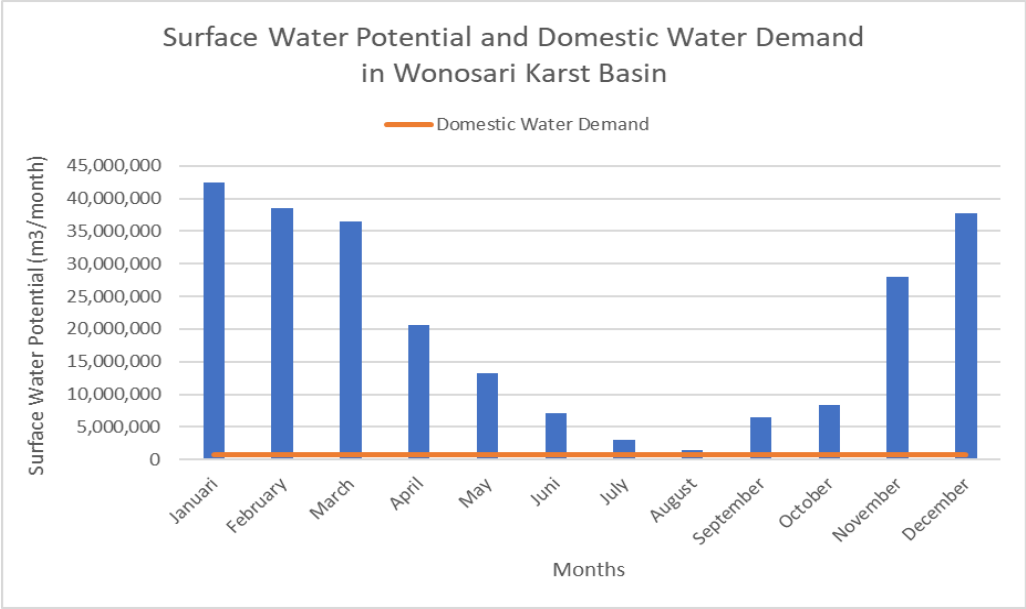

Figure 2. Graph of Surface Water Potential and Domestic Water Demand in Wonosari Karst Basin

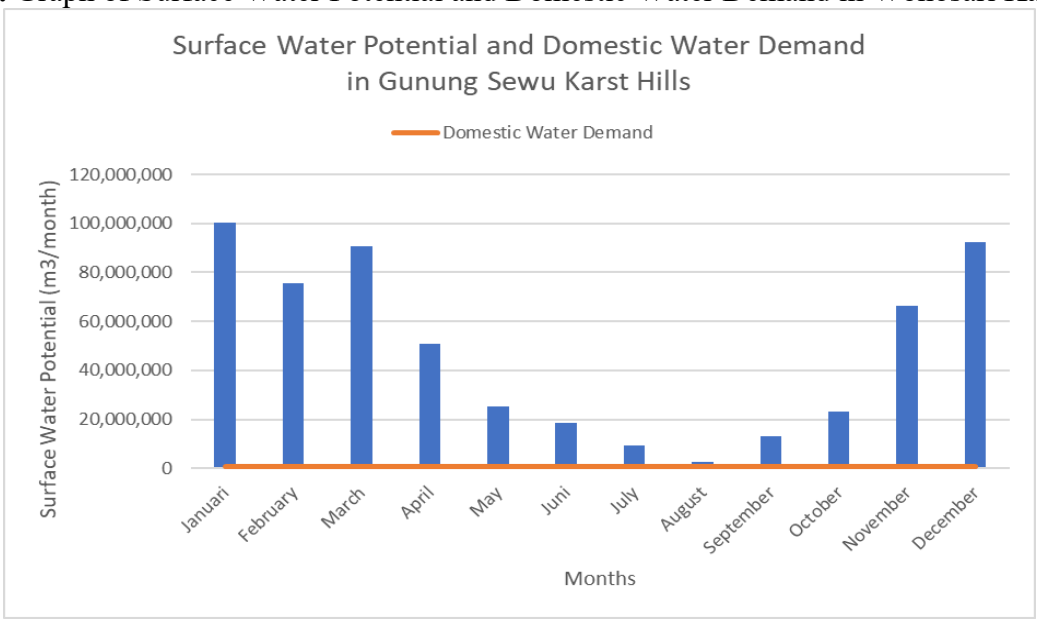

Figure 3. Graph of Surface Water Potential and Domestic Water Demand in Gunung Sewu Karst Hills

CONCLUSIONS

The water use index is inversely proportional to the surface water potential. The result shows that among the five ecoregions in Gunungkidul, the lowest water use index value is in Gunung Sewu Karst Hills, however, the highest value is in Wonosari Karst Basin. This result means that Gunung Sewu Karst Hills' surface water potential can fulfill its domestic water demand rather than the Wonosari Karst Basin's and other ecoregions. Gunung Sewu Karst Hills has the largest area and the highest population among other ecoregions which has an impact on its high domestic water demand. On the opposite, Wonosari Karst Basin's water use index value is influenced by its high population density, coverage area, and geomorphology condition.

Gunung Sewu Karst Hills and Wonosari Karst Basin have the same landscape characteristics as karst areas, yet different water use index values. This condition is

affected by the difference between its coverage area, rainfall intensity, and total population. From this result, it is known that the predominant factors that influence each ecoregion's water use index are different but mostly the total coverage area and total population.

RECOMMENDATIONS

Geomorphological characteristics in the Gunungkidul ecoregion, which is predominated by karst, affect the limited surface water potential to fulfill domestic water demand in several months. This condition may become a problem in the socio-economic of Gunungkidul Regency. The results of this study can be used as a framework for designing further development plans or regulations based on ecoregions in Gunungkidul Regency, to fulfill the domestic water demand, especially in the dry season. The program that can be implemented is storing rainfall water on a big scale using lakes, ponds, or other storage systems.

There is a result of this study that is not quite aligned with the existing theory. The karst area dominantly suffers from surface water, whilst the result shows that Gunung Sewu Karst Hills have high surface water potential for months except in August. This could be caused by the secondary data that the authors used. Therefore, field validation is necessary to get the best results. In addition, this study only calculated the surface water potential, water demand, and water use index in the domestic sector, hence, further research needs to be carried out.

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