Distribution pattern of Gunung Sewu karst doline water utilization: a case study of doline in Semanu and Ponjong Sub Subdistrict, Gunungkidul Regency

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Abstract. Gunungkidul Regency is part of the Gunung Sewu karst mega system, which has diverse morphology. The karst landscape has its uniqueness to the geohydrological system, which makes it difficult for people to use underground water. Consequently, people are more likely to use surface water. The presence of surface water is significant for the community to meet their water needs. Doline is one of the surface water resources in the karst region, which plays an essential role in meeting the water needs of the surrounding community. Semanu and Ponjong Sub Subdistricts in Gunungkidul Regency have surface water resources in the form of the doline. The purpose of this study is to determine the distribution pattern of doline water utilization based on altitude, slope, and characteristics of the doline. The variables used are doline location, land use, elevation, slope, and doline morphometry. Data were obtained from relevant agencies and field surveys. The approach method used was the spatial pattern to analyze the distribution pattern of doline water utilization. The types of doline water utilization in the research area consists of agricultural irrigation use and for domestic needs. Doline distribution in the study area has a clustering pattern. The water utilization pattern for agricultural irrigation tends to be towards the west and south of the doline. The water utilization for domestic and community consumption has a random pattern. Doline morphometry does not affect the variation of doline water utilization patterns. Meanwhile, the altitude and slope at the doline location result in a variety of the doline water utilization in the study area. The higher the doline location and the bigger the slope, then the more various usage of doline water will be.

Keywords: Doline, karst, pattern, utilization, water
1. Introduction
Gunungkidul Regency is part of the Gunung Sewu karst system, which has a diverse morphology. Mount Sewu karst topography is formed due to the dissolution of carbonate rocks and marked by the presence of underground river networks, sinkholes, and caves [1]. The process of dissolving rocks is called karstification. Karstification in the karst region can produce a variety of natural formations from small to large scale both on the surface or underground [2]. In tropical areas such as Gunungkidul Subdistrict, unique karst morphologies such as doline, uvala, and polje can form without active fluvial processes [3].

The formation of karst morphology is closely related to the hydrological system in the unique karst region. The hydrologic system in karst landscapes is indeed different from those found in volcanic areas so that it is a distinct characteristic of karst landscapes [1]. The karst landscape has a natural relief and drainage system, which is influenced by its high solubility [4]. Karst landscapes are unique to the geohydrological system, which makes it difficult for people to access underground water, so people are more likely to use surface water. The unique hydrological conditions in the karst region often lead to scarcity of water resources. Karst has the potential for vast water reserves. The water reservoir is a flow in the form of a subsurface river network system [5].

Utilization of water in the karst region by the community is not yet optimal. Communities in karst areas tend to use surface water because it is easier to get access to water [6]. The existence of surface water is essential for communities in Semanu and Ponjong Subdistricts, Gunungkidul Regency, to meet water needs. Surface water in the karst region found on the surface of rivers, springs, and doline in the karst region. Therefore doline is one of the most important sources of surface water for the people in the karst region. Doline in question is the bottom covered by a layer of watertight terarrosa so that it can accommodate a certain amount of rainwater or often referred to as lake or lake doline [7]. Doline lake is one of the surface water resources in the karst region. Lake doline has a vital role in meeting the water needs of the community in the karst region. Semanu and Ponjong SubSubdistrict, Gunungkidul Regency, are one of the karst areas where the majority of the people still use doline as a provider of surface water resources to meet their daily water needs. The size of doline will affect the dimensions of the water capacity in doline so that the amount of surface water stored in doline will be different in each lake. The existence of doline becomes an essential and staple item for the community, because its availability is limited, especially in the dry season. The importance of the existence of doline as a provider of water resources encourages people to do activities near or around doline [8]. The use of various doline water resources will result in a diversity of land uses around the doline in Semanu Subdistrict and Ponjong Subdistrict, Gunungkidul Regency. So, the purpose of this study was to determine the distribution pattern of doline water use based on height, slope, and characteristics of doline.

2. Methods
This research was conducted in the karst area of Gunung Sewu in Semanu and Ponjong Subdistricts, Gunungkidul Regency which has coordinates of 07 ° 58 '47.7 "– 08 ° 00' 09.9" LS and LS 110 ° 43 '04.6 "BT – 110 ° 38 '57.5 "East. The data in this study were doline morphometry obtained from the Public Works Department (PU); land use collected from the Geospatial Information Agency (BIG); elevation and slope derived from the National DEM (DEMNAS); and doline water utilization obtained from interview result. Data were processed using the spatial pattern method to identify spatial water distribution patterns [9].

2.1. Processing of doline morphometry measurement data
Morphometric parameters measured were length, width, and depth. The data were then processed to obtain surface area and volume data of doline. Data will be classified based on differences in area and
volume of the doline. Furthermore, doline in Semanu and Ponjong SubSubdistricts divided into three classes based on the Natural Breaks method (see equation 1). Natural Breaks method is a method of classifying data using ArcGIS 10.5 by looking at the grouping and data patterns. Data will be grouped based on the range of data from the smallest to the largest [10]. The data will be present in tabular form. This data processing aimed to divide doline based on doline morphometric size differences classification in Semanu and Ponjong Subdistricts, Gunungkidul Regency.

\[ I = \frac{\text{Max Value} - \text{Min Value}}{\text{n.c}} \]  

Where, I is the interval in the classification obtained from the results of the largest data (max value) reduced by the smallest data (min value), it is then divided by the number of classes to be made (n.c).

2.2. Use of land around doline
The land-use data were obtained from the data processing of the land use type around doline in 2018. The digitized type of land use was located within a radius of one kilometer from doline. This data processing aimed to determine what types of land use around doline in Semanu and Ponjong Subdistricts in Gunungkidul Regency in 2018.

2.3. Utilization of lake doline surface water resources
The utilization of doline surface water resources in this study will be interpreted in the use of the land around doline. Data on the use of doline in the tabular form were obtained from interviews with residents around doline. Furthermore, land use maps around doline will be overlayed and correlated with maps of doline as a surface water resource. This data processing aimed to identify what types of land use are related to the use of doline surface water resources.

3. Results and Discussion
3.1. Doline distribution patterns
The doline distribution pattern in Semanu and Ponjong Districts produced by processing the scale of the Rupa Bumi Indonesia map data 1: 25,000 using ArcGIS software. The data processing results in doline distribution patterns in Semanu and Ponjong Subdistricts, forming clustered patterns with the nearest neighbour analysis index value of 0.783 with a p-value of 0.01 with the intention of less than 1% of the likelihood of random distribution patterns such as shown in figure 1.
Figure 1. Nearest neighbourhood analysis results.

The nearest neighbour index value is 0.783, meaning that not all data distribution patterns form a grouping pattern because the value is almost 1. Based on these results, it is known that doline, which has a cluster distribution pattern, has an older age compared to doline with a random distribution pattern (random). The doline distribution pattern is shown in figure 2.

3.2. Morphometry of doline

Table 1 shows the classification of varying sizes and water capacities dolines in Semanu and Ponjong Subdistricts, Gunungkidul Regency. There are 35 doline lakes which are classified into three classes. Almost half of the doline in the Semanu and Ponjong Districts (40%) are of medium size, and only 26% are large.

Table 1. Doline area of classification.

| No | Area Of Classification | Area (m²)       | Total of Doline | Name of Doline                                                                 |
|----|------------------------|-----------------|-----------------|--------------------------------------------------------------------------------|
| 1  | Small                  | 3.000 – 10.000  | 12              | Mendak, Ceblok, Dengok, Ngapung, Badut, Jambe, Widor, Lebuh, Ngrejek, Mendak, Plabengan, Sureng |
| 2  | Moderate               | 10.001 – 22.000 | 14              | F8, Klumpit, Bindo, Jetis, F7C, Peden, Ngrejek, Belik, Bowongan, Nangsri, Wuluh, Ginaru, Bolang, Lemah mendak |
| 3  | Large                  | >22.000         | 9               | Ngampelombo, Kepleng, R19, Tanjung, Bogosari, Sunut, Kedokan, R18, Jonge         |
Based on the results of observations of the data in table 2, it shows that the morphometry of doline lake in Semanu and Ponjong SubSubdistricts in each classification has a type of utilization that is not so different. Doline morphometry does not affect variations in lake use. The use of doline in the Semanu and Ponjong Subdistricts is more influenced by natural factors such as height and slope at the doline location [11].

Table 2. Doline volume of classification.

| No | Volume of Classification | Interval (m$^3$) | Total of Doline | Utilization of Water Resources                          |
|----|--------------------------|------------------|----------------|--------------------------------------------------------|
| 1  | Small                    | < 327.000        | 27             | Water Consumption, Irrigation, Domestic, Cattle, Fisheries |
| 2  | Moderate                 | 327.000 – 647.600| 4              | Irrigation, Domestic Cattle, Fisheries                  |
| 3  | Large                    | >647.600         | 4              | Irrigation, Domestic Cattle, Fisheries                  |

3.3. Slopes and altitudes

The utilization of doline lake water resources in Semanu and Ponjong Subdistricts, Gunungkidul Regency by the community, is as a source of raw water or consumption water. The lake is used for human consumption (C), domestic water source (D), cattle consumption (T), paddy irrigation (S), and fisheries (I). Human consumption includes daily water intake and cooking purpose. The domestic water source is for other daily needs, such as daily washing, bathing, and cleaning the house.

Table 3 shows that the utilization of Doline water in Semanu and Ponjong Subdistricts is quite varied. The variation arises due to the location of the Doline has different natural conditions. The natural conditions in question are the height and slope of the Doline location. These unusual natural conditions can affect people's access to water. Therefore, people in the eastern Semanu SubDistrict still use Doline water to meet their water consumption needs. No matter how difficult the natural conditions that must be taken, but given the need for water that must still be met, it will encourage people to use all types of water resources [12]. Communities in Semanu and Ponjong Subdistricts tend to use surface water because it is easier to access water in the karst areas [6].

Table 3. Table of doline water resources utilization based on altitude and slope in Semanu and Ponjong Subdistricts, Gunungkidul Regency.

| Total Of Doline | Sub Subdistrict | Altitudes masl | Slope % | Utilization                          |
|----------------|-----------------|----------------|---------|--------------------------------------|
| 11             | √ Semanu        | < 200          | 0 – 8   | Irrigation, Domestic Cattle, Fisheries |
|                | Ponjong         |                |         |                                      |
| 13             | √               | 200 – 400      | 2 – 25  | Water Consumption, Irrigation, Domestic, Cattle, Fisheries |
| 11             | √               | 200 – 500      | 8 – 46  | Irrigation, Cattle, Fisheries         |
3.4. Land use

Utilization of doline in Semanu and Ponjong Subdistricts was observed in the use of the land around doline. The area around doline will not be separated from the influence of doline's presence as a surface water supplier in the karst region. The presence of doline as a provider of surface water in the karst region has also explained in a previous study conducted by Sutikno in 1996 [6]. Semanu and Ponjong Subdistricts, have 35 dolines scattered throughout the subdistrict area. The utilization of doline lake in the Subdistrict is very varied and affects different types of land use around doline. The existence of doline lake in Semanu and Ponjong Subdistricts has a vital role as a provider of surface water resources in the karst region. Utilization of doline water resources is shown in figure 3, and the picture explains the map of doline water resource utilization interpreted in the use of the land around doline within a radius of 1 km.

West of Semanu Subdistrict, the utilization of doline water resources, is widely used to meet domestic household needs, such as washing, bathing, cleaning the house. The next use of doline is for the benefit of the irrigation of rice fields, livestock, and fisheries. In figure 3, one of the benefits of the doline observed in Lake Jonge which located in the west of Semanu District. Around Lake Jonge, many found settlements and rice fields. In contrast to the east of Semanu Subdistrict. People there use doline water as a source of domestic water and consumption, such as drinking and cooking. Other uses of doline water are used for bathing livestock, fish breeding, and irrigation of rice fields and fields. Figure 3, Lake Belik, is a doline located east of the Semanu Subdistrict. The use of the land around Lake Belik is often found in settlements, rice fields, and agricultural fields belonging to the community. The difference in utilization is influenced by natural factors in Semanu Subdistrict. Semanu Subdistrict in the west is located at an altitude of fewer than 200 meters above sea level and has a relatively flat slope of 0 - 8%.

Figure 3. Utilization of doline water in A. Lake Jonge, B. Lake Ngampelembo, and C. Lake Belik in Semanu and Ponjong Subdistricts.
Meanwhile, in the east of Semanu Subdistrict, the average height is 200 – 400 meters above sea level, with slopes varying from 2 – 25%. The difference in natural conditions affects the difference in the utilization of doline water resources in the west and east of Semanu Subdistrict. Utilization of doline water resources in the Subdistrict of Ponjong is used for bathing and washing, bathing livestock, capturing fish, and irrigation of rice fields and fields. Figure 3 shows Lake Ngampelembo, which is one of the dolines in the Subdistrict of Ponjong. At the time of verification in the area, it will be easy to find rice fields and fields as well as community settlements around doline. People in Ponjong Sub-Subdistrict are no longer using lake water to fulfill their daily consumption water needs, such as drinking and cooking. They buy "gallon" water to meet those needs. Besides, in the Subdistrict of Ponjong, there are many underground river water sources commonly found in caves, which are the source of consumption and domestic water for the community.

Changes in land use in karst areas are greatly influenced by the location of water resources and their quantity. Communities in karst areas tend to build settlements and undergo activities near water sources, considering that water is one of the natural resources that are quite difficult to access to obtain it. As a result, many community activities in the karst region develop around water sources such as springs, surface rivers, and lakes, or doline [7].

3.5. Distribution patterns of doline water utilization
Doline is one of the natural formations that occur in the karst region. Doline has the primary function to stabilize the flow of water. Semanu and Ponjong doline Sub-Subdistricts have an economic purpose, namely, as a provider of clean water, both for drinking, domestic, irrigation, and industry, also for aquaculture and capture fisheries. Increasing the population will encourage increased clean water needs for the community. Considering that the karst area is an area that has a large availability of groundwater, but due to difficult access to obtain groundwater, the use of surface water is the best solution in meeting the water needs of the community in Semanu and Ponjong Subdistricts, Gunungkidul Regency. Therefore, if doline in the karst region is managed correctly, then doline will function optimally as a life buffer.

Figure 4 shows the utilization of doline water resources in Semanu and Ponjong Subdistricts, Gunungkidul Regency. The map shows the usage of doline water in the eastern Semanu Subdistrict has the types of utilization as consumption water (K), domestic water (D), paddy irrigation (S), cattle (T), and fisheries (I). Unlike the utilization in the west of Semanu Subdistrict, namely domestic water (D), irrigation of paddy fields (S), cattle (T), and fisheries (I). In Ponjong Subdistrict, the utilization of water resources only prioritized on the type of use as irrigation of paddy fields (S), cattle (T) and fisheries (I).

Figure 5 explains the direction of doline water distribution in Semanu and Ponjong Subdistricts, Gunungkidul Regency. The picture is described using the blue and orange arrow directions. The blue color shows the use of doline water for paddy irrigation. The orange color explains the path of doline water utilization for domestic needs and public consumption. The direction of doline water utilization for irrigation tends to the south and southwest of Semanu and Ponjong Subdistricts that influenced by altitude and slope factors, i.e., the more south and southwest, the altitude will be lower. The slope condition will be more gentle. Unlike the use of water for domestic needs and consumption that is not affected by the height and slope factors, this is because doline water is taken by the community so that, if the water source is still reachable, doline water utilized by the community.

Utilization of water in Semanu and Ponjong Subdistrict communities is not yet optimal, same as the other karst region [7]. Surface water in the karst region is only found in surface rivers, springs, and ponds in the karst region. Therefore, the community in meeting water needs will not be separated from the critical role of doline as a source of water in the karst region.
4. Conclusions

Doline volume morphometry does not affect variations and patterns of doline water resource utilization. Rainfall, altitude, and slope at doline location influence more to the variety and type of utilization around doline. Doline, which has volume morphometry, has different variations and types of land use if they are at different heights and slopes. Doline with higher altitude and slope location will produce more varied types of water utilization compared to doline with small elevation and slope.

Seasonal changes cause changes in the number of surface water resources available in Semanu and Ponjong Subdistricts, Gunungkidul Regency. In the dry season, lakes which water sources come from springs will not experience drought. The doline, which source of water comes from the accumulation of rainfall, will dry up during the dry season. Changes in the amount of water storage in doline will cause changes in land use around doline.

5. References

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