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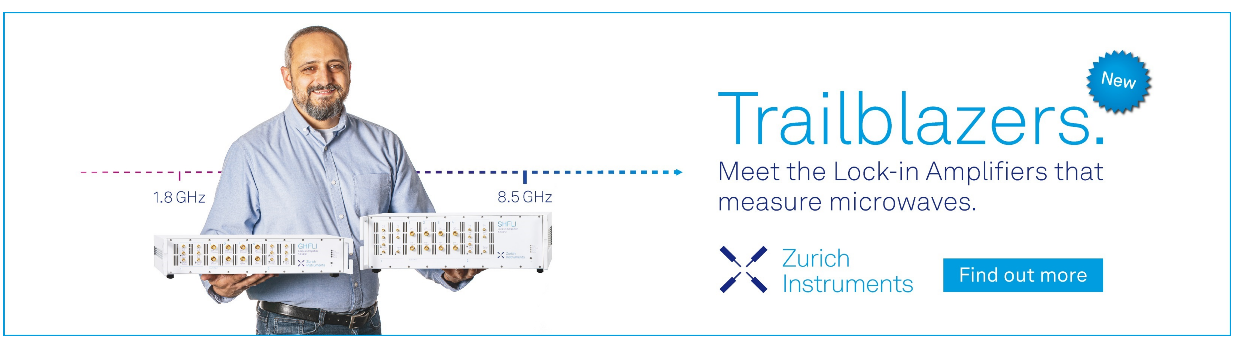

Estimation of Underground River Water Availability Based on Rainfall in the Maros Karst Region, South Sulawesi

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Abstract. Maros karst region, covering an area of 43.750 hectares, has water resources that determine the life around it. Water resources in Maros karst are in the rock layers or river underground in the cave. The data used in this study are primary and secondary data. Primary data includes characteristics of the medium. Secondary data is rainfall data from BMKG, water discharge data from the PSDA, South Sulawesi province in 1990-2010, and the other characteristics data Maros karst, namely cave, flora and fauna of the Bantimurung Bulusaraung National Park. Data analysis was conducted using laboratory test for medium characteristics Maros karst, rainfall and water discharge were analyzed using Minitab Program 1.5 to determine their profile. The average rainfall above 200 mm per year occurs in the range of 1999 to 2005. The availability of the water discharge at over 50 m^3/s was happened in 1993 and 1995. Prediction was done by modeling Autoregressive Integrated Moving Average (ARIMA), with the rainfall data shows that the average precipitation for four years (2011-2014) will sharply fluctuate. The prediction of water discharge in Maros karst region was done for the period from January to August in 2011, including the type of 0. In 2012, the addition of the water discharge started up in early 2014.

INTRODUCTION

Strategic issue in karst region is a decrease in water quality due to mining of limestone for cement and other industries. Pollution of groundwater in karst region is the consequence of geological and geomorphological conditions in the karst region [1]. Karst groundwater is in the networks of underground rivers directly connected to the surface via the river surface [2]. Indications of contamination had been encountered with inorganic waste in underground rivers. Water demand will continue to increase in coming years in various countries, including Indonesia.

In Indonesia, inequality on the distribution of water availability occurred in the Indonesian inter-island. Papua island has the largest water availability in Indonesia of 51%; 20.3% of the water is available on the Kalimantan island; 16.1% on Sumatera island, and the remaining (approximately 12.6%) is available in some islands, such as Java, Sulawesi, East Nusa Tenggara, and Maluku. Particularly, the increase in drinking water demand occur in Makassar and Maros cities, as the survey results on water discharge measurement for the rainy season where there are plenty of water resources, but relatively flow in dry season due to rainfall factor, there is around 10% difference for the Maros and Bantimurung rivers. This indicates that the needs of the population to clean water should be anticipated. In the same report, the projected water demand in 2015 will reach 2,643 l/s for the city of Makassar and 263 l/s for the city of Maros [3].

The water demand increase and Maros karst area is expected as one of the water sources. Further research on some tracks on the banks of the Bantimurung River showed that the aquifer is at the depth 0.75-5.0 m (soil water/aquifer not depressed). While the largest potential for aquifer was at the depth 12-15.7 m (ground water/aquifer depressed because it is flanked by layers of hard rock) and accumulated evenly in layers of rock [4].

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Increasing water demand for people in need springs that one expected from Maros karst. The karst region of Maros has water system that is conducive both under the cave and emerges as the river surface, such as watershed Bantimurung. The upstream of DAS Bantimurung is used as a place of tourism [5], agriculture [6] and irrigation for raw water in Maros PDAM [7]. Protection of ground water is needed, not only ground water but the rock aquifer [8]. Therefore, we will be carried out study the characteristics according to the nature of the medium, including caves, flora, and fauna, analysis the underground river flow profile based on the rainfall data, and analysis the availability of water discharge of the underground river in Maros karst.

EXPERIMENTAL METHOD

The location of this research was in Maros karst, South Sulawesi and geographically located between 4°42'49"-5°06'42" LS and 119°34'17"-119°55'13" BT. It is administratively located on the district of Maros, South Sulawesi province. Primary data includes physical properties data of the medium such as permeability, porosity and density of the medium was analyzed in the laboratory. Secondary data include the rainfall data from BMKG and water discharge data the years 1990-2010 from PSDA, South Sulawesi province. Profile of rainfall and the water discharge was determined by the program Minitab 1.5. While predictions of rainfall and the availability of underground water discharge stream was analyzed by modeling Autoregressive Integrated Moving Average (ARIMA) [9]. In addition, the characteristics data of Maros karst includes caves, flora and fauna of the Bantimurung Bulusaraung National Park.

RESULTS AND DISCUSSION

The Physical Properties of the Medium

The physical properties of the medium Maros karst region which includes permeability, porosity and density of the medium are shown in Table 1. The results showed that the specific gravity either ground limestone and clay, respectively, could be respectively classified into the type of soil silt and inorganic clay soil. Clay and limestone soil has a high porosity values so that the ability to absorb water on the rock is high. They are the main constituents of the karst region. Wet density value of limestone soil is greater than clay. In addition, low permeability values make it difficult to pass water. However, the degree of saturation is high, so that the area of research has the potential to store underground water.

TABLE 1. Physical properties of medium of Maros karst region [4]

Magnitude of Test	Unit	Type of Soil	
		Clay Soil	Limestone Soil
Specific Gravity (Gs)	-	2.80	2.61
Wet Density, ρ_{wet} = (4)/(5)	gr/cm^3	1.05	1.74
Porosity (ϕ)	%	77.30	45.17
Permeability coefficient (κ) (Constant Head Permeameter)	cm/s	8.14×10^{-3}	7.33×10^{-8}
Permeability coefficient (κ) (Falling Head Permeameter)	cm/s	1.35×10^{-3}	7.33×10^{-8}
Degree of Saturation (Sr)	%	53.48	68.16

Caves in Maros Karst Region

Karst area has 18 caves, which are spread over the area of protected forest Pattunuang and Karaengta in Maros. For Bantimurung River, there are two caves which have no artifacts, namely Batu and Mimpi caves. Batu cave has relatively dry floor, not watery and has depth of about 25 m from the entrance to the cave. Only in certain parts of ceilings drops the water. While Mimpi cave is relatively, with the length about 800 m and it takes about 30 minutes from the entrance to the cave. The floor was wet and the ceiling is filled with ornaments. The wall of the cave has beautiful ornaments and still active either to form stalagmites, stalactites and drapery and canopy [10].

Fauna Characteristics

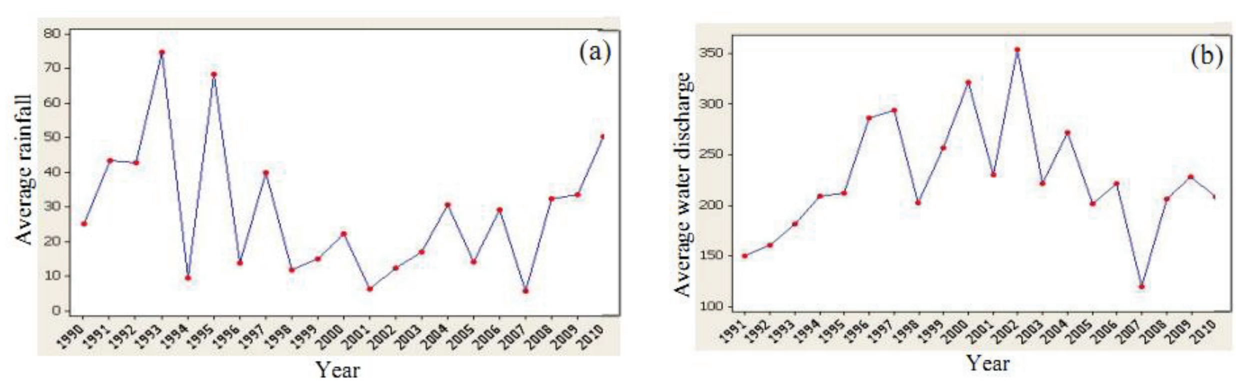
Maros karst region is the habitat for about 270 species of butterflies and rare animals, so that Bantimurung region is well known as "the kingdom of butterflies". Maros karst region is inhabited by several animal species steps, such as Sulawesi hornbills (*penelopides exarhartus*), kera without tail (*Macaca Maura*), tersius *(tarsiers sp.*), kuskus (*Phalanger Ursius*), Sulawesi weasel (*macrogilidia Rasmussen braecki*), deer (*carvus timorensis*), and a variety of wildlife sharing. Unique biota, arthropods, for example, has long antennae as organs of taste. Among the findings are transparent bodied blind cave fish (*Bostrycus sp.*) from the Saripa cave in Maros, scorpions blind cave and the only one in Southeast Asia, the blind cave shrimp and transparent stature (*Cirolana marosina*), branch-nosed bat (*Nyctmene cephalotes*), dinops hipposideros bats that live only in Sulawesi, crab spider (*cancrocaeca Xenomorph*), beetles of the blind Coleoptera types sp., some kind of cave crickets (*rhaphidophora sp.*) which have not been identified, and the new types spider (*Heteropoda beroni*) [11, 12].

Flora Potential

The content of calcium and magnesium from limestone rock which dominates the area of karst in the Bantimurung Bulusaraung National Park is high and limits the types of plants that can live in this ecosystem. Based on the forest ecosystem, the National Park Bantimurung Bulusaraung is divided into three main types of ecosystems, namely forest ecosystems over the rocks karst (limestone over forest/woods over limestone) or karst ecosystems, a lowland forest ecosystem, and lower montane forest ecosystem. Flora species existed in the Bantimurung National Park are very diverse and among them there are the types dominant as wanga palm (*Piqafetta filari*s and *Arenga sp.*) that are not found again at altitudes above 1.000 m from sea level. The type of timber includes uru (*Elmerillia sp.*), *Casuaria sp.*, duabanga moluccana, *Vatica sp.*, *Pangium edule*, *Eucalyptus deglupta*. In the lower montane forests, it is found *Litsea sp.*, Agathis philippinensis, and various types of bamboo and Ficus sumatrana [12].

River Underground Profile in Maros Karst Region

The average rainfall and the water discharge in Maros karst over 20 years are shown in Figure 1. The average rainfall above 200 mm per year occurred in the range of 1994 to 2006, with the highest rainfall average in 2001 (354.04 mm) and 1999 (321.65 mm) [Figure 1 (a)]. Figure 1 (b) shows that the highest water discharge occurred in 1993 and 1995 years which was above 50 m^3/s. There was the decline in the water discharge to the lowest in 2007, only about 5.64 m^3/s. The analysis showed that precipitation has indirect effect on the amount of the water discharge in Maros karst. Generally, there was a delay time in the karst region, indicating that the time needed by rainwater to make the water discharge volume in the river increases. The greater the delay times in a karst region, the longer it takes for rain to affect the volume of river water [13, 14].

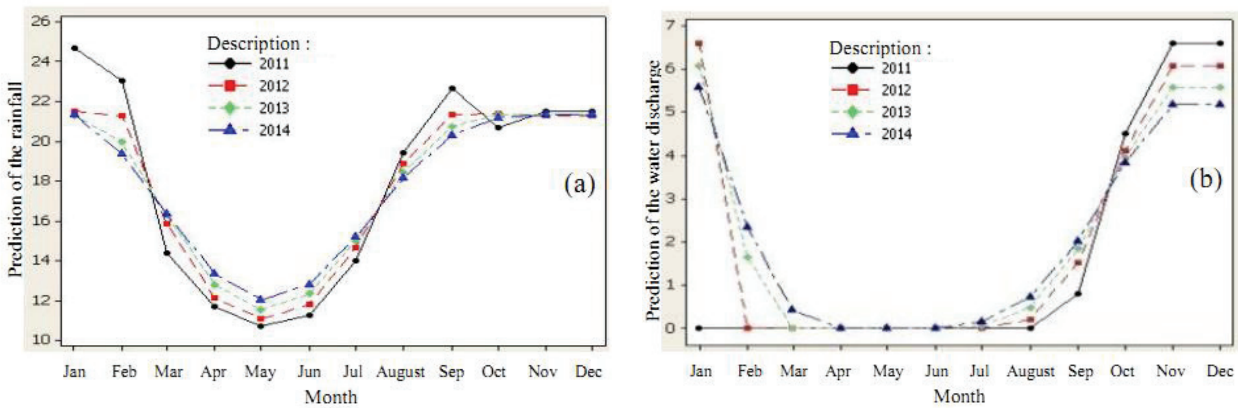


(a) (b)

FIGURE 1. (a) Average rainfall and (b) water discharge the years 1990-2010

Availability of Underground River Water Discharge in Maros Karst Region

Availability of underground water discharge of the river is a necessary condition for sustainable use. From the data of rainfall and the water discharge in 1990-2010, the prediction of rainfall was then performed and water discharge in 2011-2014 (Figure 2). Figure 2 (a) shows that the average precipitation for the next four years (2011-2014) will sharply fluctuate, starting at the beginning of January; the average rainfall is high and likely to decline until it reaches a low point in May. This situation turned to be higher since the month of May to September and eventually tend to stay for three months at the end of the year, except in 2011. In 2011, the largest rainfall average of March, May, and October are different and significantly lower than the same months in the next three years. For 2012-2014, the average rainfall in Maros karst has a similar trend.



(a) (b)

FIGURE 2. (a) Prediction rainfall and (b) water discharge the years 1990-2010

Prediction of underground water flow availability in the river Maros karst regions for the period from January to August in 2011 could be considered as type 0 [Figure 2 (b)]. Rainfall in the area does not result in the increase of water discharge, but the decrease in river discharge. Rainfall intensity is smaller than the infiltration capacity of the soil, so that there is no surface flow [7]. There is addition of water discharge on September to December. In January of 2012 there was addition of water, but was followed by the decrease in water discharge in February. In August, the water discharge increases the amount of water discharge and persists until the end of the year and continued in early 2013. In 2013, the amount of water discharge was higher than more than in the previous year. In 2014, the estimated the amount of water discharge is better than on the amount of water discharge in the previous three years. The water discharge is available since the beginning of the year on January and February. After experiencing the availability of discharge with type 0, hence, starting from June water discharge would be exists, even only about 0.01 m/s^3. This situation is gradually increased until the end of 2014.

CONCLUSIONS

Maros karst region is composed of clay and limestone soil. The analysis showed that clays have a greater tendency than limestone in water weight, porosity, water content, permeability and pore volume. Generally, the characteristics of the soil in the region of Maros karst have porosity and pore volume high and low permeability. It indicates that compiler the region of Maros karst has the relatively large ability to absorb water in a rock and the potential to save the groundwater, but is difficult to pass water. Maros karst region is a habitat for about 270 species of butterflies and rare animals, so that Bantimurung region, is well known as “the kingdom of butterflies”. The high content of calcium and magnesium from limestone rock which dominates the area of karst in the Bantimurung Bulusaraung National Park limits the types of plants that can live in these ecosystems. In addition, Maros karst region has 18 caves which are still proceed and forming cave’s ornaments, such as stalactite, stalagmites, and flowstone, which is a transit point for rainwater so that karstification process goes well. During the interval of 20 years (1991-2010), the water discharge was fluctuating especially the range of 1996 to 2010, large amounts of rainfall has no direct effect on the availability of water underground river. This is because a few years earlier, there was a longer dry season than the wet season, so the rain water coming in, did not make the water volume increases significantly.

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