Determining recharge groundwater using delineation of morphological surface in Ligarmukti karst area Bogor Regency

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Abstract. The Ligarmukti area is one part of the Klapanunggal karst hills in Bogor Regency. This area relies on springs as the fulfillment of raw water. It is feared that the limestone mining process in this area will damage groundwater recharge areas. This research was conducted to determine groundwater catchment areas in the Ligarmukti karst area. The method used is the morphological lineament delineation analysis of SRTM imagery compiled with the results of investigations in the field. Based on the results of delineation, the SRTM image was able to detect 76 alignment patterns in the direction of N 28° - 235°E. The fracture location was mostly located at elevation 280 - 700 m. The difference in direction of the alignment pattern is not too far away, so it is interpreted that the groundwater recharge pattern in the secondary porosity is derived from an aquifer system. The main catchment zone is at an altitude of 440-700 m above sea level in the hills with limestone constituent Klapanunggal Formation. The infiltration system in this area is an autogenic recharge, i.e. the recharge occurs in areas with relatively homogeneous rocks in the form of karst rocks and rainwater which is directly infiltrated in the area. This condition can be seen from the fluctuation of discharge during the rainy and dry seasons. Watershed conservation must be carried out to maintain the availability of springs by minimizing the limestone mining process in hilly areas.

1. Introduction

The study was conducted in the karst area in Ligarmukti Village, Klapanunggal District, Bogor Regency (Figure 1). The area of the study is approximately 800 ha which is divided into 3 hamlets, 6 RW and 13 RT. Ligarmukti Village is located in the southeastern part of Klapanunggal District, which borders Jonggol District. In general, the topography of Ligarmukti Village is plain and hilly with a height of between 110-130 meters above sea level.

Figure 1. Ligarmukti Village Research Location (Maria et al., 2016).

Geologically, the study area is composed of lithology in the form of limestone of the Klapanunggal and Napal Formations, clay inserts and quartz including the Jatiluhur Formation (Figure 2). The limestone
of the Klapanunggal Formation has the same age as the Lengkong and Bojonglopang Formations, tingling with the lower part of the formation, namely the Jatiluhur Formation which is in the Early Miocene age [1]. Limestone of the Klapanunggal Formation in the hilly areas and clay deposits of the Jatiluhur Formation in the mainland area (figure 2). The source of the spring appears on the bed of limestone with clay deposits. The spring is the main water source in this region despite having a fluctuating discharge because it is very dependent on rainfall [2].

![Figure 2. Geological Map of Ligarmukti Village (Modification of [1]).](image)

Karst is a landscape with typical hydrological conditions [3]. This particularity is a result of the process of dissolving rock material and the development of secondary porosity [4]. Carbonate rocks dominate karst formation because they have the most extensive distribution compared to other soluble rocks [5]. One characteristic of the karst area hydrology is the formation of caves and springs [6]. Kars morphology which hydrogeologically has an aquifer system with groundwater flow through fracture media and dissolving channels [7]. The hydrologic system of karst areas is very unique because it is strongly influenced by secondary porosity which causes water to enter the underground flow system and causes dry conditions at the surface of the land [8]. Karst aquifer is a groundwater flow system that is autogenic recharge and allogenic recharge [3]. Autogenic recharge occurs in areas with relatively homogeneous rocks in the form of karst rocks and rainfallwater which is directly infiltrated in the area. Allogenic recharge is a mechanism for water flow originating from non-karst areas into karstic regions. This mechanism is common due to complex geological conditions.

Springs are used as one of the main sources for meeting the people's raw water needs. The karst area of Ligarmukti Village found six springs with varied discharge. The amount of discharge is able to supply water needs for the surrounding community for domestic, tourism and agricultural needs. The spring that has the largest discharge is the Sodong Spring, with a debit of 312.42 liters / second and is used for water sources in Ligarmukti Village and most of it is channeled outside the Ligarmukti Village through PDAM [9]. Based on observations in the field using classification [10] the Ligarmukti area is divided into two geomorphological units namely karst hills and alluvial plains [6]. Limestone mining in the Ligarmukti karst hills can threaten the conservation area of springs. This research was conducted to determine groundwater catchment areas in the Ligarmukti karst area. The method used is the morphological lineament delineation analysis of SRTM imagery compiled with the results of
investigations in the field. The results of the study are useful as input for the protection of groundwater catchment conservation areas in karstic areas.

2. Methodology
The potential catchment areas and groundwater flows have been interpreted in this research. The SRTM (Shuttle Radar and Topography Mission) with 30-meter spatial resolution used to produce the fracture lineament map. The manual line draw of lineament using visual interpretation intended to avoid misinterpretation by system. The quantity of lineament count density by equation [11]. The result of the analysis is a density map of the alignment of the study area in units of n/km² (count of lineaments/km²). The lineament count density is used to generate the rose diagram that indicated the groundwater flow pattern. The Rose diagram can inform the majority direction of lineament. The direction showed the potential location of the springs. The springs location will be validated with ground truth check. The high density of lineament will delineate as potential of a recharge area, spring watersheds and groundwater flow patterns in the study area.

3. Results and Discussion
The Ligarmukti area is a karst hills which is rich in water resources. Springs function as the main source of water for the fulfillment of community raw water. There are 5 small springs (Cinyukcruk, Cipancur, Bulan, Cigadog, Cibulakan springs) and 1 large spring (Sodong spring). This discharge calculation is carried out during the rainy and dry seasons, the results of the discharge fluctuating following the season (Table 1). This condition proves that the springs in the Ligarmukti area have a continuous discharge.

| Spring                       | Debit (l/s) |
|------------------------------|-------------|
| Ma.Cinyukcruk (LG1)          | 10.75       |
| Ma.Cipancur (LG-2)           | 8.25        |
| Ma.Bulan-bulan (LG3)         | 62.30       |
| Ma.Cigadog (LG-4)            | 61.80       |
| Ma.Sodong (LG-5)             | 312.42      |
| Ma.Cibulakan (LG-6)          | 40.77       |

Source according to [6]

Based on field observations, it is estimated that the source of the catchment / rain catchment area from the spring is in the karst hills. At first glance this area is a barren area with characteristics of hollow limestone on hilly slopes as secondary porosity (Figure 4). But at the subsurface flow underground flowing and on the buckling slopes are found springs and underground rivers such as Sodong springs.

![Sodong Spring](image1.jpg) ![Cinyukcruk Spring](image2.jpg) ![Cibulakan Spring](image3.jpg)

**Figure 3.** The springs utilization for water sources and tourism in Ligarmukti Village.
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![Figure 4. Typical morphology of Ligarmukti karst hills.](image)

The catchment area in Ligarmukti area interpreted by lineament of morphology using SRTM image (Figure 5). The lineament counted to generate the outspread of fracture that indicated the catchment area. The quantity of lineaments was calculated using lineament density.

![Figure 5. Map of fracture straightness in the Ligarmukti karst hills.](image)

Based on the delineation results, the SRTM image successfully detected 76 straightness patterns (Figure 6). The alignments analyzed using the rosette diagram show various patterns. In general, the study area is controlled by the direction pattern of N 28° - 235° E. The fracture location is mostly located at 280 - 700 m elevation. The difference in direction of the alignment pattern is not too far away, so it is interpreted that the groundwater recharge pattern in the secondary porosity is derived from an aquifer system. Based on the analysis of morphological alignment patterns and densities, in general the potential for Kars spring recharge zone is located in the northeast-southwest region of the study area (Figure 6).
Based on the results of fracture delineation, groundwater recharge areas in the study area can be identified. The main catchment zone is at an altitude of 440-700 m above sea level in hilly areas with limestone constituent rocks in the Klapanunggal Formation (Figure 7) with secondary porosity in the form of fractures. The source of the spring appears on the bed of limestone with clay deposits. The characteristic of karst hydrological systems in this region is that there are many soil depressions (sinkholes), caves and groundwater flow through fracture media and dissolving channels (Figure 4). Cavities in the interconnected surfaces function as reservoirs of water. The process of karstification and dissolution in the Klapanunggal region is classified as young in terms of the age of the early Miocene rocks.

Fracture as a secondary porosity is a way for rainwater to enter the underground flow system, this condition causes the karst area to appear dry on the ground surface. The recharge process in karst aquifers in the Ligarmukti area is autogenic recharge, ie the recharge occurs in areas with relatively homogeneous rocks in the form of karst rocks and rainwater which is directly infiltrated in the area. This autogenic recharge system can be seen from the fluctuation of discharge during the rainy and dry seasons.
Considering that the groundwater recharge system in the Ligarmukti karst area is an autogenic recharge, conservation of catchment areas must be carried out as a step to maintain the availability of springs in the karst area. Land cover in these hills must be maintained by minimizing the process of limestone mining in hilly areas and groundwater recharge zoning.

4. Conclusion
Based on the results of delineation, the SRTM image was able to detect 76 alignment patterns in the direction of N 28° – 235° E. The fracture location was mostly located at 280-700 m elevation. The difference in direction of the alignment pattern is not too far away, so it is interpreted that the groundwater recharge pattern in the secondary porosity is derived from an aquifer system. The main catchment zone is at an altitude of 440-700 m above sea level in the hills with limestone constituent Klapanunggal Formation. The infiltration system in this area is an autogenic recharge, i.e. the recharge occurs in areas with relatively homogeneous rocks in the form of karst rocks and rainwater which is directly infiltrated in the area. This condition can be seen from the fluctuation of discharge during the rainy and dry seasons. Watershed conservation must be carried out to maintain the availability of springs by minimizing the limestone mining process in hilly areas.

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