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CHARACTERISTICS OF ENDOKARST PHENOMENON ON MOUNT SEWU IN GUNUNG KIDUL REGENCY, YOGYAKARTA SPECIAL REGION

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ABSTRACT

Indonesia is a country that has a variety of interesting landforms. One of them is karst landforms. The distribution of karst areas in Indonesia is mostly composed of carbonate rocks, and a few karst areas consist of other rocks. Not all areas where carbonate rocks can be classified into karst areas. Because the formation of karst depends on climatic factors, orographic factors, and the lithology structure of the area. The phenomenon of endokarst is part of the karst landforms below the surface, which includes caves (stalactite and stalagmite formations), and underground river water flows. Caves and underground river water flow are characteristic of the endokarst of Mount Sewu. These caves and underground rivers have great potential for subsurface water resources (Santosa, 2015). The Mount Sewu is also a holokarst type karst. The phenomenon of the Mount Sewu endokarst is inseparable from the geological, geomorphological, hydrological, ecological, and cultural characteristics of the area. The existence of geological and geomorphological forms of karst on Mount Sewu brings many benefits, such as as a limestone mineral resource, a supplier of water resources, the Mount Sewu karst area as a geopark and ecotourism, and the existence of biodiversity. Therefore, because it is known that endokarsts have the potential for landforms in the form of caves and underground river water flows, it is very important to know and study karst landforms, especially regarding endokarsts, so that the karst landforms in Indonesia, especially in Mount Sewu, Gunung Kidul Regency. can be managed sustainably and utilized wisely.
Keywords: *endokarst phenomenon, geology and geomorphology, Mount Sewu.*

INTRODUCTION

Nowadays, the existence of karst in Indonesia seems to be starting to be noticed by various parties because it is considered to have a very strategic value. The karst phenomenon in Indonesia has similarities with other tropical countries but also has essential differences with other parts of the earth with the characteristics of a colder climate or a drier climate (Haryono, 2011).

The distribution of karst areas in Indonesia is composed of carbonate rocks, and only a few karst areas consist of other rocks. Not all areas containing carbonate rocks can be karstified to form karst areas. This depends on climatic factors, orographic factors, as well as the structure and lithology of the region (Balazs, 1968).

The karst area located in Mount Sewu, Gunung Kidul Regency has a height of only 300-500 meters and the relief is only about 50-150 meters. This Mount Sewu karst has been karstified from the end of the Pliocene to the beginning of the Pleistocene and is already in the Miocene period. The area of the karst area in Mount Sewu reaches 3,300 km2 which passes through three provinces, namely the Province of the Special Region of Yogyakarta, Central Java Province, and East Java Province. Under the karst dome of Mount Sewu, there are several limestone caves and underground river flows or it can also be called the endokarst phenomenon (Lehmann, 1936).

The endokarst phenomenon is a phenomenon of karst areas that are below the surface, including caves that can be vertical caves, cimne caves, or horizontal caves. Another uniqueness of the cave is that there are underground chambers (chambers) and rivers in some caves with natural dams. The endokarst phenomenon found in Mount Sewu is in the form of caves that tend to vary which are generally controlled by the structure and flow of underground rivers. Caves are fissures and fracture systems that are generally formed in areas with limestone (GEGAMA, 1995).

Inside the cave, there are many other karst formations, such as the presence of stalagmites and stalactites. This is because at the time of the formation process of karst geomorphology in Mount Sewu was dominated by the dissolution process, resulting in water descending vertically to the ground and forming underground rivers. As a result of the dissolution process in the karst area, it results in the appearance of cracks in the cave to form cave passages that function as corridors to the underground river (Koesoemadinata, 1980).

The karst phenomenon which is currently considered to have strategic value not only as an area that meets domestic water needs, as evidenced by the Mount Sewu karst has three underground river flow systems, namely the Bribin-Baron system, the Sundak system, and the Ngobaran system which was later built. dam by the government. These three systems play an important role in the water needs of the people of Gunung Kidul Regency, which is characteristic of a dry area with very little surface water (Ko, 1997).

RESEARCH METHOD

The research method technique used by researchers in writing articles is a literature study approach, namely by researching and understanding books, articles from various national and international journals, documents, or other written sources that are relevant and support the title of the article that has been determined by the researcher. Researchers in obtaining data and information use secondary data collection techniques which are carried out using various data sources in the form of literature studies.

RESULTS AND DISCUSSION

Endokarst Phenomenon in General

The endokarst phenomenon is part of the karst landform that is below the surface, usually including caves and underground river flows. A cave is defined as a passage that is formed naturally through the process of dissolution (karstification) in which water descends vertically and forms an underground river flow. There are various sizes of these caves, namely there is a minimum size of approximately 0.3 meters and there is a smaller size called a protocave (Gillieson, 1991).

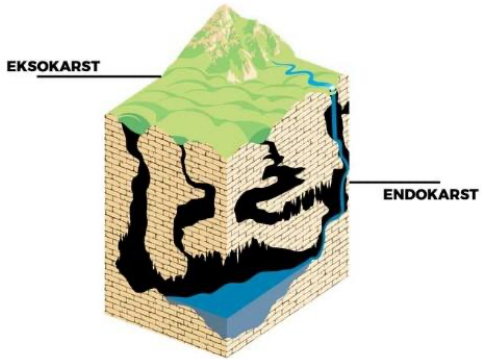


Figure 1. Endokarst Phenomenon Illustration.

In Figure 1, an indicator of the development of karst landforms in an area is seen from the presence of karst caves in it. As explained above, the cave is formed from the composition of limestone and carbonate which has undergone a karstification process for a very long time. As for several other factors as the formation of this cave is dependent on rock

lithology, geological structure, regional topography, dense vegetation, high rainfall, and hydrological conditions of the area. The study of cave development is closely related to the study of geomorphology and hydrology of karst areas (Palmer, 1991).

Figure 2. Illustration of Endokarst Formation.

Apart from the formation of the karst cave above, it can be seen in the illustration in Figure 2 that another endokarst phenomenon is the existence of an underground river flow which is a source of water for the community around the karst area. This lower river flow is formed due to water droplets from the surface continuously downwards and due to the permeability of limestone and carbonate rocks which are chemically soluble causing cracks so that leakage occurs in this karst area unit. The existence of this groundwater is unique in that its distribution depends on the process of dissolving (karstification) in the area (Van Dam, 1989).

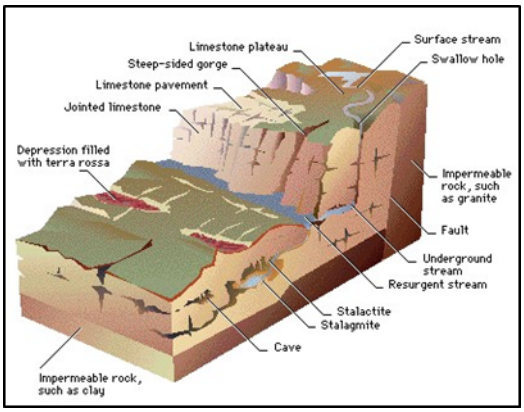


Figure 3. Karst Region Morphogenesis.

The nature of the existing karst aquifer is a source of large supplies which until now have not been used optimally. In fact, if you look at the karst area in Gunung Kidul Regency, the Special Region of Yogyakarta, which has hundreds of dolina, which have been combined into one called uvala. The morphogenesis of the karst area can be seen in Figure 3, clearly describing the morphogenesis of karst including endokarst (Van Dam, 1989).

The Genesis Process for the Formation of the Mount Sewu Endokarst Phenomenon, Gunung Kidul Regency

Karstification is the process of forming karst landforms which are dominated by the dissolution process (Adji and Haryono, 2004). The most ideal karst topography is formed on limestone, which is a rock that has a calcium carbonate ($CaCO_3$) content of more than 90%. Another carbonate rock that can form karst is dolomite with the chemical composition formula $(CaMg)(CO_3)_2$ (Kusumayudha, 2005).

Figure 4. Seropan Cave Karst Cliffs.

In Figure 4, it can be seen that the uniqueness of the karst area is that one of them is the endokarst phenomenon which is defined as the presence of caves and rivers or underground water flows. The caves are generally terraced with a size of less than one meter to hundreds of square meters with a vertical or horizontal shape. Almost all of the caves in the karst area are decorated with very diverse geomorphological formations, ranging from very small to very large with varying shapes and colors, and as shown in Figure 4, the formation of cliffs in Seropan Cave, Mount Sewu can be seen.

Because the characteristics of the presence of endokarst are caves and rivers or underground flows, the following is a description of the process of genesis or formation of endokarst in Mount Sewu, Gunung Kidul Regency, namely:

1. Cave

The cave is a drop of water from the roof of the cave which also falls to the floor of the cave and when the water evaporates, the calcite mineral will be deposited on the floor of the cave. This process produces stalagmite formations that are elongated and tapering upwards (Sari, 2020).

There is the Gesing-Jlamprong-Sinden Cave complex which is a cave located in Semanu District, Gunung Kidul Regency, where the cave is located in the central region of the Mount Sewu Karst. This cave complex consists of three caves that are interconnected by forming a cave system. Although located in one complex, each of these three caves has different geomorphological characteristics (Haryono, 2011).

This area is composed of limestone from the Neogene period (Middle Miocene to Upper Pliocene) which is known as the Wonosari-Punung Formation and is specifically a transition between layered limestones that dominate the Wonosari Basin in the north-southwest and reef limestones that dominate to the south (Haryono, 2011). Caves formed in carbonate rock areas are divided into three types, namely pit caves, phreatic caves, and fracture caves (Myloire and Carew, 2003). Gesing Cave in Mount Sewu genesis belongs to the fracture cave type, which is a type of cave formed due to the widening of cracks in the limestone layer (Ashari, 2013).

Meanwhile, Jlamprong Cave in Mount Sewu is classified as a phreatic cave, which is a type of cave that forms near and above the groundwater level by the lowering of the groundwater level. In the process of genesis, this type of cave was formed due to the dissolution of limestone by groundwater flow. The process of dissolving by water that occurs continuously forms a cave passage. And the last one is Sinden Cave in Mount Sewu whose genesis belongs to the pit cave type. This type is formed by the excavation (excavation) of the vadose flow (broken karst underground river flow) when it reaches the groundwater level. This cave has the characteristic that the mouth of the cave descends from the land surface with a steep slope (Ashari, 2013).

2. Underground Streams in Caves

Karst areas in general have the potential to store abundant water sources. In Figure 5, it can be seen that there is an illustration of the hydrological system in the karst. Karst groundwater potential can be found above and below the surface. Karst areas have carbonate rock properties that have many cavities and are easily soluble in water, so that the surface drainage system does not develop and is more dominated by the subsurface drainage system. The dissolution process in karst landscapes results in less surface runoff and more development of subsurface flow systems (White, 1988).

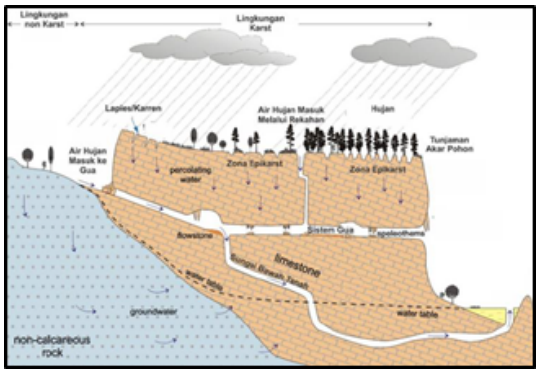


Figure 5. Karst Hydrological System.

The main sources of groundwater components in karst areas are divided into four, namely:

1. Surface runoff (river) that enters the karst aquifer through the ponor is known as allogenic recharge.
2. Surface runoff and rain that falls into a closed karst basin and then enter the karst aquifer through the ponor, is known as internal runoff.
3. Rainwater that falls to the ground surface and then slowly infiltrates through the soil pores.
4. Reimbursement from aquifers above limestone (White, 1988).

The dissolution process in the limestone area itself is very large. This is related to the physical and chemical properties of limestone. The water drainage system in the karst area is the conduit system and the diffuse system. The conduit system is a river flow system that directly enters the ponor or underground cave, while the diffuse system is

a flow system that flows downward through fractures (White, 1988).

The level of karstification development will affect the characteristics of groundwater input, storage capacity, and water release. Karst aquifers with high karstification have a low water storage capacity and rapid release of water, whereas aquifers with low karstification will be dominated by the diffuse flow type with high storage capacity and low release (Adji, 2014).

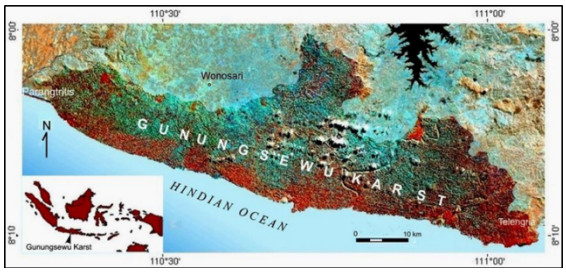
The drainage system in the Mount Sewu karst area is a conduit system, namely a river flow system that directly enters the ponor or underground cave. This is because the type of genesis of the karst development of Mount Sewu is a holocrast with a perfect level of karstification development so that the constituent rocks are relatively soluble, both from the viewpoint of the landform and the subsurface hydrology. The conduit drainage system will form an underground river that flows through limestone dissolution caves in Mount Sewu (Priambada, 2018).

Geological and Geomorphological Characteristics of Mount Sewu Endokarst Phenomenon, Gunung Kidul Regency

Moun Sewu karst is one of the largest karst areas on the island of Java as well as the most famous karst area due to the unique characteristics of geological and geomorphological formations in the area. It can be seen in Figure 6, because of the unique characteristics of the existing karst landforms, the Mount Sewu karst area is designated as a World Heritage (Prakarsa and Ahmadin, 2017).

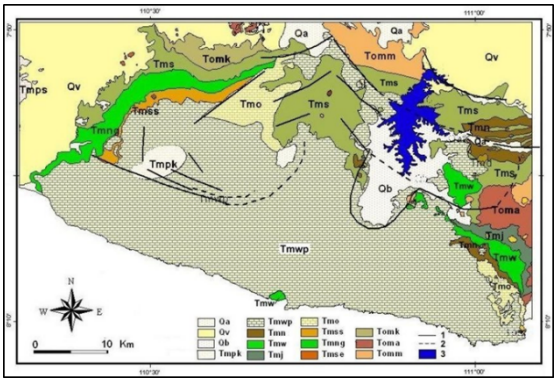
Figure 6. Mount Sewu Karst Area.

Its uniqueness is in the form of cone-shaped hills, drainage valleys called dolina which are always filled with water every rainy season which is then called lakes, with hundreds of caves and underground rivers that are characteristic of endokarst in Mount Sewu. These underground caves and streams or rivers have great potential for subsurface water resources (Santosa, 2015). In Figure 7, there is a map of the Mount Sewu karst landform, in which the Mount Sewu karst area is a holokarst type karst characterized by thousands of hills remaining from dissolution (Adji, 2006).



Fugure 7. Map of Mount Sewu Karst Landform.

We know that the Mount Sewu karst has become one of the Geopark areas, in the Mount Sewu karst area found various endokarst phenomena that cannot be separated from geological characteristics such as on the map in Figure 8, geomorphology, hydrology, ecology, and culture in the area (Wiratmoko and Fahrudi, 2017)



Fugure 8. Geological Map of Mount Sewu Karst.

Karst is a unique landform from the earth's surface (exokarst) and subsurface (endokarst), especially its genesis characteristic is that it is formed by the dissolution of carbonate rock deposition by groundwater flow. The dissolution process is generally accompanied by other processes such as collapse, transport in the form of a

solution through underground channels, as well as landslides and subsidence on the surface. The karstification process lasts for millions of years and finally produces the characteristics of the present landform (Maryanto, 2006).

The main characteristic of the geomorphological formation process of karst landforms is dissolution. Limestone and dolomite are easily dissolved by water. This continuous dissolution ultimately creates a very diverse karst landform. The dissolution process itself can occur in all types of rock, both in igneous, sedimentary, and metamorphic rocks (Maryanto, 2006).

The karstification process will only develop perfectly in rocks that have easily soluble properties, such as carbonate rocks or evaporites (formed by evaporation). This Mount Sewu karst area has very unique characteristics, it is characterized by the presence of a phenomenon on the surface (exokarst) and below the surface (endokarst) (Samudra, 2011).

Gambar 9. Surface Karst Phenomenon (Exokarst) of Mount Sewu.

In Figure 9, there is a karst phenomenon on the surface (exokarst) including positive formations, such as karst hills which number ±40,000 cone-shaped hills. The apex of the cone is rounded (sinusoidal) or tapers to the karst conical). The formations between the limestone hills form dolina, both open and closed. Rivers that flow on the surface of the karst area are very rare (Samudra, 2011).

Figure 10. Underground Water Flows Below the Karst Surface (Endokarst).

However, it can be seen in Figure 10 that in the karst phenomenon below the surface (endokarst) a sink or cave will be found, the surface river immediately turns into a river or underground water flow. Beneath the karst surface (endokarst) of Mount Sewu, water flows along the cave passages to form a more complex network of groundwater systems. In addition, the negative form of karst is in the form of karst valleys and karst lakes where in the rainy season it is filled with rainwater as a temporary shelter, but in the end, the lake is seasonal (Samudra, 2011).

1. Geological Characteristics of Mount Sewu Endokarst, Gunung Kidul Regency

The highland area of the Mount Sewu karst area has an altitude ranging from 200-300 meters above sea level. The existence of an uplift process caused by tectonic movements in the heights of the southern mountains, causing the area to find many geomorphological forms such as caves (endokarst) and karst hills (exokarst). Hemispherical hills and convex slopes are the characteristics of this type of tropical karst (Najib, 2010).

The process of forming this karst landform is dominated by geological elements, such as fractures and cracks. Referring to Figure 8 which is a geological map of Mount Sewu karst, it is known that there are a lot of sediments in the Mount Sewu karst area, such as coastal rock sediments and piles of marine carcasses found on the seven southern coasts of Java Island. The lowlands of the Mount Sewu karst area are located on the alluvial plain which is an alluvial area and is a coastal area (Najib, 2010).

2. Geomorphological Characteristics of Mount Sewu Endokarst, Gunung Kidul Regency

The characteristic of Mount Sewu karst is the steep slope topography that dominates the southern edge which is directly adjacent to the Indian Ocean. The northern part is bounded by mountains consisting of volcanic rocks, karstica of volcanic origin, and igneous rocks from the remains of ancient volcanic activity (Wiratmoko and Fahrudi, 2017).

Figure 11. Illustration of Geomorphological Forms in Mount Sewu Cave.

In Figure 11, it can be seen that the characteristics of the morphological form and the karstification process that are no less interesting are below the ground surface or in the cave (endokarst) (Wiratmoko and Fahrudi, 2017). Under the soil surface (endokarst) of Mount Sewu, cave systems develop, either horizontal caves or vertical caves, or a combination of the two. Dissolving underground for hundreds of thousands of years has resulted in various types of cave formations or decorations such as stalactites, stalagmites, pillars, sinter, and flowstones (Kusumayudha et al, 2015).

Figure 12. Endokarst Formation in Jlamprong Cave, Mount Sewu.

Viewing from Figure 12, that the characteristics of the Mount Sewu endokarst are that the formation of the endokarst is influenced by the presence of structural fractures, and the stalactite layer is always found after the fracture, namely on the roof of the cave. This is controlled by variations in the physical properties of the existing lithology and geological structures. These rock fractures and fractures allow rainwater to enter the deeper limestone layers (Chemistra et al, 2018).

Utilization of the Mount Sewu Endokarst Phenomenon, Gunung Kidul Regency

Mount Sewu is karst with a landform composed of limestone. Endokarst becomes the subsurface of a karst landform (White, 1988). The phenomenon of endokarst produces caves that are formed due to the dissolving process of rock. Caves are unique and distinctive ecosystems because of their conditions that do not allow sunlight to enter or sunlight can only enter through the cracks (Adji, 2010).

The existence of geological formations and karst geomorphology in Mount Sewu brings many benefits from various aspects. The utilization of the endokarst phenomenon in Mount Sewu is as follows:

1. Limestone Mineral Resources

Gunung Mount Sewu is geologically formed from the limestone of Neogene's (Middle Miocene) age. Limestone or limestone is chemically a compound of calcium carbonate ($CaCO_3$), which occurs due to the breakdown of organic waste materials. This limestone is a reef limestone and usually has a high $CaCO_3$ content (Cahyadi, 2010).

Limestone is one of the mining commodities in the Mount Sewu karst area. Limestone mining activities are carried out on a large, medium, and small scale. Limestone mining is mostly carried out, especially in Ponjong District, Gunung Kidul Regency. Mineral resources in the form of limestone in the Mount Sewu endokarst area are used as calcium carbonate flour which can be used as building raw materials (paint, cement, bricks), chemical industry (insecticides, fungicides,

disinfectants), cosmetic industry (powder and soap), and other materials. for the glue and shoe polish industry (Cahyadi, 2010).

2. Water Resources Supplier

The source of underground water flow is a hydrological system that has great potential in the endokarst area of Mount Sewu. The karst landform area physically shows dry conditions, but below the karst surface (endokarst) there is potential for water resources and several springs and has been used as a raw water source by PDAM which can supply water to surrounding villages and settlements in the area. the lower plains (Haryono, 2001).

One of the main sources of water supply that has been managed and utilized in the Mount Sewu karst area is the underground river watershed in Bribin Cave. Bribin Cave is a significant source of water for dealing with drought in the Mount Sewu karst area. The underground river discharge is high and has been developed as the main domestic water source. The potential quality of cave water and underground drainage shows that it is still below the class B quality standard for drinking water (can be drunk by processing or cooking) (Adji, 1999). This karst area is often dubbed a giant water tank that can be used to meet the needs of human life (Haryono, 2001).

3. Mount Sewu Karst Area as Geopark and Ecotourism Area

Geopark is a management concept of sustainable development of the earth's area, which includes three natural diversities, namely geodiversity (geological diversity), biodiversity (biological diversity), and cultural diversity (cultural diversity). Various parties for efforts to protect, preserve, and empower communities to maintain the use of ecosystems that aim to build a people's economy based on the principle of protection or conservation (Hertanto, 2009).

The karst landforms, both in the exokarst and endokarst sections, offer beauty, uniqueness, and scarcity that have a high selling value so that they can be utilized by the tourism sector. Regarding tourism, tourism development is currently emerging with a back to nature concept, namely a tourism concept that enjoys the beauty of natural panoramas with cool air, away from the noise, and beautiful views. This is known as ecotourism (Hertanto, 2009).

Some of the potential uses of endokarst areas as ecotourism, among others:

a) Natural tourism along the cave, in the endokarst area of Mount Sewu there are many caves with the beauty of interesting stalactites and stalagmites.
b) Caving which aims to know the culture. Because many areas around the Mount Sewu karst are related to archaeological and historical sites in the Mount Sewu endokarst area.
c) Tracking around the Mount Sewu endokarst area.
d) Show the karst cliffs on the endokarst section which has a variety of beauty and uniqueness (Hertanto, 2009).

4. Biodiversity

The endokarst area that is below the surface in the form of a cave is a habitat for various kinds of fauna, one of which is bats. Bats have an important role in the circulation of energy in the cave because they produce guano which is a source of energy for small fauna. Fish that live in caves such as catfish and other types of fish are also used for consumption by the community. Vegetation in the endokarst area varies depending on the size of the cave. Some of the vegetation that can be found in caves in the Mount Sewu endokarst area is in the form of ferns that can be used by the community for consumption or sale (Sridhar, 2006).

CONCLUSIONS

Kawasan The karst area in Mount Sewu, Gunung Kidul Regency has a height of only 300-500 meters. The area of the karst area in Mount Sewu reaches 3,300 km2 through three provinces, namely the Province of the Special Region of Yogyakarta, Central Java Province, and East Java Province. This Mount Sewu karst area has two unique phenomena, namely the karst phenomenon on the surface (exokarst) and below the surface (endokarst).

The endokarst phenomenon found on Mount Sewu is in the form of caves and underground river flows. The Gesing-Jlamprong-Sinden Cave Complex is a cave located in Semanu District, Gunung Kidul Regency. This cave complex consists of three caves that are interconnected by forming a cave system. In addition, the drainage system in the karst area of Mount Sewu is a conduit system, the system will form an underground river that flows through limestone dissolving caves in Mount Sewu. The existence of the endokarst phenomenon in Mount Sewu, Gunung Kidul Regency has many benefits for the surrounding community, including:

1. As a mineral resource of limestone, it is used as industrial raw material.
2. As a supplier of water resources, below the surface of the karst (endokarst) there is potential for water resources and several springs and has been used as a raw water source by PDAM which can supply water.
3. As a geopark and ecotourism area and has high biodiversity.

RECOMMENDATIONS

1. The endokarst phenomenon in the Mount Sewu area, Gunung Kidul Regency has the potential for landforms in the form of caves and underground river flows, so it is very important to know and study the karst landforms so that the area can be managed sustainably and used wisely.
2. The local government can use the karst area in the Mount Sewu Region, Gunung Kidul Regency wisely, because this area has a high tourism value, potential as a reservoir for minerals, and a producer of wallet bird nests so that it can increase the income of the surrounding community.

REFERENCES

Adji, T. N., dkk. 1999. *Kawasan Karst dan Prospek Pengembangannya di Indonesia*. Dipresentasikan dalam Seminar PIT IGI, 26-27 Oktober 1999. Jakarta: Universitas Indonesia.

Adji, T. N., dan Haryono, E. 2004. *Geomorfologi dan Hidrologi Karst Bahan Ajar*. Yogyakarta: Kelompok Studi Karst Universitas Gadjah Mada.

Adji, T. N. 2006. *Peranan Geomorfologi dalam Kajian Kerentanan Air Bawah Tanah Karst Gunung Sewu*. Indonesia Cave and Karst Journal, 2(1), pp. 68-79.

Adji, T. N. 2010. *Karst Glosarium Indonesia*. Yogyakarta: Universitas Gajah Mada.

Adji, T. N., dkk. 2014. *Analisis Tingkat Perkembangan Akuifer Karst di Kawasan Karst Gunung Sewu, Daerah Istimewa Yogyakarta dan Karst Rengel, Tuban, Jawa Timur Berdasarkan Analisis Hidrograf*. Prosidung Seminar PIT IGI, 15 November 2014. Yogyakarta: Universitas Negeri Yogyakarta.

Ashari, A. 2013. *Pola Lorong Gua Dan Speleogenesis Pada Sistem Perguaan Gesing-Jlamprong-Sinden Karst Gunungsewu*. Jurnal Geomedia Volume 11 Nomor 2 Hal 207 - 222.

Balazs. 1968. *Karst Region in Indonesia*. Journal Karszt-Es Barkangkutatas, Volume V: Budapest.

Cahyadi, A. 2010. *Pengelolaan Kawasan Karst dan Peranannya dalam Siklus Karbon di Indonesia*. Makalah dalam Seminar Nasional Perubahan Iklim di Indonesia. Sekolah Pasca Sarjana UGM Yogyakarta.

Chemistra, P., dkk. 2018. *Identifikasi Litologi Lapisan Sedimen Pada Daerah Karst Pacitan Menggunakan Metode Mikrotremor HVSR*. Jurnal Teknik ITS, pp. 7(1), 77-80.

GEGAMA. 1995. *Goa Bribin - Sebuah Laporan Pemetaan dan Pemotretan*. BAPPEDA DIY dan Dinas Pekerjaan Umum DIY. Mahasiswa Pecinta Alam FakuItas Geografi UGM.

Gillieson, D. 1991. *Caves: Processes, Development, Managements*. UK: Blackwell Publisherrs Ltd, Oxford.

Hartawan, B. S. 2020. *Characteristics of Sewu Mountain Karst as Geopark Area*. Journal of Global Environmental Science 1 (1) 2020: 7-12.

Haryono, E., dkk. 1999. *Kawasan Karst dan Prospek Pengembangannya di Indonesia*. Seminar PIR IGI di Universitas Indonesia.

Haryono, E. 2001. *Nilai Hidrologi Bukit Karst*. Seminar Nasional Eko-Hidrolik. Yogyakarta: Teknik Sipil Universitas Gadjah Mada.

Haryono, E. 2011. *Introduction Mount Sewu Karst Java-Indonesia*. Field Guide Asian Trans Disciplinary Karst Conference 2011.

Hertanto, H. B. 2009. *Prinsip dan Kriteria Ekowisata Berbasis Masyarakat*. Dirjen Pengembangan Destinasi Pariwisata Departemen Kebudayaan dan Pariwisata dan WWF Indonesia.

Ko, R. K. T. 1997. *Karstospeleologi*. Bogor: Himpunan Kegiatan Speleologi Indonesia (HIKESPI).

Koesoemadinata, R. P. 1980. *Geologi Minyak dan Gas Bumi*. Bandung: Institut Teknologi Bandung.

Kusumayudha, S. B. 2005. *Hidrogeologi Karst dan Geometri Fraktal di Daerah Gunungsewu*. Yogyakarta: BPAD Daerah Istimewa Yogyakarta.

Kusumayudha, S. B., dkk. 2015. *Geomorphologic Model of Gunungsewu Karst, Gunung Kidul Regency, Yogyakarta Special Territory, Indonesia: The Role of Lithologic Variation and Geologic Structure*. Journal of Geological Resource and Engineering.

Lehmann, H. 1936. *Morphologische studien auf Java*. Geogr. Abhandl. 9, Stutgard.

Linhua, S. 1996. *Mechanism of Karst Depresion Evolution and Its Hydrological Ecolution*. Journal Acta Geographica Sinica, 41, 41-50.

Maryanto, I., dkk. 2006. *Manajemen Bioregional: Kars, Masalah dan Pemecahannya, Dilengkapi Kasus Jabodetabek*. Bogor: Puslit Biologi LIPI.

Myloire, J. E., dan Carew, J. L. 2003. *Karst Development on Carbonate Island*. Speleogenesis and Karst Akuifer 1 (2): 1-21.

Najib. 2010. *Buku Panduan Praktikum Geomorfologi dan Geologi*. Semarang: Undip Press.

Palmer, A. 1991. *Origin and Morphology of Limestone Caves*. Journal Geological Society of America Bulletin, v. 103, p. 1-21.

Pannekoek, A. J. 1949. *Outline of the Geomorphology of Java*. Leiden: E. J. Brill.

Permadani, R., dkk. 2014. *Potensi Situs-Situs Warisan Geologi di Area Karst Gunung Sewu Sebagai Pendukung Peluang Pengembangan Geopark di Indonesia Untuk Aset Geowisata Kreatif*. Semarang: Universitas Diponegoro.

Prakarsa, T. B. P., dan Ahmadin, K. 2017. *Diversitas Arthropoda Gua di kawasan Karst Gunung Sewu, Studi Gua-Gua di Kabupaten Wonogiri*. BIOTROPIC The Journal of Tropical Biology, 1(2), pp. 31-36.

Priambada, A. P. 2018. *Kondisi Geohidrologi Kawasan Karst Gunung Sewu, Gunung Kidul, Daerah Istimewa Yogyakarta*. Yogyakarta: Fakultas Geografi UGM.

Samudra, H. 2011. *Nilai Strategis Kawasan Kars Di Indonesia*. Bandung: Pusat Pengembangan dan Pengembangan Geologi.

Santosa, L. W. 2015. *Keistimewaan Yogyakarta dari Sudut Pandang Geomorfologi*. Yogyakarta: UGM Press.

Sari, R. P. 2020. *Analisis Mineral Pembentuk Facies Gua Salukang Kallang Kawasan Karst Taman Nasional Bantimurung Bulusaraung Maros*. Jurnal Sains dan Pendidikan Fisika, 15(3).

Sridhar, R. P. N. 2006. *Polymerase Chain Reaction (PCR).* Dept. Of Microbiology. JJMMC, Davangere.

Van Dam, J. C. 1989. *Exploration of Groundwater Resources*. Yogyakarta: PAU UGM Yogyakarta.

White, W. B. 1988. *Geomorphology and Hydrology of Karst Terrain*. New York: Oxford University Press.

Wiratmoko, D., dan Fahrudi, E. Z. 2017. *Situs Geopark Gunung Sewu Geo Area Pacitan sebagai Sumber Belajar Ilmu-Ilmu Sosial*. Jurnal JIPSINDO, 4(2), pp. 150-165.