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Analysis of Characteristics, Functions, and Problems in Karst Sangkulirang-Mangkalihat Region

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ABSTRACT. Karst Sangkulirang-Mangkalihat has unique characteristics, both in terms of morphology and hydrology. The uniqueness of this region encouraged the authors to conduct research and dig deeper into information about the area. Primary purpose of this research is to know the characteristics, the functions, and the problem of Karst Sangkulirang-Mangkalihat. The research method used in this study is a qualitative method with a descriptive approach and literature review. Based on research result, it has many caves in which there are paintings of historical value that are over 10,000 year's old. It is known that the positive morphology of karst area is in the form of conical hills and karst towers, while the negative morphology is doline. Karst Sangkulirang-Mangkalihat has 3 functions, namely ecological function, economic function, then educational and cultural functions. The ecological functions of Karst Sangkulirang-Mangkalihat region include living areas of flora and fauna, storage of groundwater, and carbon absorbent. While the educational and cultural functions of the region include as a medium of learning the history of prehistoric people and an enhancer of cultural wisdom. The economic functions of the region include being a provider of rattan commodities that can be sold and the storage of carbon reserves of economic value. Ecological, economic, then educational and cultural functions can be disrupted due to several problems, including overlapping karst protection regulations and the rise of coal cement raw material mining activities.

Keywords: Characteristics, Functions, Problem, Karst Sangkulirang-Mangkalihat.

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1. Introduction

East Kalimantan province is one of the provinces in Indonesia that has a unique landscape. The unique landscape in East Kalimantan Province is Karst Sangkulirang-Mangkalihat. Karst is a landscape formed due to the process of karstification or dissolving and has a distinctive hydrological pattern (Widyaningsih, 2017). Etymologically, karst is derived from the word "Kras" which means rocky arid land, the word derived from the German derived in Slovenian. Karst function is generally distinguished into three aspects, namely ecological aspect, hydrological aspect, and socio-cultural aspect (Dzulkipli et al., 2018).

Based on the report of research team from Bogor Agricultural Institute, Indonesia has a karst area of 15.4 million hectares (Yogi, 2020). Some of the karst areas that can be found in Indonesia are Karst Gunung Kendeng, Karst Maros, Karst Gunung Sewu, and Karst Sangkulirang-Mangkalihat. Karst Sangkulirang-Mangkalihat region became a gorgeous place for all researchers because the area has its own unique characteristics compared to karst in other regions. Generally, a karst region has underground rivers and caves. But in the Karst Sangkulirang-Mangkalihat region, the caves has hand-shaped, boats, and animal paintings in the cave walls. Animal paintings of wild bulls in the caves in this region are 40,000 years old and it is the oldest cave paintings in the world. In the Karst Sangkulirang-Mangkalihat region you can see dozens of caves with long tunnels, inside which there is flow stone radiating a crystal of calcite.

Karst Sangkulirang-Mangkalihat stretches across in two districts, namely Berau regency and East Kutai Regency (Yogi, 2020). In the Karst Sangkulirang-Mangkalihat Region there are many underground rivers and caves with historical value. Karst Sangkulirang-Mangkalihat plays an important role in the lives of living beings, especially humans. Researchers divided the functions of Karst Sangkulirang-Mangkalihat into three functions, namely ecological functions, educational and cultural functions, and economic functions. The rise of limestone mining triggered by the massive production of mining business permits and overlapping regulations became a nightmare for the sustainability of Karst Sangkulirang-Mangkalihat. Limestone mining activities can damage karst areas whose notable serves as water storage. If it is damaged, karst cannot be recovered, because karst is classified as an unrepairable resource. The function of karst area into mining is also colored by the felling of trees and forests, even though the forest is a habitat for various types of fauna, it has the potential to decrease biodiversity. Based on the previous description, it can be seen that the aim of this research is to know about characteristics, functions, and problems in karst Sangkulirang-Mangkalihat.

2. Materials and Methods

The research method used by researchers is qualitative method with descriptive approach. Researchers used the latest journals for literature review and enrich references. Researchers used a descriptive approach to describe more

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details of the data obtained. With a descriptive approach, data can be analyzed in depth and accurately.

2.1 Study Area

Overall, the research was conducted in Karst Sangkulirang-Mangkalihat Region, East Kalimantan Province. Research on the rate of water infiltration was conducted in one of the villages still located within the Karst Sangkulirang-Mangkalihat Region, the village is Bengalon Village, East Kutai Regency. Research on carbon uptake was conducted in Karst Biduk-Biduk Region, East Kutai Regency, this region is still one part of Karst Sangkulirang-Mangkalihat Region.

2.2 Data Analysis

Data obtained from a study must be processed and analyzed first. The information and data about characteristics and problems in Karst Sangkulirang-Mangkalihat were analyzed decriptively, it will be decsribed in detail to get an adequate explanation. In this study, the data about the functions from Karst Sangkulirang-Mangkalihat were analyzed with various calculation formulas. To calculate diversity can use the Shanon-Wiener Index (Wiyanata et al., 2018). Here is the formula for calculating diversity:

H' = Pi ln Pi
H' = Diversity index
ni = Numbers of individuals per types
N = Number of individuals of all types
Pi $= \frac{ni}{N}$

Whereas the formula for calculate total organic carbon is:

NDVI $= \frac{(NIR - Red)}{(NIR + Red)}$
NIR = Reflective value from Near-Infrared Band
Red = Red ribbon bounce value

To calculate the total uptake of inorganic carbon can use the following formula:

$$MC = \frac{Ar\ C}{Mr\ CaCO3} X \frac{Mr\ CaCO3}{Mr\ CaO} \text{ x \% CaO x BJ CaCO3 x V CaCO3}$$

To calculate the total economic carbon value can use the following formula:

ECV = (OCS + ICS) X CV
ECV = Total economic carbon value
OCS = Total organic carbon stock
ICS = Total anorganic carbon stock
CV = Standard carbon price per ton

3. Result and Discussion

3.1 Karst Sangkulirang-Mangkalihat Characteristics

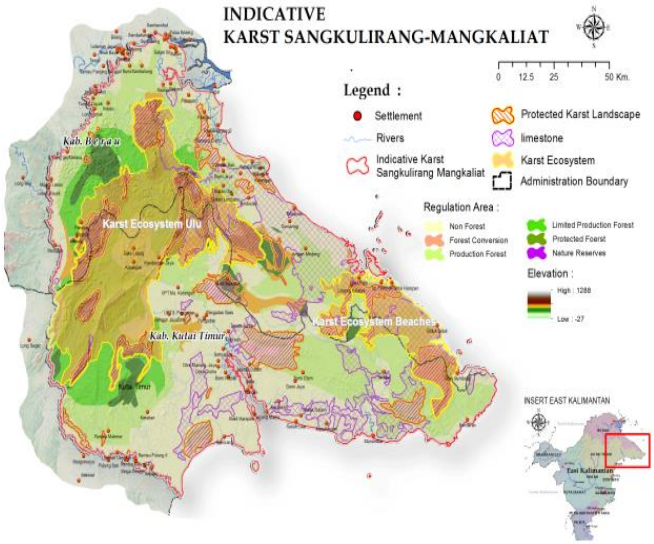

Fig.1 Karst Sangkulirang-Mangkalihat Distribution Map
Source : Musnanda, (2016)

Karst Sangkulirang-Mangkalihat Region is located in East Kalimantan Province, more precisely stretching in Berau Regency and East Kutai Regency. The total area of Karst Sangkulirang-Mangkalihat Region is 1,867,676 hectares. In Karst Sangkulirang-Mangkalihat Region there are many beautiful and green hills, steep walls, and underground caves. The uniqueness of the area can be found in a number of caves in the Karst Sangkulirang-Mangkalihat Region, in the cave of that region there are many hand paintings and various kinds of animals footprint that has historical value. The paintings found in the caves of the area are even 10,000 years old. After being researched, it turned out that the Karst Sangkulirang Mountains were the starting place of the entry of the ancient human clump of Austronesia (Nurdini et al., 2020).

Karst Sangkulirang-Mangkalihat Region, both in Berau regency and East Kutai Regency has tropical climate. In the tropical karst region such as Karst Sangkulirang-Mangkalihat area, many dolines are found to form cockpits karst. Doline is a form of negative karst morphology. Doline is a bowl-shaped basin with a depth of hundred meters and has walls with slopes of ramps up to steep (Haryono et al., 2016). Karst Sangkulirang-Mangkalihat also has positive morphology, namely the conical hills and karst towers, which is characteristic of karst in tropical climates.

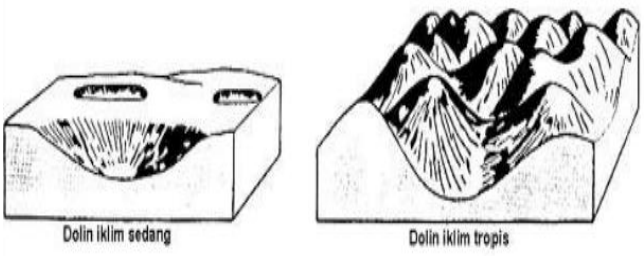

Fig.2 The Difference between Doline Tropical and Medium Climate
Source : Permatasari, (2013)

The Karst Sangkulirang-Mangkalihat Region also has a distinctive hydrological cycle. Karst Sangkulirang-Mangkalihat Region plays a vital role as one of the springs, Karst Sangkulirang-Mangkalihat Region is the upstream of the five main rivers that are often utilized by the people of Berau and East Kutai Districts. The Karst Sangkulirang-Mangkalihat Region has a ponor that serves as a water sinkhole. For the water flow scheme in the Karst Area, it is generally the same as the water flow scheme in other karst areas. Here is the water flow system scheme in Karst Sangkulirang-Mangkalihat Region:

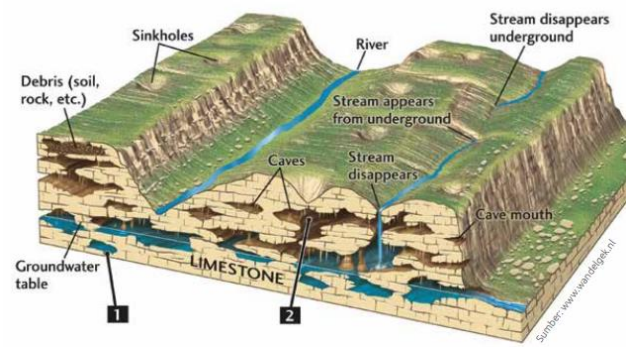

Fig.3 Water Flow Scheme in Karst Region
Source : Nugroho, (2014)

Generally, water in limestone can flow through two media, namely the fracture medium and the space between the grains. The flow components in the Sangkulirang-Mangkalihat Karst aquifer are divided into two, namely the diffusion flow component and the channel flow component. In the diffusion flow component, groundwater flows slowly, while in the channel component, groundwater flows fast and turbulent (Tjoen, 2015).

3.2 Function of Karst Sangkulirang-Mangkalihat Region

Karst Sangkulirang-Mangkalihat Region has three functions, namely ecological functions, educational and cultural functions, and economic functions. The ecological function of Karst Sangkulirang-Mangkalihat Region is as a living place of various flora and fauna, as a water storage, and carbon absorber. Recent surveys show that the forest above East Kalimantan's Karst Sangkulirang-Mangkalihat Region is a fairly comfortable habitat for orangutans (Marshall et al., 2007). In addition to orangutans, in the Region of Karst Sangkulirang-Mangkalihat also found a variety of new animal species. Based on research from entomologists, Namely Dr. L. Deharveng, Dr. Y. Suhardjono, Dr. A. Bedos, and C. Rahmad who captured several thousand arthropods in the Karst Sangkulirang-Mangkalihat Region in both caves, forests, and soil, stated that 60% of the specimens captured were new species (Salas et al., 2005). New species found in the Karst Sangkulirang-Mangkalihat Region include Nemacheilus marang, Sarax sangkulirangensis, Sarax cavernicola, and Sarax mardua (Sutrisno et al., 2015). In the Region of Karst Sangkulirang-Mangkalihat there are also many plants. Here is the composition of plants identified in several locations of Karst Sangkulirang-Mangkalihat Region:

Table 1. Composition of Plants Identified in Several Locations of Karst Sangkulirang-Mangkalihat

Location	Family	Type	Number of Individuals
Suaran	18	39	80
Tondoyan	16	32	66
Gergaji	28	57	111
Biatan Ulu	19	38	108
Lobang Kelatak	21	41	89
Biduk-Biduk-TL. Sulaiman	20	41	84
Total	41	162	538

Source: Dzulkipli et al., (2018)

From table 1, it can be known that there are 538 plants identified in some areas of Karst Sangkulirang-Mangkalihat. The composition of plant species at each research site varies, the highest number of species found in Gergaji with 57 species and 28 families. While the lowest number of plant species is found in Tondoyan with 32 species and 16 families. The difference in the number of plant species in a region depends heavily on acclimatic, edafik, altitude, and latitude factors (Dzulkipli et al., 2018).

In addition to being a place of life for flora and fauna, The Karst Sangkulirang-Mangkalihat Region also serves as water storage because the area has a distinctive hydrological cycle. Speaking of hydrological cycles, it is also necessary to discuss the rate of water infiltration and land cover. This type of land cover will affect the rate of infiltration and hydrological cycle in a region.

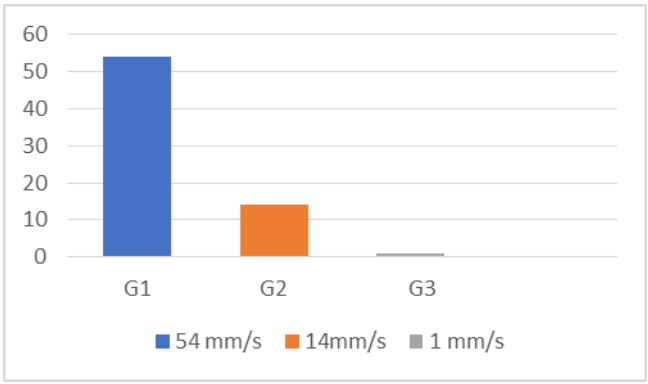

Fig. 4 Comparison of Limestone's Ability to Absorb Rainwater
Source: Processed Data, (2021)

Karst Sangkulirang-Mangkalihat Region is composed of limestone. Limestone rocks can absorb rainwater because it has cavities. Based on figure 4, it is known that G1 is a symbol for limestone rocks that are still original and untouched by mining activities, G2 is a symbol of limestone rocks in karst area that has been mined and reclaimed by planting trees, while G3 is a symbol for limestone in karst area that has been mined, but not reclaimed. From the chart in figure 4 can be taken information that limestone rocks that have not been touched mining activity has the ability to absorb the highest rainwater, namely 54 mm / s. While limestone rocks that have been mined and not reclaimed, have the ability to absorb the least water, namely 1 mm / s. The absorption of water or the rate of infiltration in the karst area is apparently controlled by several factors, including the land cover factor and the physical nature of the soil.

Table 2. Infiltration Rate at Some Karst Sangkulirang-Mangkalihat Land Cover

No.	Drop Distance (mm)	Shrubs		Secondary Forest Land Cover	
		Times (minute)	Infiltration Rate (mm/h)	Times (minute)	Infiltration Rate (mm/h)
1	10	6,56	961,9	10,48	96,19
2	20	7,05	1271,11	12,25	153,36
3	30	8,08	576,63	13,68	214,48
4	40	9,7	514,45	15,63	247,82
5	50	11,76	609,59	16,98	285,37
6	60	13,06	646,69	19,04	300,79
7	70	13,93	720,73	21,54	330,9
8	80	15,77	652,38	22,98	348,09
9	90	17,73	589,56	26,02	320,52
10	100	20,64	499,35	29,34	301,28
	Average	**12,43**	**704,44**	**18,79**	**259,88**
	Class	**Very Fast**		**Very Fast**	

Source: Sarminah and Indirwan, (2017)

Table 3. Infiltration Rate at Karst Sangkulirang-Mangkalihat Region without Land Cover

No.	Drop Distance (mm)	Karst without Land Cover	
		Times (minute)	Infiltration Rate (mm/h)
1	10	30,88	42,79
2	20	35,58	71,82
3	30	38,56	91,56
4	40	42,42	98,89
5	50	49,71	98,65
6	60	53,73	107,15
7	70	58,1	103,16
8	80	63,55	103,7
9	90	68,69	107,15
10	100	74,8	106,43
	Average	**51,6**	**93,07**
	Class	**Fast**	

Source: Sarminah and Indirwan, (2017)

Table 4. Physical Structure of Soil in Some Sangkulirang-Mangkalihat Karst Land Cover

No.	Land Cover	Soil Texture	Soil Structure	Bulk Density (gr/cm3)
1	Shrubs	Sand	Single Grain	1,07
2	Secondary Forest	Clay	Granular	1,26
3	Karst without Land Cover	Clay	Granular	1,27

No.	Land Cover	Porosity (%)	Percentage by weight (%)
1	Shrubs	39,65	3,11
2	Secondary forest	34,63	12
3	Karst without Land Cover	34,27	18,46

Source: Sarminah and Indirwan, (2017)

Based on the data in table 2 and table 3, it can be noted that the fastest rate of water infiltration occurs in shrubs cover, water infiltration rate in areas with shrubs cover of 704.44 mm/h and including very fast. The rate of water infiltration in areas with secondary forest land cover is known to be 259.88 mm/h, the rate of infiltration in areas with secondary forest land cover is very fast. While the rate of water infiltration in the karst area without land cover is known to be 93.07 mm/h and belongs to the fast category. The rate of water infiltration in areas with shrubs cover is higher than the area with secondary forest land cover, this is because areas with shrubs cover have a relatively harder soil to escape from sand that is relatively easier to escape water, while areas with secondary forest land cover have a relatively harder clay soil texture to escape water (Sarminah and Indirwan, 2017). The rate of water infiltration in areas with secondary forest cover is higher than karst areas without land cover, this is because areas with secondary forest land cover tend to get more sunlight triggering evaporation and reduction of water levels in the soil, in addition to litter in thicker secondary forests, thus reducing the effect of raindrop blows that can damage the physical properties of the soil (Sarminah and Indirwan, 2017).

Apart from being water storage, it turns out that the Sangkulirang-Mangkalihat Karst area also acts as a carbon sink. Based on IPCC (Intergovernmental Panel on Climate Change) data, karst areas are able to absorb large amounts of carbon. In every 1 km2 karst area is able to absorb 218,86 kg of carbon in the atmosphere every year. Carbon reserves in the Sangkulirang-Mangkalihat Karst Region, more precisely in the Biduk-Biduk Forest, are divided into two, namely organic carbon and inorganic carbon stocks.

Table 5. Organic, Inorganic Carbon Stocks, and the Economic Value of Sangkulirang-Mangkalihat Karst Carbon

	Total Stok (Ton)	Economic Value per Ton (USD)	Carbon Economy Value (USD)
Organic Carbon Stock	7,773,358	5	38,866,790
Inorganic Carbon Stock	9,026,535,501	5	45,132,677,506
Total	**9,037,339,666**		**45,171,544,296**

Source: Danardono et al., (2019)

Organic carbon stocks are the amount of carbon stored in the root zone, vegetation, and litter (Danardono et al., 2019). Inorganic carbon is the form from carbon minerals, either from weathering of the parent material, or from the reaction of soil minerals with carbon dioxides in atmospher. The amount of carbon stored in karst areas can be of added value in economic terms. Based on the data in Table 4, it is known that the organic carbon stock in the Biduk-Biduk Forest of the Sangkulirang-Mangkalihat Karst Region is 7.773.358 tons, while the inorganic carbon stock is 9.026.535.501 tons. The total carbon stock in the area amounted to 9.037.339.666 tons and the total carbon economic value in the area was USD 45.171.544.296.

From the data in table 4, it can be seen that the Sangkulirang-Mangkalihat Karst Region also has an economic function. Apart from the economic value of carbon, various plants in the Sangkulirang-Mangkalihat Karst Region can also be of economic value because they can be sold, for example rattan trees. Rattan can be found in several forests of the Sangkulirang-Mangkalihat Karst Region. The following is the diversity in several forests in the Sangkulirang-Mangkalihat Karst Region:

Table 6. Rattan Diversity in Several Forests in the Sangkulirang-Mangkalihat Karst Region

Location	Diversity Index (H')
Suaran	1,25
Tondoyan	1,2
Gunung Gergaji	0,54
Biantan Ulu	1,76
Lobang Kelatak	1,18
Biduk-Biduk	1,22

Source: Wiyanata et al., (2018)

From Table 5, the highest rattan diversity index is in the Biantan Ulu Region and the lowest is in the Gunung Gergaji Region. If the diversity value index is less than 1, then the diversity in the area is classified as low. If the diversity value index is more than 1 and less than 3, then the diversity in the area is classified as moderate. If the diversity value index is more than 3, then the diversity in the area is high (Wiyanata et al., 2018). From table 5, the diversity of rattan in the Gunung Gergaji Region is low and the rest is moderate.

The next function of Karst Sangkulirang-Mangkalihat Region is educational and cultural function. In the cave of Karst Sangkulirang-Mangkalihat Region there are many hand-shaped paintings and animals. The painting is a trace of a relic from prehistoric human life. Some of the paintings found in the cave of Karst Sangkulirang-Mangkalihat region are more than 5000 years old (Azmi, 2018). These paintings can be a medium for learning about the history of ancient humans. It should be a valuable asset that is protected and preserved.

Fig.5 Palm Paintings Found in Karst Sangkulirang Cave

3.3 Problems in Karst Sangkulirang-Mangkalihat Region

Consider the importance of the function of Karst Sangkulirang-Mangkalihat Region in ecological, economical, educational and cultural aspects, it is necessary to protect and conserve the Region. However, in reality the various existing regulations overlapped and weaken the protection of the area. The ease with which the issuance of mining business permits also exacerbates efforts to protect karst in the area. The difference in the extent to which the Sangkulirang-Mangkalihat Karst ecosystem was determined in several regulations caused uncertainty about the status in several Regions of Berau and East Kutai Regencies, whether they were classified as karst areas or not (Widyaningsih, 2017). For example, in the Regulation of the Governor of East Kalimantan No. 67 of 2012, the regulation states that the Region of the Karst Sangkulirang-Mangkalihat Region is 1.867.676 hectares, of which 362.796,11 hectares are listed as geological protected areas. Whereas in the East Kalimantan Provincial Regulation No. 1 of 2016, it is stated that the geological protected area in the Sangkulirang-Mangkalihat Karst Region is only 307.337 hectares. There are 217 coal mining business permits, 14 cement material mining and cement factories, 41 IUPHHKHT, 92 IUPHHKHA and 370 plantation business permits. Of the total Region of the Sangkulirang-Mangkalihat Karst Region, 50% has been used for mining activities (Widyaningsih, 2017). The massive mining intensity has the potential to damage the environment and interfere with ecological functions, economical functions, as well as educational and cultural functions.

4. Conclusion

Karst Sangkulirang-Mangkalihat Region has unique characteristics. In Karst Sangkulirang-Mangkalihat Region there are many beautiful green hills, steep walls, and underground caves. In the cave of the region there are many hand paintings and paintings of various animals footprint that has historical value. In the tropical karst region such as Karst Sangkulirang-Mangkalihat Region, many dolines are found in form cockpits karst. Karst Sangkulirang-Mangkalihat has positive morphology in the form of conical hills and karst

towers. In ecology aspect, Karst Sangkulirang-Mangkalihat is a place to live for rare and endangered species, such as orangutans. In economic aspect, it can increase income for the surrounding community because the plants faund in this region can be sold, such as rattan. In addition, the carbon storage can be converted financially so that the country get benefits. In education and cultural aspect, this region acts as a place to research and study prehistoric culture from the remains of paintings in the cave. Problems in the form of massive mining activities and overlapping karst region protection regulations have the potential to interfere the function of Karst Sangkulirang-Mangkalihat region. The large number of mining due to the ease of obtaining permits and overlapping regulations can damage the karst ecosystem so that plant diversity will decrease and animals lose their habitat, the community also feel the impact in the economic aspect because the rattan commodity also decreases in quantity and quality.

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