Utilization of the maros karst landscape based on the morphology (case study in bantimurung subdistrict, maros district, sulawesi selatan)

R P Setiadi*, A Damayanti2, M Dimyati2,3
1Bachelor Program of Geography, Universitas Indonesia, Depok − Indonesia
2Department of Geography, Faculty of Mathematic and Natural Science, Universitas Indonesia, Depok − Indonesia
3Ministry of Research, Technology, and Higher Education, Jakarta − Indonesia

*Restu.pratama@ui.ac.id

Abstract. Karst region of Maros Regency is valuable due to the natural resources available for the local economy. This study aims to map the karst geomorphology units using GIS techniques and to illustrate the use of the landscape by surrounding communities. Information on karst distribution is needed because the karst potential has scientific, economic, and humanitarian values, which are a wealth of resources. The variables used in this study are geological, altitude, drainage pattern, and slope maps. We determine the distribution of karst geomorphological units using the overlay method. Primary data processing and descriptive analysis are used to determine the utilization of each karst geomorphology unit. The result is that the karst has an area of 33.58 km² or 20% of the total area, which covers the 10.17 km² plain karst, 15.84 km² plateau karst, 6.07 km² cone karst, and 1.49 km² tower karst. The plain karst is used for agricultural land, while the plateau karst and cone karst for tourism services, with the cone karst in the form of guano fertilizer sources. Meanwhile, tower karsts are utilized for limestone mining.

1. Introduction
The karst area is a nature reserve protected area. The karst ecosystem is not only seen in the uniqueness, scarcity, and beauty of the landscape but also characterized by the existence of underground life phenomena and alleyways with all its components [1]. Karst is a natural resource that is not renewable and there are many natural phenomena are unique and rare and have important values for life and ecosystems so that the use of space and regulation of its territory for development needs to be careful so as not to damage the environment [1].

Indonesia is a country with a wide span of karst regions. It is estimated that Indonesia has a karst area of 15.4 million ha [2]. Throughout the Indonesian archipelago, the area of the karst reaches almost 20% of the total area [2]. The karst area also has potential, benefits, and important roles for ecosystems and humans. The existence of karst areas in Indonesia today is considered to have very strategic values because in addition to being a supplier area and water reservoir for domestic purposes, karst also has natural resources that can be utilized to increase foreign exchange such as tourism and mining [3].

The karst area in Indonesia is found in every major island, both Sumatra, Java, Kalimantan, Irian, Sulawesi, and also in the Nusa Tenggara Islands. South Sulawesi has a karst area that is scattered in several areas of the regency [3]. The most famous are the karst area in Maros Regency and Pangkep Regency. The Maros-Pangkep Karst area is the second largest and most beautiful in the world after the karst region in China [3]. The uniqueness of the Maros Pangkep karst area which is not found in other karst areas in Indonesia because it has a unique landscape commonly called tower karst [3].

Unfortunately, limestones are the main constituents of karst, which are also continuously sought after and utilized by the cement industry. These needs will certainly continue to increase amid the acceleration of infrastructure development being promoted by the government. In the past two decades,
environmental issues and conservation began to emerge. Karst is increasingly becoming a concern when it comes to cement mining exploitation [4].

In the long term, the karst region continues to experience interference from exploitation for economic purposes, so it is necessary to try to protect the function of the karst region itself [5]. The clash between economic interests and environmental conservation in the karst region is due to a lack of public knowledge and comprehensive information about the region. The choice of alternatives to protect the function of the karst region needs to be based on the characteristics of the karst region and its potential [6].

Therefore, information on karst distribution is needed because it relates to karst potential which has biodiversity and non-biological values and has scientific, economic and humanitarian values, is a wealth of resources that need to be managed as well as possible [6]. The management of the karst area aims to optimize the use of the karst area, to support sustainable and environmentally sound development [7]. These regional management efforts include research, utilization, and protection of natural karst resources. The progress of geography and remote sensing technology (GIS) is expected to be useful in supporting these management efforts. Previous studies relating to karst mapping have been carried out in Bijie District, China using the overlay method [8] The use of GIS in karst mapping has also been carried out in the Mediterranean Karst region using supervised classification [9]. The update on this research is to show the aspects of human geography in the form of karst utilization by the surrounding community.

2. Methodology

2.1. Regional Descriptions

Bantimurung Subdistrict has an area of 173.70 km², at an average height above 500 meters above sea level. Divided into smaller administrative areas into 8 villages namely Baruga Village, Tukamasea Village, Mattoangin Village, Alatengae Village, Minasa Baji Village, Mangeloreng Village, Kalabbirang Village, and Leang-leang Village. The distance of the district capital with this area is ± 3 km, but with the subdistrict capital around 9 km [11]. Administratively, the Bantimurung Subdistrict is limited by the following regions: The North is bordered by North Maros Subdistrict and Pangkep Subdistrict; Eastside borders with Cenrana Subdistrict; The South is bordered by Simbang Subdistrict; The West is bordered by Turikale Subdistrict and New Maros Subdistrict [11].

2.2. Materials

Variables used to determine the distribution of karst geomorphological units include elevation, slope, geology, and stream patterns. Furthermore, the variable to determine the use of karst is the karst geomorphology unit and land use. All variables are processed using ArcGIS 10.3 software. The research mindset is shown in Figure 1.

Figure 1. Research Mindset

2.3. Method

Data collection used in this study is in the form of primary data collection and secondary data.
Primary data is collected through interviews and observations. Interviews were used to explore information about the utilization of each karst geomorphology unit. The number of informants adjusted information needs. Observations were made to verify the data in the form of karst morphology, morphometry, altitude, and slope. The sampling technique used in this study is the *cluster sampling* which refers to a line of transects made based on elevation. Secondary data in this study were obtained from the results of various literature studies in the form of books, journals, and proceedings. Administrative data, river network, road network, geology, and land use were obtained from the Badan Informasi Geospasial 2018 with a scale of 1:50,000. Meanwhile, data on altitude, slope, and stream patterns are obtained from the USGS DEM 2018. The data is collected and processed to be used in making maps of the karst geomorphology unit. The sample point map in this study is shown in Figure 2.

![Sample Point Map](image)

Processing of primary data is formed in maps and tables. Meanwhile, secondary data is processed using ArcGIS 10.3 Software. Administrative map, road network, river network obtained from South Sulawesi Province SHP *clip* process. The DEM data of Bantimurung Subdistrict was extracted to produce an Altitude Map, Slope Map, and Stream Pattern Map. Meanwhile, Geological Map are produced from the SHP Geology *clip* process of South Sulawesi Province. After that, an *overlay* process was carried out on all four maps to obtain a map of the distribution of karst geomorphological units. Next, to determine the extent of each map, the *calculate geometry* process is used. The map and its area are then analyzed to determine the distribution pattern of the karst geomorphology unit and its utilization.

The analysis to determine the distribution of karst geomorphology units is done by *overlay* based on the classification of Van Zuidam's geomorphological unit [12]. Analysis to explain the utilization of karst geomorphology units was carried out in a descriptively. This analysis is to find out variations in land use in each karst geomorphology unit in Bantimurung Subdistrict.

### 3. Result and Discussion

#### 3.1. Slope

Bantimurung Subdistrict tends to have a relatively flat slope. In the west, precisely in Mattoangin Village, Alatengae Village, Minasa Baji Village, and Mengeloeng Village, are dominated by slope classes 0-2% with an area of around 66.12 km² or 38.04% of the total area. In the eastern and northern parts, namely in Baruga and Tukamasea villages tend to be steeper with a slope of 2-7% which also has the largest area, which is around 71.99 km² or 41.42% of the total area. Slope classes with a value of more than 7% are only found in the central and southern parts of Leang-leang Village and Kalabirang Village, namely the slope class 7-13% with an area of 24.44 km² (14.06%), slope class 20-45% with an area of 6.11 km² (3.51%), and the narrowest is the slope class 13-20% with an area of 5.17 km² (2.98%).

A slope is a form of variation in changes in the surface of the earth globally, regionally or specifically in the form of a particular region. The variables used in identifying the slope are the slope angle, altitude...
above sea level, and the shape of the landscape due to the force of the geomorphological unit that works [13]. Slopes are part of a landscape that has a sloping angle and height difference in a certain place. The slope angle is a variable of high difference between two places compared to a relatively flat or flat area [14]. The slope map of the Bantimurung subdistrict is shown in Figure 3. While the area on each slope is shown in table 1.

![Figure 3. Slope Map of Bantimurung](image)

### Table 1. Slope Area

| Slope     | Area (km²) | Percentage (%) |
|-----------|------------|----------------|
| 0 - 2%    | 66.12      | 38.04          |
| 2 - 7%    | 71.99      | 41.42          |
| 7 - 13%   | 24.44      | 14.06          |
| 13 - 20%  | 5.17       | 2.98           |
| 20 - 45%  | 6.11       | 3.51           |

3.2. **Elevation**

The elevation in Bantimurung Subdistric varies from <100 masl to more than 650 masl. In the western part of Bantimurung Subdistric, namely Mattoangin Village, Alatengae Village, Minasa Baji Village, and Mangeloreng Village tends to have relatively low altitudes between 0 - 100 masl. Class of elevation 0-100 masl has the largest area among other altitude classes, which reaches 75.38 km² or 43.43% of the total area. While in the central part of Bantimurung District tends to have a higher elevation, which is between 101 - 250 masl with an area of about 30.36 km² or 17.50% of the total area. The more eastward, elevation tends to increase, as in Baruga Village and Tukamasea Village where the elevation has a value between 251 - 400 masl with an area of 36.64 km² (21.11%). In the easternmost part, namely Leang-leang Village, and Kalabbirang Village has an elevation between 401 - 650 masl with an area of 25.06 km² (14.44%). Some of these areas also have the highest elevation values with a value of > 650 masl, but have the smallest area which is around 6.10 km² (3.52%).

The elevation is the height of a point above the reference plane where the reference usually used is the average height of the sea surface [15]. Altitude or elevation is the vertical position of an object from a certain point [16]. Commonly used datums are the sea surface and geoid surface of WGS-84 used by GPS. Therefore, the altitude is often expressed as an elevation of the sea level or commonly abbreviated as meters above sea level (masl). Elevation maps in Bantimurung Subdistrict are shown in Figure 4. While the area is shown in table 2.
3.3. Geology

Bantimurung Subdistrict is divided into five lithology units, namely the Camba Volcanic Mountains unit with an area of 16.83 km² or 9.83% of the total area, which occupies the northern part of Leang-leang Village. Alluvium sediment units that occupy hilly areas are spread evenly in Mattoangin Village, Alatengae Village, Minasa Baji Village, and Mengeloreng Village with an area of 48.34 km² or 28.22% of the total area. The unit of Tonasa karst hilly formation, this hilly unit has the largest area reaching 94.69 km² (55.29%), spread almost in all villages in Bantimurung Subdistrict, except Alatengae Village. Extrusive basalt igneous rock units, located in the western part spread in Baruga Village and Tukamasea Village with an area of 7.53 km² (4.40%). Andesite occupies part of the area of Kalabbirang Village with an area of 3.87 km² (2.26%). The geological structure in Bantimurung Subdistrict is in the form of folds and faults. The fold is formed from endogenous energy in the form of pressure. If the pressure on the rock layer is horizontal and collides, the earth's surface will fold to form peaks and valleys [17]. The fault is the process of changing the position of rocks due to the work of endogenous forces which suppress hard rock structures so that between one and the other rock structures become broken and separated. Usually, faults occur due to the presence of fast-moving endogenous forces and regarding less elastic rock structures [17]. Fold can be found in the northern region, precisely in Leang-leang Village which part of its territory is a volcanic mountain unit. While the fault can be found in the area which is a unit of karst Tonasa formation. The Tonasa Formation is then used to determine the karst geomorphology unit. Figure 5 shows the geological map of the Bantimurung Subdistrict. The area of the geology is shown in table 6.

![Elevation Map of Bantimurung](image_url)

**Figure 4. Elevation Map of Bantimurung**

**Table 2. Elevation Area**

| Elevation (masl) | Area (km²) | Percentage (%) |
|------------------|------------|----------------|
| 0 - 100          | 75.38      | 43.43          |
| 101 - 250        | 30.36      | 17.50          |
| 251 - 400        | 36.64      | 21.11          |
| 401 - 650        | 25.06      | 14.44          |
| > 650            | 6.10       | 3.52           |

- Bantimurung Subdistrict is divided into five lithology units,
  - Camba Volcanic Mountains unit
  - Alluvium sediment units
  - Tonasa karst hilly formation
  - Extrusive basalt igneous rock units
  - Andesite
  - Geological structure in Bantimurung Subdistrict
  - Folds and faults
  - Tonasa Formation
  - Lithology units
  - Figure 5 shows the geological map of the Bantimurung Subdistrict.
Table 3. Geology Area

| Rock Type             | Area (km²) | Percentage (%) |
|-----------------------|------------|----------------|
| Alluvial              | 48.34      | 28.22          |
| Basalt                | 7.53       | 4.40           |
| Andesite              | 3.87       | 2.26           |
| Camba Volcano Rock    | 16.83      | 9.83           |
| Tonasa Formation      | 94.69      | 55.29          |

3.4. Stream Pattern

The pattern of the stream in Bantimurung Subdistrict has quite varied characteristics. In the western part, precisely in Mattoangin and Mangeloreng Villages, the flow patterns formed tend to be parallel with an area of 38.95 km² or 22.31% of the total area. Parallel flow patterns are characterized by major tributaries that are parallel or nearly parallel, boil down to major rivers with acute angles, and develop on slopes controlled by monoclinal, isoclinal, or cesarean fold structures that are parallel to short spacing [18].

While in the central and northern parts, precisely in the Village of Kalabbirang and Desa Baruga tend to have a rectangular pattern with an area of 81.94 km² or 46.94% of the total area. The rectangular flow is the flow pattern from the meeting between the flow forms a right angle or almost right angle, this flow pattern develops in the fracture and fracture area [18]. Then in the northeast part of Alatengae Village, Minasa Baji Village, and also in the northern part of Tukamasea Village tend to have a dendritic pattern that reaches 53.67 km² or 30.75% of the total area. The pattern of dendritic river flow generally develops or appears among homogeneous rocks such as sedimentary rocks with horizontal or homogeneous igneous rocks [18]. For more details, the map of the river flow pattern of Maros Regency is shown in Figure 6. For the area in each river flow pattern shown in table 4.
3.5. Landuse

Landuse in Bantimurung Subdistrict is still dominated by forest with an area reaching 117.92 km² (68.46%) which occupies Leang-leang Village, Kalabbirang Village, Tukamasea Village, and Baruga Village. While built-up areas such as settlements were only found in the western part of Bantimurung Subdistrict, namely in Mattoangin Village, Alatengae Village, and Minasa Baji Village, with an area of 3.70 km² or only 2.15% of the total area. Land to support human needs such as rice fields, moorlands, fields, and pond water is also found only in the western part of Bantimurung Subdistrict in Mattoangin Village, Alatengae Village, Minasa Baji Village, and Mangeloreng Village with a total area of 50.64 km² (29.40%). The landuse map of Bantimurung Subdistrict is shown in Figure 7. The area in each landuse is shown in table 5.
Table 5. Landuse Area

| Landuse    | Area (km²) | Percentage (%) |
|------------|------------|----------------|
| Settlement | 3.70       | 2.15           |
| Jungle     | 117.92     | 68.46          |
| Shrubs     | 14.92      | 8.66           |
| Agriculture| 8.96       | 5.20           |
| Moor       | 16.84      | 9.78           |
| Pond Water | 9.91       | 5.75           |

3.6. Distribution of the Karst Geomorphology Unit

The distribution of karstic rocks in Bantimurung Subdistrict is located in the central part that extends from the northwestern tip of Bantimurung Subdistrict located in Baruga Village to the southeastern tip in Kalabbirang Village. The karst rock extends 33.58 km² in size and forms part of the karstic rock formations of Tonasa that stretch from Pangkajeke Kepulauan Regency to Maros Regency [19]. The karst geomorphology unit in Bantimurung Subdistrict is in the form of plain karst, plateau karst, conical karst, and tower karst. The map of the distribution of karst geomorphology units in Bantimurung Subdistrict is shown in Figure 8. While Table 6 shows the area of each of the karst geomorphology units.

Table 6. Karst Geomorphological Unit Area of Bantimurung

| Geomorphological Karst Unit | Area (km²) | Percentage (%) |
|-----------------------------|------------|----------------|
| plain karst                 | 10.17 km²  | 30.29          |
| Plateau Karst               | 15.84 km²  | 47.18          |
| Conical Karst               | 6.07 km²   | 18.08          |
| Tower Karst                 | 1.49 km²   | 4.44           |

The plain karst tends to be spread evenly in the karst area of Bantimurung Subdistrict. The plain karst in Bantimurung sub-district has an area of 10.17 km² or 30.29% of the total karst area. The plain karst is a geomorphological unit on the slopes of 0 - 2%. The plain karst has a flat topography [20].

The distribution of plateau karst in Bantimurung Subdistrict is almost evenly distributed in each region, but it dominates slightly in the eastern part of Bantimurung Subdistrict. Of all geomorphological units, the plateau karst has the highest area value of 15.84 km² or 47.18% of the total karst area. Plateau Karst or conical karst are geomorphological units in the form of hilly highlands. The percentage of the slope is greater than the plain karst, which is in the range of 2 - 7% with a fairly flat topography [20].
The spread of conical karst in Bantimurung Subdistrict tends to be spread evenly, but slightly dominates in the northern part of the karst area of Bantimurung Subdistrict. The conical karst area in Bantimurung Subdistrict is 6.07 km² or 18.08% of the total karst area. The conical karst is a cone-shaped geomorphological unit interspersed with holes and gaps. Conical karst is found in karstic rocks which have slopes between 7 - 25% with relatively steep topography [21].

The tower karst is spread side by side with the conical karst, which is almost evenly distributed throughout the karst region, but slightly dominates in the northern part of the karst area of Bantimurung Subdistrict. The total area of the tower karst in Bantimurung Subdistrict is 1.49 km² or 4.44% of the total karst area. The tower karst is a variation of the karst landscape dominated by steep or vertical limestone towers. The tower karst is found in karstic rocks with slopes of more than 25% with very steep topography. The elevation of the tower karst varies from 70 m to 100 m from the ground surface [12].

3.7. Utilization of the Maros Karst Landscape

Plain karst in Bantimurung Subdistrict tends to be used by the community as an agricultural area in the form of irrigated rice fields and rainfed rice fields. Plain karst were found at sample points located in Mangeloreng Village and Tukamasea Village. Karst layers over 40 million years old are deposited by volcanic sediments at the top, so they can become a fertile land for agriculture [3]. The harvest period of rice fields in Bantimurung Subdistrict varies between 1 to 3 times a year. The local community working in the agricultural sector earns an average of Rp. 1,000,000 - Rp. 3,000,000 in one month.

The plateau karst in Bantimurung Subdistrict is more likely to be used as a tourism sector because the plateau karst has a not so steep slope that is easily accessible by tourists. Plateau karst was found at sample points in Leang-Leang Village and Kalabbirang Village. One of the areas that entered the geomorphological unit of the plateau karst is Bantimurung National Park, which is southeast of Bantimurung Subdistrict. Bantimurung National Park is managed by the local government and functions to increase regional income.

Conical karst in Bantimurung Subdistrict generally has caves, so it can be used in the tourism sector and also as a source of guano fertilizer that can be sold by the local community. Karst Hill is found in Leang-leang Village and Kalabbirang Village. One of them is the Reading Cave located in Leang-Leang Village. The cave is managed by a community of local residents. For one-time entry, visitors are charged Rp. 15,000. The average income earned is around Rp. 1,000,000 up to Rp. 3,000,000 in one month. The cave can also be used as a fertilizer producer, namely fertilizer derived from bat droppings whose habitat is in the cave. The fertilizer is also called guano fertilizer. One of them is a cave in Leang-Leang Village that is used by the surrounding community as a producer of guano fertilizer. Finding guano fertilizer is a side livelihood for the surrounding community. The average yield obtained by the community from selling guano fertilizer is around Rp. 1,000,000 in one month.

The tower karst generally has large amounts of limestone with dolomite content, so it is exploited and utilized by mining companies. One of the limestone quarries was found at the sample point in Baruga Village. The mine is managed by PT. BOSOWA and also PT. TONASA. So far the Bantimurung District Government is still closely monitoring the mining industry. Only certain areas, and not conservation areas, may be used as mines. People who work in the limestone mining sector generally earn Rp. 3,000,000 up to Rp. 6,000,000 per month. Besides contributing to environmental damage, the other side of mining is building the economy of the community.

4. Conclusions

The karst geomorphological units found in Bantimurung Subdistrict are plain karst, plateau karst, conical karst, and tower karst. The area of each geomorphological unit is the 10.17 km² of plain karst, 15.84 km² of plateau karst, 6.07 km² of conical karst, and 1.49 km² of tower karst. Utilization by surrounding communities on the plain karst is in the form of agricultural land, on the plateau karst in the form of tourism services, on conical karst in the form of tourism services and guano fertilizer sources, in tower karsts in the form of limestone mining.

5. Acknowledgement

The research was funded by HIBAH PITTA B with the theme "Disaster Mitigation Study" with contract number NKB-0646 / UN2.R3.1 / HKP.05.00 / 2019.
Reference

[1] Kasri 1999 *Kawasan Karst di Indonesia Potensi dan Pengelolaan Lingkungannya* (Kantor Menteri Negara Lingkungan Hidup, Jakarta, Indonesia).

[2] Badan Perencana Pembangunan Nasional 2003 *Strategi dan Rencana Aksi Keanekaragaman Hayati Indonesia* (LIPI, Bogor, Indonesia).

[3] BLHD Sulsel 2016 *Database Karst Sulawesi Selatan 2016* (Badan Lingkungan Hidup, Sulawesi Selatan, Indonesia).

[4] Prihatmoko S 2017 *Geologi di Pusaran Konflik Karst Berita IAGI Edisi: X/Februari 2017* (Ikatan Ahli Geologi Indonesia, Jakarta, Indonesia)

[5] Sutikno 1997 *Penyuluhan Bencana Alam Gerakan Tanah* (Direktorat Geologi Tata Lingkungan, Bandung, Indonesia).

[6] Haryono E & Sutikno 2000 *Perlindungan Fungsi Kawasan Karst Seminar Perlindungan Penghuni Kawasan Karst Masa Lalu, Masa Kini dan Masa Datan Terhadap Penurunan Fungsi Kualitas Lingkungan*, PSLEMLIT UNS & KMLH, Surakarta, Indonesia.

[7] PERMEN ESDM 2012 No. 17 Tahun 2012 *Tentang Penetapan Kawasan Bentang Alam Karst*, Jakarta, Indonesia.

[8] Qiuhao H & Yunlong C 2017 *Mapping Karst Rock in Southwest China Mountain Research and Development Vol 29 No 1 Feb 2009: 14-2.

[9] Galiiano 2018 *Epikarst Mapping by Remote Sensing* Catena 2018 v.165 pp. 1-11.

[10] BPS 2018 *Kabupaten Maros Dalam Angka 2018* (Badan Pusat Statistik, Maros, Indonesia).

[11] BPS 2017 *Kecamatan Bantimurung Dalam Angka 2017* (Badan Pusat Statistik, Maros, Indonesia).

[12] Van Zuidam A 1979 *Terrain Analysis and Classification Using Aerial Photographs A Geomorphological Approach* (ITC, Netherlands).

[13] Ford D & Williams P 1992 *Kurst Region* (Chapman and Hall : London, UK).

[14] Ford D & Williams P 2007 *Kurst Geomorphology and Hydrology* (John Wiley : Wesst Sussex, UK).

[15] KBBI 2019 *Kamus Besar Bahasa Indonesia* (https://kbbi.web.id/elevasi)

[16] Young, Andrew J, John T 2002 *Human Adaptation to High Terrestrial Altitude Medical Aspects of Harsh Environments* (BordenInstitute : Washington DC, US)

[17] Ruhimat M 2006 *Bentuk Muka Bumi* (Erlangga : Jakarta, Indonesia)

[18] Easterbrook & Don J 1969 *Chapter 7 Origins of Stream Valleys and Drainage Patterns Principles of Geomorphology* McGraw-Hill Book Company pp 148-153 ISBN 0-07-018780-0.

[19] Samodra H 2001 *Nilai Strategis Kawasan Kars Di Indonesia Jurnal Pengelolaan Dan Perlindungan Pusat Penelitian dan Pengembangan Geologi* (Badan Geologi Departemen Energi dan Sumberdaya Mineral, Bandung, Indonesia).

[20] White W 1988 *Geomorphology and Hydrology of Karst Terrains* New (Oxford University Press: New York, US).

[21] Desaunettes R 1977 *Catalogue of Landforms for Indonesia* (Institut Pertanian Bogor, Bogor, Indonesia).