Karst Valley Land Morphology and Its Uses Patterns in Gunungsewu Karst, Indonesia

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Abstract. Gunungsewu karst has hilly and valley landforms. Land on karst topography has many limitations. Agricultural activities carried out by the community are carried out on lands that have many limitations. Therefore, intensive efforts are needed to help increase land productivity, especially on karst valley land in the dry season. This study aims to identify the morphological characteristics of karst valley land and its land use patterns. The method used in this study is using remote sensing, GIS and field surveys. The analysis was conducted using visual and digital interpretation techniques on Landsat 9 OLI satellite imagery and tabular and graphic analysis on respondent interview data. The results showed that the Gunungsewu karst area has two types of open karst valley land, namely single karst valley land types and interconnected. There are different karst valley land type distribution characteristics between the north and south sides of the Gunungsewu karst. Agricultural activities are carried out mainly in the rainy season with the main crop being polowijo. There is a period of empty uncultivated land because there is no source of irrigation water and the soil becomes hard in the dry season making it difficult to cultivate traditionally for agriculture.

Keywords: Water Holding Capacity, Gunungsewu karst, soil.

1 Introduction

Gunungsewu Karst has a topography in the form of hills and valleys that are interconnected with other karst features [1,2]. The valleys and slopes of karst hills are the main land used in agricultural business for people in the Gunungsewu karst area. However, the land in the Gunungsewu karst area has many limitations, especially related to water sources for irrigation. The bedrock of Gunungsewu karst forms a lot of stout as a water entrance to the karst underground river system. Not all hills or karst valleys can be accessed easily. Refference [3] stated that this region has the highest geographical difficulty index (IKG) in DIY. However, people use the land at the bottom of the valley and hillsides as much as possible for their agricultural business to meet their daily needs [4,5,6]. Land in the Gunungsewu karst valley is currently more often used as agricultural land than land on the slopes of karst hills.

A. Mustofa et al. (eds.), *Proceedings of the International Joint Conference on Arts and Humanities 2023 (IJCAH 2023)*, Advances in Social Science, Education and Humanities Research 785,
https://doi.org/10.2991/978-2-38476-152-4_168

Crops cultivated on this land are generally crops such as beans, corn, and cassava [7]. Land use for agriculture is carried out especially during the rainy season. This condition is caused because there is no sufficient water source for watering plants during the dry season. This is in line with [8] and [9] who concluded that agricultural activities in the Gunungsewu karst area are very dependent on rainwater. Entering the dry season, all agricultural activities will stop, especially on land above the slopes of karst hills [10]. Water for watering plants is difficult to get. Drought also causes karst soil to be very hard because it contains a lot of clay. This condition results in unproductive land, and residents have no source of income from their agriculture.

Rainwater is the main source of irrigation for lands in the Gunungsewu karst area. The annual rainfall thickness reaches more than 1500 mm per year [7, 11, 12]. Rainfall data shows rain occurs from November to May with the highest intensity in December – January - February [13, 14, 15]. The characteristics of karst soils in general have a high clay content [16,17]. This condition makes karst soil able to absorb rainwater because of the high water holding capacity of clay (Vengadaramana et al, 2012). Water absorption can then be utilized by plants to grow. Based on these conditions, agricultural activities can be carried out after high intensity rain. However, the soil layer, especially on the slopes of karst hills, is not thick and there are many ponors at the bottom of karst valleys. This condition results in most of the water entering the karst underground water system [12,19].

Efforts to increase the productivity of karst valley land need to be done to help people in the Gunungsewu karst area in an effort to meet food needs, especially during the dry season. In this regard, the distribution of karst valley land with open land without vegetation needs to be known with certainty. This information can be used as a basis for priority assessment of the location of integrated irrigation system development. In addition, information about planting patterns applied by residents is needed as a basis for planning the distribution of water sources.

In line with efforts to increase land productivity in the Gunungsewu karst valley for dry season agriculture, it is very necessary to identify the distribution of open and dry karst valley land during the dry season. Identification is intended to determine the distribution, extent, and current pattern of use by the population. Information related to the distribution and area of the open Gunungsewu karst valley can be identified through satellite image data and processed using a geographic information system. Information related to land use patterns can be obtained through in-depth discussions with land-cultivating farmers in the Gunungsewu karst area. In accordance with this, this research was carried out in the Gunungsewu karst area. The purpose of this study was to determine the distribution of Gunungsewu karst valley land during the dry season, and the pattern of its use for agriculture.

2 Method

2.1 Population

The population in this study is the spectral value of Landsat 9 OLI satellite images and land-cultivating farmers in the Gunungsewu karst valley. The first population was

intended to determine the distribution of open karst valley land locations. The second population is intended to determine land use patterns in the Gunungsewu karst valley. Samples from the first population were conducted through digital and visual analysis of Landsat 9 OLI imagery. Samples from the second population were taken using the snowball sampling technique on land-cultivating farmers encountered on a predetermined sampling route. Data was taken through a questionnaire-guided question and answer method.

2.2 Analysis

Initial field observations were made to obtain samples of coordinate points from the Gunungsewu karst valley which were open and there was no vegetation. The initial field observation point is guided by the results of the initial image interpretation based on the 5-4-3 multispectral image. The image was cut based on the boundary of the Gunungsewu karst area. Based on the sample of field coordinates, an interpretation was carried out on the spectral value of image pixels from each Landsat 9 OLI image band. The spectral value of the Landsat 9 OLI image is the spectral of the image that the TOA process has performed. Spectral values that are attached to the coordinate points of the field and its surroundings, are identified and tabulated. The selection of pixels taken as samples is also aided through the interpretation of Landsat 9 OLI multispectral 5-4-3 imagery to facilitate the distinction of open and closed areas by vegetation. Simple statistical analysis is performed to determine the minimum and maximum values of the spectral set. This analysis aims to determine the maximum and minimum threshold values of each band related to the location of open karst valley land in the field. Classification is carried out on each image channel based on the maximum and minimum threshold values. Imagery is classified into two classes, namely (1) open karst valley land, and (2) vegetation-covered karst hills. Classification is done using the Raster Calculator procedure in QGIS. Classification is carried out using the following formulation:

$$\text{If (criteria, results match criteria, results do not match criteria)} \quad (1)$$

Raster classified images are converted into shapefile format. The area of a polygon is calculated using the $area function in the "field calculator" procedure in QGIS. The result of this process is to generate extensive data of each polygon in the shapefile. Polygon area data was used for karst valley land area analysis in each sub-district in the study area. Extensive data is also used in the eliminate process. The eliminate process is carried out to combine polygons that have an area below the minimum polygon area threshold. Shapefiles are performed visual analysis to identify polygons that are considered insignificant and need to be eliminated. The results of the analysis produce a threshold value to select the shapefile. Polygon selection is carried out on polygons that have an area less than the threshold value. The eliminate process is then carried out on all selected features to be combined with the polygon that has the longest boundary line. The result of this process is a map of the distribution of Gunungsewu karst valleys and hills. The distribution of the location points of open karst valley land samples is shown in Fig. 1.

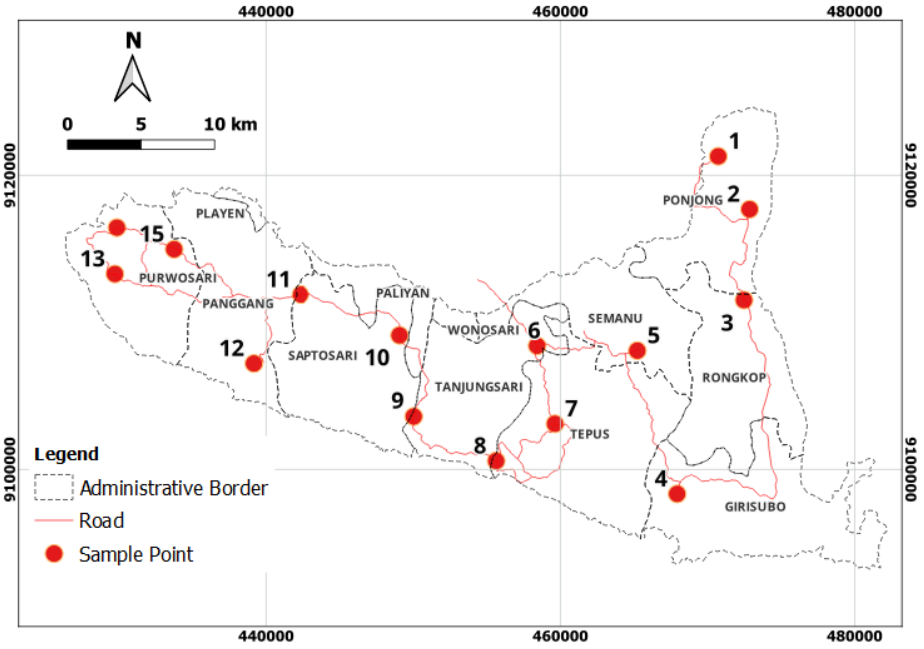

Fig. 1. Open karst valley land sample site

Complies with Fig 1. This study took as many as fifteen sample locations spread throughout the western, central and eastern Gunungsewu karst areas. The location of the sample is expected to provide spectral image classification values for Gunungsewu karst land cover with high accuracy. The coordinates of each sample point are verified after a field survey, so that each sample point is completely located on empty karst valley land.

Data from questionnaires are processed by tabulation, percentage and graph methods. Descriptive and exploratory analysis is applied to data that has been carried out tabular, percentage and graph analysis. Descriptive and exploratory analysis is directed to answer related to land conditions, planting patterns on the land, and opinions of sharecroppers on crop irrigation technology. The results of the analysis are described in the form of descriptions and graphs.

3 Result and Discusion

3.1 Results

The results of the analysis showed the distribution of Gunungsewu karst valleys and hills. Based on the analysis of karst valley karst valley land polygons, it is known that there are two types of Gunungsewu karst valley polygons. The first type is a single open karst valley land that is separate and not related to another open karst valley polygon. This open karst valley land area is a basin surrounded by karst hills with no

plants and dry land on the valley floor. The difference in elevation from the base to the top of the surrounding karst hill varies. The landforms of these karst valleys vary from rounded to irregular. The second type is open karst valley land which is interconnected with adjacent open karst valley land. This land is irregularly shaped and extensive. Areas of the second type form many areas of local plains and some parts are built-up land and roads. Based on the results of image analysis, it is known that the distribution of interconnected karst valley land polygons is widely found on the north side of karst Gunungsewu areas, especially in Paliyan, Wonosari and Semanu Districts. The morphology of this area is partly in the form of relatively flat land that is large and partly in the form of basins between interconnected hills. The land in this area is dry agricultural land. Plants that are widely cultivated are crops such as corn, crabs, and beans. In times of long drought it often turns into wasteland without vegetation. The distribution of karst valleys and hills can be seen in Fig 2.

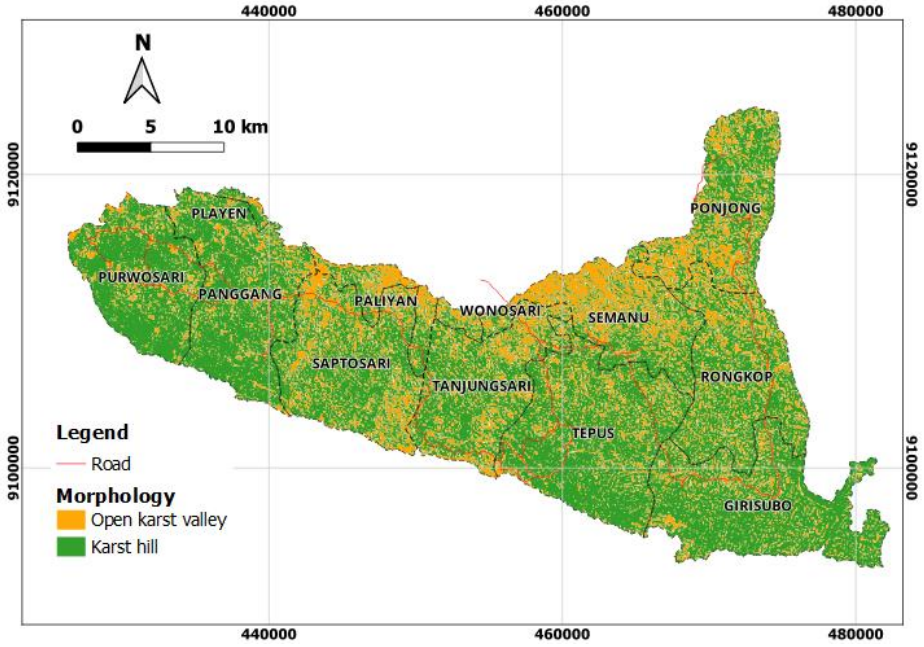

Fig. 2. Distribution of open karst valleys and Gunungsewu karst hills

Spatial analysis based on administrative boundaries is known the number of polygons, area, and average area of polygons per subdistrict. The area of Gunungsewu karst area is known to be 75,043.06 ha consisting of an open karst valley land area of 22,692.28 ha or 30.24% and a karst hilly area of 52,350.78 ha or 69.76%. The figure shows that the area with karst hill morphology is wider than the open karst valley land area. The land area is spread across twelve districts in the Gunungsewu karst area. In that area, Semanu is a sub-district that has the largest open karst valley land of 3,265.18 hectares. The average area of each karst valley polygon is 4.42 hectares. The distribution of land

is mostly on the north side bordering the Wonosari ledok. The order of the districts with the largest karst valley land can be clearly seen in Fig 3 below.

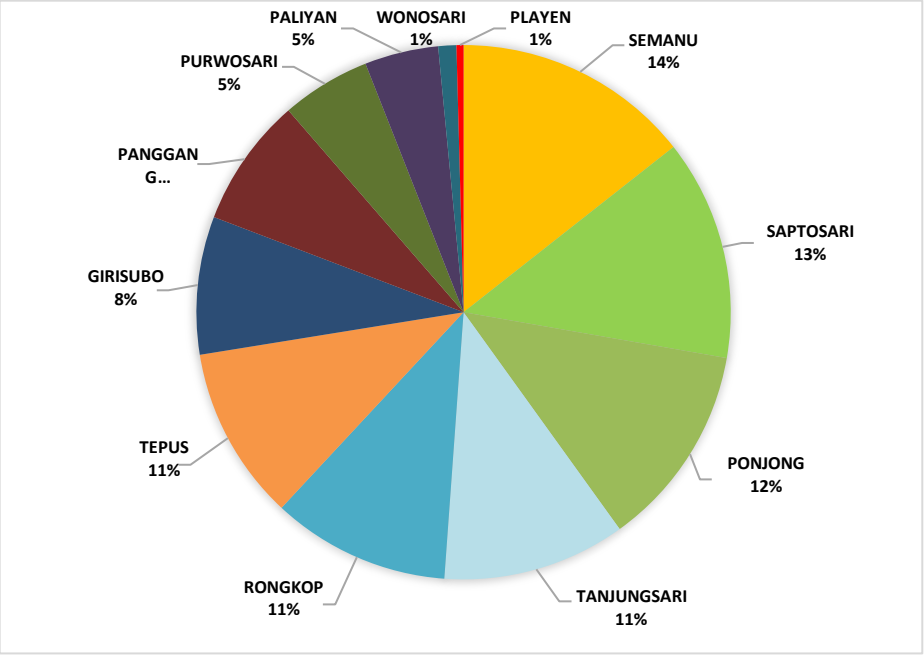

Fig. 3. Percentage of open karst valley land area per sub-district in Gunungsewu

Based on the results of polygon calculations on the map, it is known that the land area of the karst valley of each sub-district is not in harmony with the number of karst valley polygons in each sub-district. The calculation results show that the sub-district which is geographically located on the south side and borders the sea has a large number of open karst valley land polygons. In order of districts that have the highest number of karst valley land polygons are Tepus District 2452 polygons, Girisubo 2070 polygons, Panggang 1905 polygons, Saptosari 1832 polygons, Rongkop 1616 polygons, Tanjungsari 1347 polygons, Purwosari 1269 polygons, Ponjong 1004 polygons, Semanu 738 polygons, Paliyan 307 polygons, Wonosari 109 polygons, and Playen as many as 57 polygons.

Variations in karst valley land characteristics are also found in the average area of open karst valley land polygons in each sub-district. The average polygon area of open karst land in the Gunungsewu karst area ranges from 0.91 ha to 4.41 ha. The average polygon area of the largest open karst land is in the Semanu sub-district, which is 4.42 ha. While the average polygon area of the narrowest open karst valley land is spread in the Girisubo District area. The average distribution of the polygon area shows that the open karst valley land with a large average area is spread on the north side of the Gunungsewu karst area, and will be smaller towards the south side of the Gunungsewu karst area. The average area of Gunungsewu karst valley land polygons in each sub-

district is as follows: Semanu 4.42 ha, Paliyan 3.3 ha, Ponjong 2.79 ha, Wonosari 2.28 ha, Tanjungsari 1.87 ha, Playen 1.70 ha, Saptosari 1.65 ha, Rongkop 1.51 ha, Tepus 0.97 ha, Purwosari 0.96 ha, Panggang 0.93 ha, and Girisubo 0.91 ha. The data shows that there are some areas that have karst valley characteristics that are less than one hectare on average. This area of land is spread across Tepus, Purwosari, Panggang, and Girisubo Districts. The four sub-districts have areas bordering the sea on the south side. The extent indicates that this type of land is singular and not connected to land in other basins around it.

The calculation of the correlation between the number of polygons of open karst valley land and the average area of each polygon yielded a correlation of -0.614. This negative correlation value indicates that areas that have more open karst valley land polygons, tend to have many karst valleys with small areas. However, this does not mean that in areas where karst valley land is generally open to such a large place, there is no valley basin with a narrow area. Open karst valley land polygons are scattered randomly throughout the Gunungsewu karst area with different percentages between these regions. Digital and visual analysis of the map shows that there is a large open karst valley land on the south side and bordering the sea. This land polygon is spread in Saptosari and Tanjungsari sub-districts. Field observations show that this basin is in the form of empty agricultural land that is quite large and some in the form of built-up land areas and clustered settlements. The land is located in a relatively elongated inter-hill basin with a terraced elevation. The slopes of karst hills on the upper side of the land have a vegetation cover of shrubs to woody trees with varying densities. The slope has a moderate to steep slope that forms an escarpment. Escarpment is mostly found on the polygonal side of karst valley land which has an elongated pattern. This is possible due to the collapse of the place. This condition is mostly found in the southern region of the Gunungsewu karst.

Karst valley land by residents is used as agricultural land and other uses such as settlements. Land use for agriculture is carried out when there is water that can be used for watering plants. The results of the questionnaire showed that there were some karst valley lands that were inundated when there was rain. The waterlogged land will dry during the long dry season. The soil on karst valley land will remain wet between one and three days after rain. This condition will change during the dry season. 90% of respondents stated that during the dry season the soil will become hard to very hard to cultivate. This condition often results in the soil becoming difficult to be used as agricultural land traditionally.

Based on the results of the analysis of respondents' answers, it is known that several planting patterns carried out on karst valley land, namely rice-polowijo-polowijo, polowijo-polowijo-polowijo, and polowijo-polowijo-empty are not planted. The main types of crops cultivated are polowijo types, namely beans, corn, and cassava. Rice is cultivated in several areas of wetland and submerged in water. The method of planting carried out on one plot of land varies. The first method is done with similar plants and will change with other types of plants when it has been harvested. The second method is mixed or intercropped planting. In many locations karst valley land that has empty time is not planted because the soil becomes hard in the dry season. In addition, there is no source of water that can be used to irrigate plants. Respondents revealed that karst

valley land in vacant conditions without crops ranged from less than one month to four months. Short empty time is found in karst valley lands where there is standing water at the bottom. Water at the bottom of the basin can be used as a source of irrigation as long as the water has not dried. There are several methods of watering water carried out by farmers. The respondents' answers indicate the method of watering is carried out manually with lead or using a pump. Some respondents gave the answer that the plant is not watered. This condition occurs in karst valley land where there is no water source. Existing plants are corn and cassava.

3.2 Discussion

The results of image analysis and field observations show that Gunungsewu karst has two types of open karst valley land, namely single karst valley land and karst valley land that are interconnected with adjacent karst valleys. The findings of this study are in line with [11] which states that there is a morphology of polygonal and labyrinth type karst. The morphology of the polygonal type karst forms a single basin surrounded by karst hills, while the labyrinth-shaped type of valley extends parallel to the row of karst hills extending in a certain direction. This finding also supports the opinion [15] which explains the relationship between karst features in one place and another. This condition can form karst features that are interconnected between one place and another so as to form karst feature characteristics with elongated patterns. Many interconnected and extensive open karst valley lands are found on the north side of the Gunungsewu karst, especially in the Paliyan, Wonosari and Semanu sub-districts. Meanwhile, there are more single karst valley lands on the south and west sides of the Gunungsewu karst. This condition shows that there are differences in karst morphological characteristics in this region. Areas with wide-open karst valley land are related to land morphology in the form of elongated valleys or large relatively flat land between karst hills. In areas that have a lot of land, single karst valleys tend to have a narrow average polygon land area. This is very possible with the characteristics of the carstification process that occurs at the site. Refference [2] explained that the linkage of surface karst features can result from the carstification process that occurs in bedrock. The composition of karst bedrock and geological processes that have occurred will also have an influence on the morphology outside the karst region.

Land in karst valleys is used as agricultural land. This corroborates the conclusions of [4,5,6]. The type of plant chosen by farmers is the polowijo type plant. This condition is in line with the statement [8,9] which states that land in the Gunungsewu karst has dependence on rain as the main water. Agricultural activities on karst valley land rely heavily on rainwater, so the majority of agricultural activities on this land are carried out during the rainy season. In the dry season, water accumulates on the karst underground river network. There is not much water on the surface. Access to get water from underground requires a large cost and it is not easy to find access to the underground river system. This is the cause of underground river water has not been much sought as an alternative to irrigating plants in karst valley land.

Not every karst valley forms a lake. This is related to the presence of many fractures in karst bedrock as an entrance for the water to enter the underground river system [12,

19]. In karst valleys that have lakes, most will dry out in just a few months after infrequent rainfall. This is due to evaporation water that occurs in the lake water body, as well as intensive use for irrigation of agricultural crops on the land around the lake. Plant watering activities manually or using a pump will accelerate the reduction of the amount of water in the karst lake. When the lake water runs out, the karst valley land no longer has a source of water that can be used for irrigation. The land will turn into dry land with limited agricultural activities. In conditions like this, the types of plants planted are usually corn and cassava.

The condition of the land becomes empty without planting when there is no rain for a long time. This is in line with [10] which states that karst land agricultural activities often stop entering the dry season. The soil texture becomes hard as the soil condition becomes dry. This condition is very difficult to be processed traditionally for agricultural activities. This is in line with [16,17], who explained that karst soil contains a lot of clay so that it has large wrinkle properties. Soils that contain a lot of clay will become hard when dry.

4 Conclusion

There are two types of Gunungsewu karst valley land, namely single open karst valley land type and interconnected karst valley land. Single karst valley land is widely spread on the south and west sides of the Gunungsewu karst, while many interconnected open karst valleys are found on the north side of the central part of the Gunungsewu karst. The average land area of open karst valleys ranges from 0.91 ha to 4.42 ha. Open karst valley land with the highest average area is spread in Semanu District, while karst valley land with the lowest average area is spread in Girisubo District. Agricultural activities on karst valley land depend on rain as the main source of water. The main crop planted on the land is polowijo which is mostly planted in the rainy season. Many fields become open vacant land during the dry season because there is no water source for irrigation and hard soil makes it difficult to cultivate traditionally.

Acknowledgment
This research is funded by Unesa's Non-APBN funds in 2023 through the Unesa Rector's Decree Number 1118/UN38/HK/PP/2023.

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