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Classification of Slope for Coffee Plantation in Ngajum District, Indonesia

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***Abstract*—**Slope classification activity aims to provide information to coffee farmers about the slope, especially in Ngajum District, Malang Regency. Ngajum is one of the sub-districts located on the slopes of Mount Kawi. The people of Ngajum generally work as cattle and goat breeders as well as coffee plantations. Information on the slope (altitude) affects the classification of the quality of the coffee produced. In addition, the varieties of coffee planted also depend on the slope of the mountain slopes. Making a slope map utilizes satellite imagery which has altitude information, namely in the form of Digital Elevation Model (DEM) satellite imagery. Administrative boundary data are used according to the sub-district so that the slope classification can be focused. The method used in this activity is the analysis of spatial data from the results of slope classification. Slope class is divided into 7 (seven) slope classes, i.e. flat, wavy, wavy-bumpy, bumpy-hilly, hilly-mountainous, steep mountain, and mountainous. The results of slope classification show that 2377.171 Ha or 35.971% of the Ngajum area is undulating class. The slope of the wavy slope is a suitable class for coffee cultivation but must be accompanied by the suitability of other parameters so that the productivity of coffee plants increases. The drawback of the results of this activity is that it has not been able to determine which varieties of coffee plants are suitable for planting with the slope of the area, so further research is needed.

***Keywords*—** Coffee Plantation, DEM, Land Suitability Satellite Imagery, Slope.

I. INTRODUCTION

The coffee plant was first introduced by the VOC in the period 1696-1699. Coffee entered through Batavia which was brought by the Commander of the Dutch Troops Adrian Van Ommen from Malabar – India. The type introduced is Arabica coffee. Initially, the planting was only for research purposes, but because the results were quite profitable as a trading commodity, the VOC began to spread coffee seeds to various regions in Indonesia. Indonesian coffee exports were first carried out in 1711 by the VOC and within 10 years it increased to 60 tons/year. In 1878, the development of Arabica coffee experienced a lot of Hemelia Vastatrix (HV) disease which attacked coffee leaves, so the VOC brought Robusta coffee to Indonesia in 1900. Indonesia is the fourth largest coffee producing country in the world after Colombia, Brazil and Vietnam (Dermawan, Mega, & Kusmiyarti, 2018). Coffee productivity was affected by altitude, shade and Total management Intensities Index (TMI) (Anhar, et al., 2021)

The suitability of the optimal use of agricultural land affects the commodity characteristics of plants in a region. Altitude, air temperature, and rainfall are according to the characteristics for the growth and production of coffee plants, the conditions are adjusted to the type of coffee to be planted. Physical aspects that affect the growth of coffee plants include the slope of the slope.

The altitude for Robusta coffee ranges from 100 – 600 meters above sea level, Arabica ranges from 1,000 – 2,000 meters above sea level, and Liberika varies from 0 – 900 meters above sea level. – 24°C; 15° – 25°C and 21° – 30°C. The rainfall required for Robusta and Arabica coffees is the same, ranging from 1,250 – 2,500 mm/year, while for Liberika coffee the value is higher, ranging from 1,250 – 3,500 mm/year. The dry month with rainfall less than 60 mm/month for Robusta and Liberika coffee is the same, which is around 3 months/year, while for Arabica coffee it ranges from 1-3 months/year (Kementrian Pertanian, 2014). Meanwhile, Robusta coffee is grown at altitudes ranging from 400-800 meters above sea level with an acidity level (pH) of around 5 - 6.5 and an average temperature ranging from 21°C - 24°C (Dermawan, Mega, & Kusmiyarti, 2018).

Coffee is one of the new commodities developed in Malang Regency. The majority of residents in Ngajum District have gardening, farming and animal husbandry livelihoods. Cultivated plantation crops include coffee and cloves. The types of coffee developed include Robusta and Arabica. Lack of information about coffee farmers regarding the slope of the slope has the potential for wrong planting of coffee varieties, so that the quality of the coffee plants produced is not optimal. From this background, it is necessary to have a slope map prepared based on the condition of the Ngajum area.

Slope information is generated using remote sensing methods. Remote sensing methods utilize satellite imagery without direct contact with objects. The satellite images used in data processing are DEM (Digital Elevation Model) satellite images, namely DEMNAS (Digital Elevation Model Nasional). DEMNAS is one of the data products from the Badan Informasi Geospasial (BIG).

DEM is a fundamental depiction of the shape of the earth's surface in three dimensions. Ideally, DEM records the surface between the atmosphere and the lithosphere using a discrete two-dimensional grid, with complexity derived from the fusion of the hydrosphere, cryosphere, bosphere and anthroposphere. DEM processing depends on the purpose and characteristics of the recording sensor used. DEM is a general term used, specifically DSM and DTM. In general, DEM is produced by recordings using a near infrared light wave sensor and SAR (Synthetic Aperture Radar) (Guth, et al., 2021). DEM data can be obtained from remote sensing methods using satellite sensors or photo camera sensors. Data scanned using a satellite sensor is called a satellite image, while data scanned using a photo camera sensor is called a photo image. DEMNAS is one of the results of a scan using a satellite sensor.

DEM data can be used for several purposes, including water resource management, disaster management, geological applications, infrastructure, agricultural applications, 3D visualization, ecological modeling, commercial forests, and mapping. In this activity the DEM is utilized for Slope Mapping. The creation of a Slope Map is combined with the knowledge of Geographic Information Systems (GIS) where each layer represents the required information, for example the point layer contains information on the height of a place. Geographic Information System (GIS) is designed for data that has spatial references (data that have coordinates). Spatial data is referenced to a datum/reference (eg WGS 84 datum). In this activity, the GIS method is used for DEM data processing which is focused on the slope.

II. LITERATURE REVIEW

A. *Effect of slope for coffee plantation*

Slope is a factor that plays a role in the formation and development of soil through erosion, transportation, and deposition. The degree of slope determines the flow rate and volume of surface water, while the position of the slope determines the rate of erosion. The position of the slope of the slope affects the thickness of the top soil layer (top soil), but does not affect soil texture, soil bulk density, soil pH, soil C-organic content and soil CEC (Arifin, Putri, Sandrawati, & Harryanto, 2018).

One factor that has not been explored is the influence of environmental conditions, such as cultivation land slopes (Abubakar, Hasni, Widayat, Muzaifa, & Rinaldi, 2023). Influence of slope and land use also affects the physical properties of the soil. This can occur due to differences in vegetation characteristics, canopy density and thickness of the canopy cover in an area. The physical properties of soil in forests are better than plantations which have lower levels of organic matter, higher bulk density, lower percentage of clay, higher percentage of dust, making it easier for soil erosion to occur (Sinaga, Amelia, & Batubara, 2020).

The variations in slope gradients influenced the coffee soil fertility. Some of variable Organic Matter (OM), clay, Cation Exchange Capacity (CEC), P, Magnesium (Mg), and Na generally showed decreasing trend with increasing slope gradient, whereas sands was opposite (Kedir, 2021). Slopes are classified into 7 (seven classes) of morphology as listed in Table 1. In Indonesia, there are 3 (three) types of coffee, namely Robusta, Arabica and Liberika. Robusta coffee plants are suitable for planting at an altitude of 300-900 meters above sea level, while Arabica coffee plants are suitable for planting at an altitude of 1,000 meters above sea level (Rahayu, 2019).

Table 1. Slope Classes

No	Relief	Slope (%)	Morphology (◦)
1	Flat or almost flat	0 – 2	0 – 2
2	Wavy	2 – 7	2 – 4
3	Wavy-Bumpy	7 – 15	4 – 8
4	Bumpy-Hilly	15 – 30	8 – 16
5	Hilly-Mountainous	30 – 70	16 – 35
6	Steep Mountain	70 – 140	35 – 55
7	Mountainous	>140	>55

(Van Zuidam, 1985; (Alfarabi, Supriatna, Manessa, Rustanto, & Yoanna, 2019)

In order to increase coffee production in Indonesia, land suitability based on the type of use must be considered. The suitability of the land for coffee plants is divided into 4 (four) classes as shown in Table 2. The combination of information tables 2 and 3 can determine the suitability of coffee varieties based on slope parameters.

Table 2. Land Suitability Class based on slope and altitude

SPL	Slope class (%)	LS of slope for Arabica & Robusta	Altitude ASL(m)	LS of Altitude	
				Robusta	Arabica
1	<8	S1	0-100	S3	N
2	>40	N	300-400	S1	N
3	26-30	S3	100-200	S2	N
4	8-15	S2	0-100	S3	N
5	<8	S1	100-200	S2	N
6	8-15	S2	0-100	S3	N
7	<8	S1	300-400	S1	N
8	8-15	S2	500-600	S2	N
9	<8	S1	0-100	S3	N
10	8-15	S2	100-200	S2	N
11	8-15	S2	100-200	S2	N
12	<8	S1	300-400	S1	N
13	8-15	S2	300-400	S1	N

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SPL	Slope class (%)	LS of slope for Arabica & Robusta	Altitude ASL(m)	LS of Altitude	
				Robusta	Arabica
14	<8	S1	0-100	S3	N
15	8-15	S2	100-200	S2	N
16	<8	S1	100-200	S2	N
17	<8	S1	0-100	S3	N
18	8-15	S2	100-200	S2	N

(Fachruddin, Fadhil, Syafriandi, & Dahlan, 2021)

S1 (very suitable), is land with a classification that does not require land management because it does not affect land productivity. S2 (suitable), land in the criteria for this class requires a level of land management. In this class the parameter factors reduce productivity so that the profit level decreases. S3 (according to marginal), land with this class classification must be applied to the level of management. N (not suitable), is a type of land class that cannot be used for coffee plant production. Slope parameters can be used to determine of land erosion with mountainous class levels (Azsari, Mulyani, & Iswahyudi, 2022).

B. Digital Elevation Model Nasional (DEMNAS)

DEMNAS was built from several data sources, namely IFSAR data with a resolution of 5 m, TERRASAR-X with a resolution of 5 m, and ALOS PALSAR with a resolution of 11.25 m added with stereo-plotting mass point data (Sulistiana, Parapat, & Aristomo, 2019). Figure 1. shows spatial resolution of DEMNAS is 0.27-arcsecond or approximately 8.33 m (Badan Informasi Geospasial, n.d.).

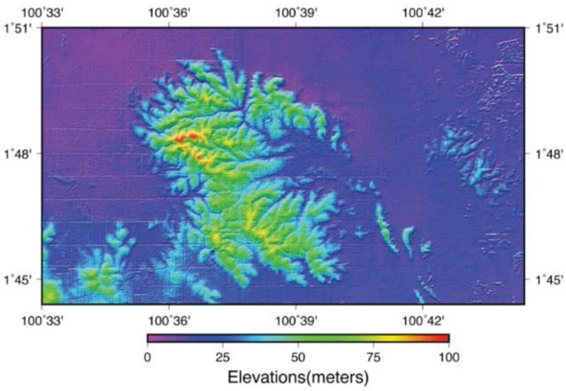

Figure. 1. DEMNAS (Badan Informasi Geospasial, n.d.)

DEMNAS imagery was used for alley cropping planting pattern design on cultivated area, result showed that land slope reached 20.92% in average (Santoso, Tsani, Surnayanti, & Riniarti, 2021).

III. Research Methods

The case study is located in Ngajum District, Malang Regency, shown in Figure 2. Ngajum is one of the sub-districts located in Malang Regency, precisely on the slopes of Mount Kawi. Ngajum consists of 9 sub-districts. Ngajum District has an area of 6,609 Ha which is dominated by forests.

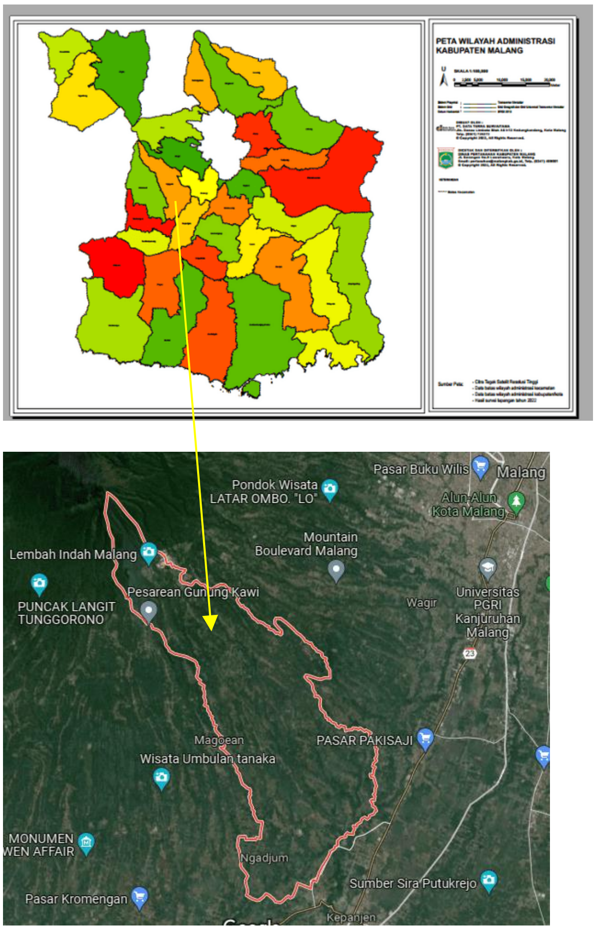

Figure. 2. Case study (Kecamatan Ngajum, 2022)

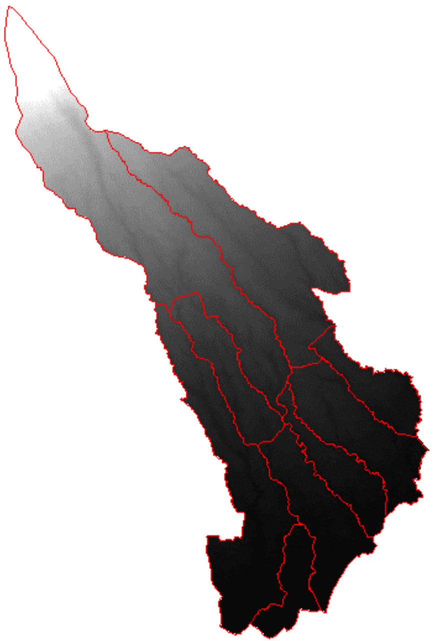

Figure. 3. DEMNAS Ngajum

DEMNAS image was obtained from the website page https://tanahair.indonesia.go.id. The image is downloaded according to the area of Ngajum District, Malang Regency. There are 2 DEM image scenes used in that area. Mosaic process was carried out to combine image scenes and cut the sub-district administrative boundaries based on the 1:25,000 scale Indonesian Topographical Map so that the area covered was processed according to the case study used. The results of mosaic processing and cutting of the DEMNAS image area according to the case study are shown in Figure 3.The next processing stage is the resampling process to adjust the map scale to be used. DEMNAS has a spatial resolution of 8,343 meters with a maximum map scale that can be produced is 1:17,000. So, scale adjustment was made to 1:25,000. After the resampling process is complete, then slope classification process is carried out.

IV. Results and Discussion

As visually there is no difference in DEMNAS which has been resampled. However, if the DEMNAS pixel measurement process is carried out, then the results of the resampling process will be seen through the pixel size. Figure 4 shows spatial resolution before the resampling process is 7.5° or 8.343 meters, while after the DEMNAS resampling process it has a spatial resolution of 12.5 meters and is shown in Figure 5.

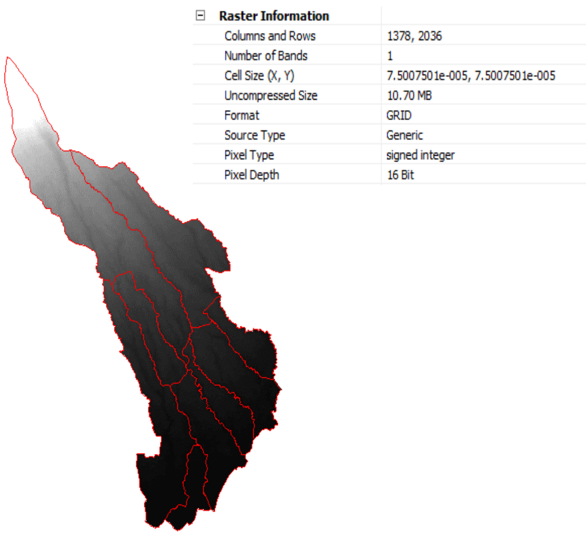

Figure. 4. DEMNAS before resample process

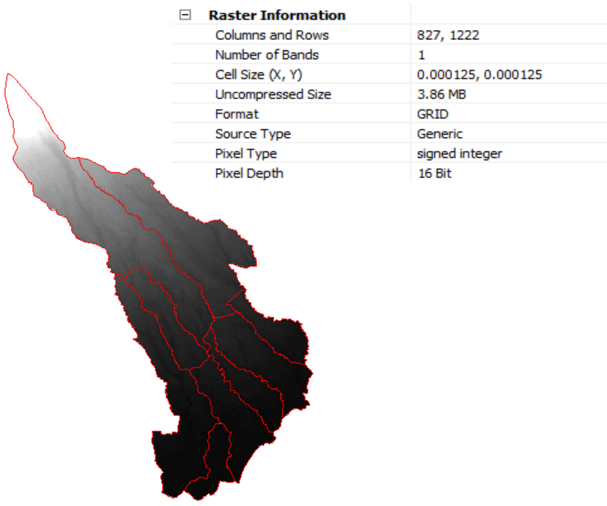

Figure. 5. DEMNAS after resample process

Figure 6. is the result of a visualization of the slope classification based on the 7 (seven) slope classification classes listed in Table 1. It can be seen visually that Ngajum District is dominated by Bumpy-Hilly classes.

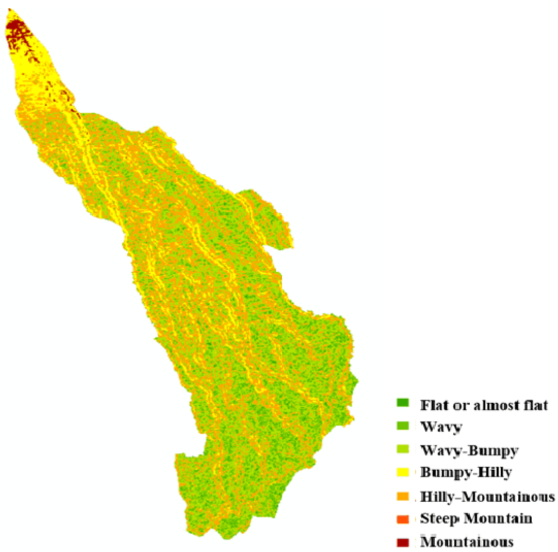

Figure. 6. Slopes Classification of Ngajum

Table 3. is a broad breakdown of each slope class. Ngajum area of Malang Regency is dominated by the wavy-bumpy class with a percentage of 35.9715%. It is shown by Figure 7.

Table 3. Ngajum Slope Classes

No	Relief	Slope (%)	Area (Ha)
1	Flat or almost flat	0 – 2	151,835
2	Wavy	2 – 7	879,976
3	Wavy-Bumpy	7 – 15	2.377,171
4	Bumpy-Hilly	15 – 30	2.271,141
5	Hilly-Mountainous	30 – 70	872,081
6	Steep Mountain	70 – 140	56,271
7	Mountainous	>140	0,013

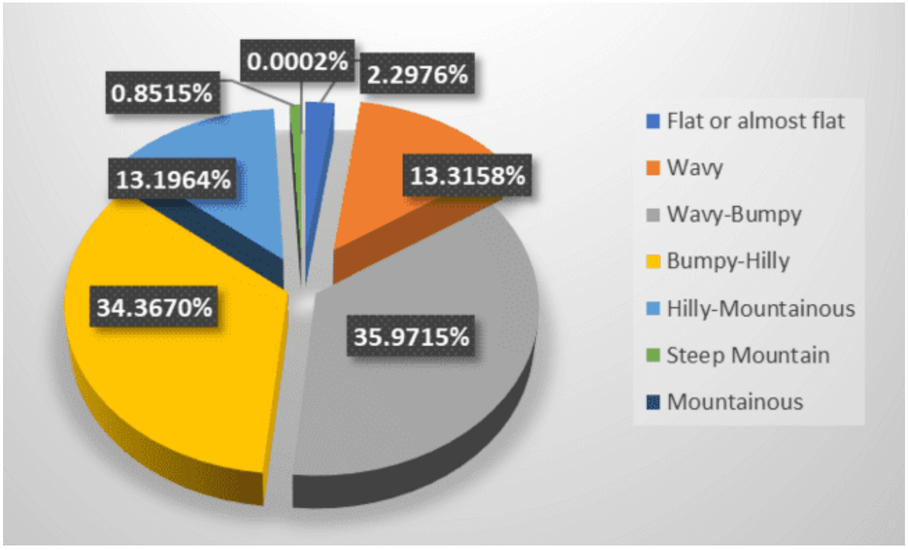

Figure. 7. Percentages of Ngajum Slope

Based on the suitability of coffee land with the slope parameter in Table 2, most of the Ngajum is included in the class suitable for coffee farming. To find out the potential suitability of land in Ngajum for coffee farming, a classification calculation must be carried out according to the parameters of Table 3. so that land management and coffee plant productivity are maximized.

The result of the slope classification based on the sub-district Ngajum contained in Figure 8. From It can be seen that Balesari is an area that has mountainous slopes. Balesari is a village area in the Ngajum which is closest to Mount Kawi.

Figure. 8. Slopes Classification of Sub-district Ngajum

V. CONCLUSION

Most of the Ngajum District area is suitable for coffee farming when viewed from the results of the classification of the slope with wavy characteristics with a slope class of 7-15% of 2,377.171 Ha. The types of coffee that are suitable for planting on the slopes are Robusta and Arabica. However, for more optimal crop yields, it is necessary to calculate land suitability. the current study has limitations that need to be addressed in future research. The slope classification alone does not provide comprehensive information about the optimal coffee varieties for specific slope conditions. Other factors such as soil type, nutrient content, microclimate, and land management practices also play crucial roles in determining the best coffee varieties for different slopes. Integrating these factors into the slope classification framework can offer a more holistic understanding of land suitability for coffee cultivation.

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