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Mapping of coffee land zoning based on sensory attributes of wine coffee

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ABSTRACT

The primary aimed of this study is to carry out land zoning of Arabica coffee area based on the characteristics of organoleptic sensory attributes with the optimal taste of coffee wine at different levels of altitudes. The study was conducted on the hillsides of Mount Bawakaraeng Lompobattang, South Sulawesi Province which has Arabica coffee plants at different altitudes, namely, 1000-1200 m.asl (A), 1200-1400 m.asl (B), 1400-1600 m.asl (C), and 1600-1800 m.asl (D). Quality tests of coffee beans and organoleptic sensory attribute taste tests were carried out including fragrance or aroma, flavor, aftertaste, acidity, body, uniformity, balance, clean cup, sweetness, overall, and taint or defect. The results of the study showed that the coffee beans were classified as quality 1 with large bean size; while the characteristics of uniformity, clean cup, and sweetness are the basic or essential characteristics of the coffee beans tested in this study because they showed the highest score of 10 and this score is consistent for all levels of altitudes. The results of compiling organoleptic sensory attribute data and satellite imagery analysis were used for mapping potential coffee fields with Specialty Grade, covering area of 20,025.54 ha or equal to 2.00% of the research area of 1,011,693 ha. In addition, coffee land zones can also be mapped with the level of coffee wine taste based on the distribution pattern of dominant organoleptic sensory attributes at different altitude. The order of the optimal level of coffee wine taste can be written as the land zoning, as follows: D > B > C > A. The land zoning D covers an area of 3,351.60 ha; B 5,738.53 ha; C 4,381.27 ha; and A 3,552.10 ha. Overall, it can be concluded that the taste of wine coffee tends to be better or optimal as the level of altitude increases.

Key words: Altitude; anaerobic fermentation; geographic information system; hillsides; specialty grade.

1 INTRODUCTION

Arabica coffee plants are known as plantation crops, which are widely planted and can grow well at altitudes > 1,000 meters above sea level (m.a.s.l) along the hillsides. However, this phenomenon illustrates that crop yields will be constrained by accessibility from the field to the market and in the end, production costs will inevitably increase. On the other hand, farming communities living along the foot of the mountain generally have relatively low levels of welfare knowledge and technology such as the area on the hillsides of Mount Latimojong, South Sulawesi Province. Arabica coffee plants are also commonly found in the hillsides of Mount Bawakareng-Lompobattang, hereinafter referred to as the Karaeng Lompo area in topographical Banjar units or toposequence. The hillsides area of Karaeng Lompo is a very potential arabica coffee producer. Nurdin and Yusran (2007), stated that the Karaeng Lompo Mountains region covers seven district administrative areas, namely Gowa, Takalar, Jeneponto, Bantaeng, Bulukumba, Sinjai, and Bone Regencies covering an area of 1,011,693 ha with a forest area of 259,174.00 ha or 25.62% of the total area.

Observing this phenomenon, it is very important to conduct site-specific research with environmental indicators such as altitude, slope, and land conditions. Chairuddin et al. (2013) stated that the soil development rate of each profile corresponds to altitude and slope, revealing different types and levels of environmental indicators related to soil development. Overall related to geographical indicators which lead to the discovery of unique flavors so that the selling value of Arabica coffee products in the area can be high, at least greater than the total cost of production; so that it can be a solution in increasing regional original income, and it is hoped that at the same time it will increase the welfare of the farming community. Folmer (2017) explained that to protect the future well-being of farmers, this platform will also help facilitate the generational transfer of farms from parents to children, motivating young people to carry out coffee production.

In order to find the uniqueness of optimal characteristics of coffee taste, especially the taste of wine (wine coffee), it must first be able to maintain the quality of raw materials. In this case, the quality of coffee beans which is classified as specialty grade. According to Sanz-Uribe et al. (2017) that the quality and flavor of a coffee cup are the results of the variety, the environmental offer, the agricultural practices (Geeraert et al., 2019), as well as the process followed to obtain the green beans that are finally roasted and ground.

The technique or practice of coffee cultivation is very important to pay attention to starting from the preparation stage to the post-harvest process in order to get quality coffee beans classified as specialty grades with a distinctive taste (De Carvalho et al., 2016). One of them is the anaerobic fermentation process to get the taste of wine coffee. The fermentation process in processing red coffee cherries has also been carried out in several places in Indonesia, such as Aceh (Gayo), Sumatra (Mandailing), and West Java (Garut) to get the aroma of the wine. The difference between this study and other studies is that the coffee beans produced in this study not only have the aroma of the wine but also the taste of wine when the coffee is served (coffee cupping). In addition, the coffee beans before roasting show a unique characteristic, namely a black color which is known as black honey wine (BWH), not green beans.

The description above is the background of this research, so it is necessary to map the zoning in the toposequences along the hillside area of Karaeng Lompo based on differences in altitude based on Geographic Information Systems, plant cultivation practices, and correct harvesting processing. According to Noponen et al. (2017), the sustainable agriculture network, a coalition of independent conservation organizations, sustainability includes environmental protection, social justice, and improved livelihoods, all of which can be achieved by following better farm-management practices. Basically, there have been many studies regarding the influence of altitude on coffee quality (Tolessa et al., 2016; Worku et al., 2018; Girma et al., 2020; Tassew et al., 2021). However, there are very few studies related to the effect of altitude on the quality of black honey coffee with the wine taste. Therefore, this research is intended to be able to map and find zoning areas that have the potential to have quality coffee beans classified as specialty grade with unique or specific aromas and flavors of "wine coffee" that are optimal and consistent. This study aims to map coffee land zones that can produce quality specialty grade coffee with the unique aroma and taste of optimal coffee wine based on altitude, while its use is expected to be a basic guideline in determining and finding the quality of specialty grade coffee beans with the aroma and wine taste.

2 MATERIAL AND METHODS

The research was conducted in the hillsides area of Mount Bawakaraeng (5°15'47.8" S – 120°00'36.9" E) and Mount Lompobattang (5°24'14.7" S – 119°55'16.4" E), in South Sulawesi Province. Average annual temperatures are 22 °C during the daytime and 15 °C at night. The average annual rainfall is 2846 mm. The research was carried out from the beginning of July 2018 to the end of December 2021.

There are three following stages in this research, are preparation, determination of the location of the coffee plantation, and harvest and post-harvest process. The flow chart of the research stages is presented in Figure 1, and is described in detail as follows:

1. Preparation

The preparation stage begins with an inventory and identification of land through analysis of tabular data and image data within the hillside area of Mount Bawakaraeng and Mount Lompobattang (hereinafter referred to as the Karaeng Lompo Region). At this preparatory stage, the Zoning Map of the distribution area of Arabica coffee in the Karaeng Lompo Region was made from the results of data interpretation and analysis through overlapping Regional Administration Maps, Indonesian Earth Map, Geological Map, Soil Type Map, Land Use Map, Satellite Imagery Mosaic Spot 6/7, Digital Elevation Model (DEM) Alos Palsar 12.4 m, and Rainfall Map.

Overall, this preparatory stage is based on a Geographic Information System (GIS) conducted at the Geographic Information System Laboratory and Land Use Planning, Department of Soil Science, Faculty of Agriculture, Hasanuddin University using ArcGIS software. In the current information age, it is almost impossible for land use plans to be made without using geospatial information technology as the main tool (Baja, 2012). The resulting map is used as a base map or work map in the implementation of the research stages.

2. Determining the location of the coffee plantation

The principle at this stage is ground truth by using GPS (Global Positioning System) to ensure the existence of coffee plantations related to geographical position, altitude, accessibility, land conditions, and coffee plantation conditions. Baja (2012) suggests that from a spatial planning perspective, the main element of land use is zoning or the zoning process. Land zoning means zoning or segmenting land, segmentation distinguishes one space segment from another in terms of the basic character of the space/land, functions, goals, and objectives, as well as targets to be achieved in space within a specified time period. Therefore, the altitude of coffee plantations required in this study is divided into Zone A, Zone B. Zone C, and Zone D. Zone A is the coffee plantation area with an altitude of 1,000 – 1,200 m.a.s.l. Zone B is the area of a coffee plantation with an altitude of 1,200 – 1,400 m.a.s.l. Zone C is the coffee plantation area with an altitude of 1,400 – 1,600 m.a.s.l. And zone D is the coffee plantation area with an altitude of 1,600 – 1,800 m.a.s.l. The location of the spread of coffee plantations on the hillside of Karaeng Lompo and directions for the research area points are presented in Figure 2.

After determining the location of the representative, then the harvest time is scheduled. Harvest time is calculated at the peak of harvest so that each location is carried out in a different period of time. According to Haile and Kang (2019) that coffee quality is associated with pre-harvest and post-harvest management activities and postharvest processing activities contribute about 60% of the quality of green coffee beans.

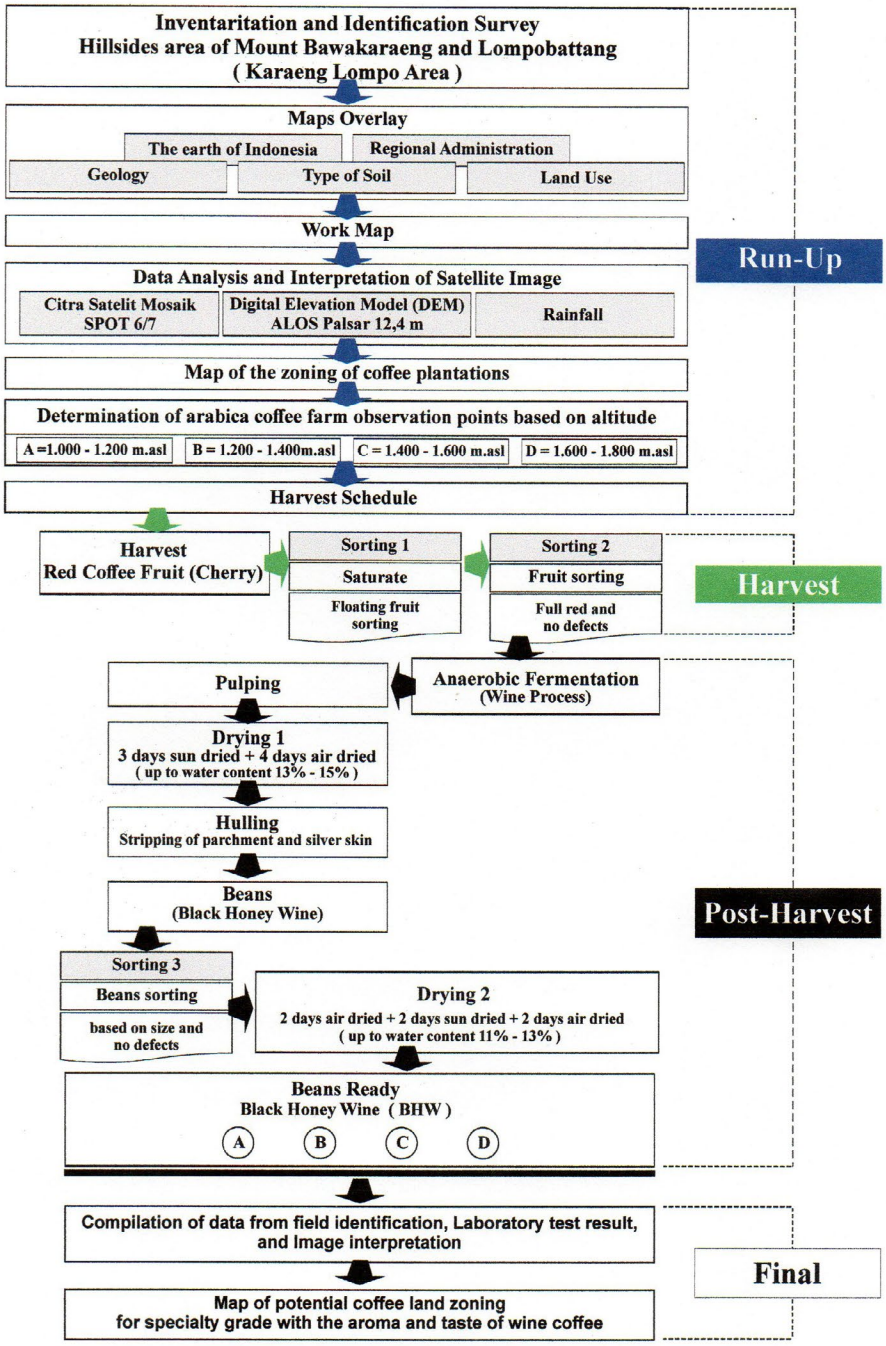

Figure 1: Research flow chart.

3. Harvest and Post Harvest

Harvesting is done manually by selectively selecting ripe fruit with full red fruit (coffee cherries) in each zone. Next, sorting 1 is done by soaking coffee cherries in water to separate the floating fruit, then sorting 2 is separating the whole and unblemished fruit. The cherries from sorting 2 were prepared as raw materials in the post-harvest process by anaerobic fermentation for 8 weeks. The fermentation process to get the taste of coffee wine refers to the patent design of Chairuddin and Suhardjo (2019). After that, sorting 3 were carried out on the quality and size, using the analytical method based on SNI 01-2907-2008; 7.1 against Life insects; SNI 01-2907-2008; 7.2 against Rotted/ Mouldy; SNI 01-2907-2008; 7.3 to Moisture content; SNI 01-2907-2008; 7.4.1 on the size of the coffee beans; and SNI 01-2907-2008; 7.4.2. against Foreign matters and Defect numbers (Ministry of Agriculture, 2012; SNI 01-2907-2008, 2008). Measurement of water content is also carried out separately and specifically by using a Wile Coffee and Cocoa Moisture Meter.

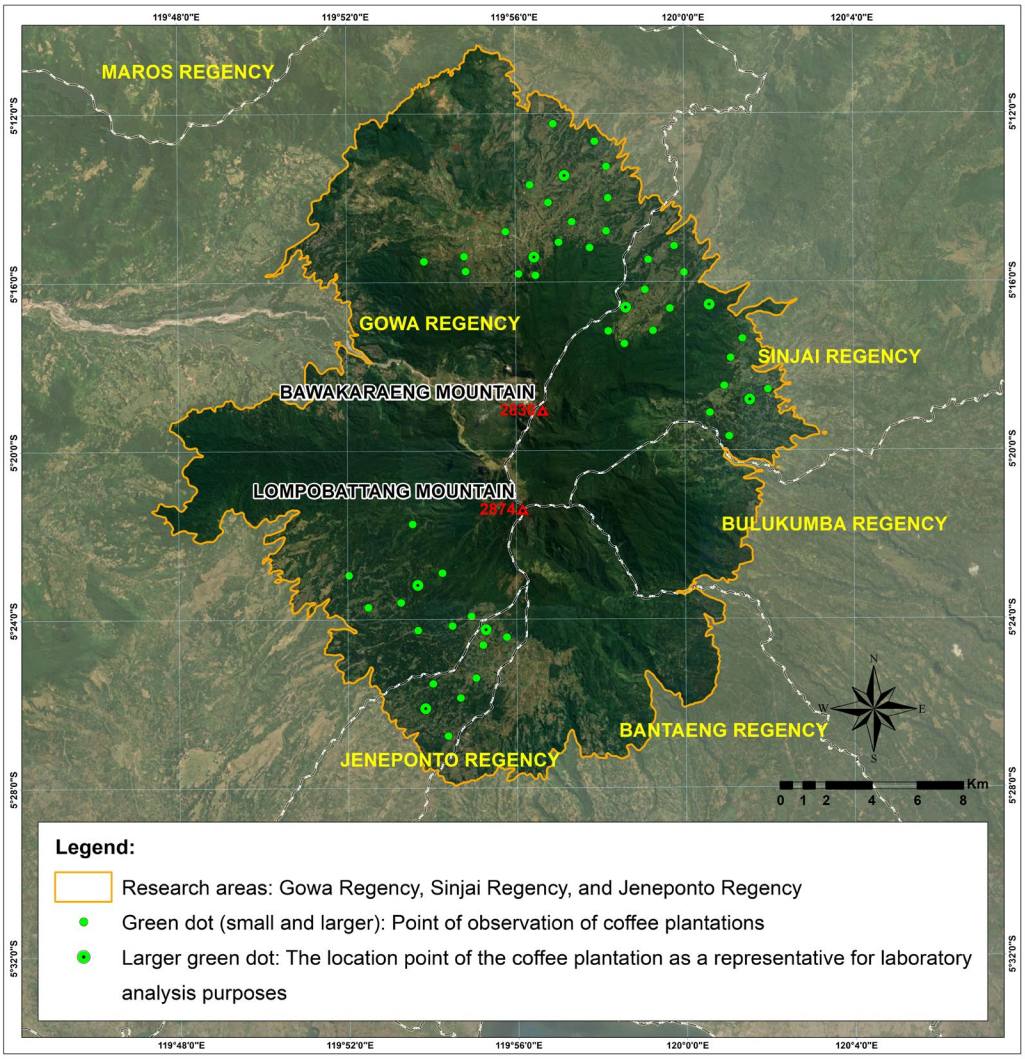

Figure 2: The location of the spread of coffee plantations on the hillside of Karaeng Lompo and directions for the research area points (green dots).

4. Final Stage in Research

At this final stage, there are two important works, namely: 1. Reinforcing the previously planned area zoning such as zoning A is at a position of 1,000 - 1,200 m.a.s.l, zoning B is 1,200 - 1,400 m.a.s.l, zoning C is 1,400 - 1,600 m.a.s.l, and zoning D is 1,600 - 1,800 m.a.s.l. This zoning segregation uses a geographic information system approach; and 2. Grouping of coffee beans according to their respective zoning, which means that 4 groups were obtained based on the zoning of the 52 coffee plantation points studied (Figure 2). Carefully selected 1 kg of coffee beans which represent the zonation for the purposes of analyzing the quality and characteristics of organoleptic sensory attributes carried out at the testing laboratory, Indonesian Coffee and Cocoa Research Institute, and the Center for Plantation Products Industry, Ministry of Industry of the Republic of Indonesia, Makassar, South Sulawesi.

The quality analysis consists of the presence of Life insects, Rotted/Mouldy, Moisture content, Coffee bean size, and Defect number; while the characteristics of the organoleptic sensory attributes are Fragrance/Aroma, Flavor, Aftertaste, Acidity, Body, Uniformity, Balance, Clean cup, Sweetness, Overall, and Taint/Defect. These attributes are the most important attributes in the coffee taste test (Ngugi; Cheserek; Omondi, 2021).

Each characteristic in the test will get a description of the taste score; score 6.00 - 6.75 = Good; 7.00 - 7.75 = Very good; 8.00 - 8.75 = Excellent; and 9.00 - 9.75 = Outstanding. Final score notation: Minimum score for specialty grade = 80.

Testing the characteristics of sensory organoleptic attributes for determining the level of coffee wine flavor is by paying attention to the comments of each dominant characteristic by using a sequence of numbers 1 to 7, the smaller the number the more dominant the flavor conveyed, in other words, the number 1 gives the impression of being dominant rather than number 2, number 2 gives a more dominant impression than number 3, and so on. The final result at this stage, by compiling field data, data from testing laboratory results, and interpretation

of satellite image data can be made as a zoning map of coffee land that has the potential as Specialty Grade, and a zoning map of coffee land with coffee wine flavor levels. Overall, the map can show the geographical position and the area covered.

3 RESULTS

The coffee beans produced in this study are referred to as "black honey wine" (BHW), in contrast to the term coffee beans which are often referred to as green beans. The results of the analysis of the coffee bean quality test; on the characteristics of Life insect are absent, Rotted or Mouldy is absent, the Moisture content is 11.8%, Coffee bean size is large, foreign meter is 0%, and Defect number is 0.1%. Meanwhile, the sensory attribute testing for taste characteristics consisted of Fragrance or Aroma, Flavor, Aftertaste, Acidity, Balance, Clean cup, Sweetness, Body, Uniformity, Overall, and Taint/Defect. This is intended to obtain the overall performance on the quality and characteristics of the tested BHW beans. The summary of the sensory attribute test results for all coffee beans based on altitude is presented in Table 1.

Meanwhile, the comments on the results of the taste test described for zone A (altitude 1,000-1,200 m.a.s.l) are Natural, Dried Fruit, Winy, Very Acid, Sourish, Not Balance, Acetic Acid; zone B (altitude 1,200-1,400 m.a.s.l) is Natural, Dried Fruit, Winy, Fruity, Citric Acid; zone C (altitude 1,400-1,600 m.a.s.l) are Dried Fruit, Winy, Natural, Very Salty, Tropical Fruit, Fruity, Lemony; and zone D (altitude 1,600-1,800 m.a.s.l) are Natural, Dried Fruit, Winy, Spicy, Fruity, Tropical Fruit, Mango Kweni. If the characteristics of the organoleptic are ordered based on the taste obtained from the beginning to the end of the test, the test results can be ordered from 1 to 7. The summary of comments on the results of organoleptic testing based on altitude is presented in Table 2.

4 DISCUSSION

The coffee beans produced in this study are referred to as "black honey wine" (BHW); while the results of the analysis of the coffee bean quality test on the characteristics of Life insect, Rotted/Mouldy, Moisture content, coffee bean size, Foreign matters, and Defect number, it is concluded that the coffee beans are classified as quality 1 with large size based on SNI 2907-2008.

The results of the Taste Test showed that in all samples, the taint/defect characteristics obtained a value of 0.00. This revealed that there were no negative aromas or defects that reduced the quality of the coffee such as Taint or polluted smell and Fault or bad taste. Referring to the scores obtained on the characteristics of Uniformity, Clean Cup, and Sweetness for all samples showing a score of 10.00 with outstanding criteria. This indicates that the aroma of each cup is uniform. There is no negative value from the taste and sweetness it has. This is the basic characteristic of the coffee beans tested in this study. These basic characteristics are not affected by differences in altitude. In contrast to the characteristics of Fragrance or aroma, Flavor, Aftertaste, Acidity, Body, Balance, and Overall shows that there is a positive correlation between these attributes and altitude. Similar findings were reported from Ethiopia by Addis Tassew et al. (2021) that the elevation gradient had a significant ($P < 0.001$) effect on most of the cup quality variables. In addition, Worku et al. (2017) concluded that altitude positively affects coffee sucrose content and increases acidity.

Table 1: Summary of characteristic attribute sensory test of results for all coffee beans based on altitude.

Characteristic Attribute Sensory	Altitude (m.a.s.l)			
	1.000 – 1.200	1.200 – 1.400	1.400 – 1.600	1.600 – 1.800
	A	B	C	D
Fragrance/aroma	7.50	8.00	7.75	8.00
Flavor	7.00	7.75	7.75	8.00
Aftertaste	6.50	7.75	7.75	8.00
Acidity	6.50	7.75	7.75	8.00
Body	6.75	7.75	7.75	8.00
Uniformity	10.00	10.00	10.00	10.00
Balance	6.50	7.75	7.75	8.00
Clean cup	10.00	10.00	10.00	10.00
Sweetness	10.00	10.00	10.00	10.00
Overall	6.75	7.75	7.75	8.00
Taint/Defect:	0.00	0.00	0.00	0.00
Final score:	77.50	84.50	84.25	86.00
Notation:	Not Specialty Grade	Specialty Grade	Specialty Grade	Specialty Grade

Table 2: Summary of the comments on the results of organoleptic testing based on altitude.

Characteristics Organoleptic	Altitude (m.a.s.l)			
	1,000 – 1,200	1,200 – 1,400	1,400 – 1,600	1,600 – 1,800
	A	B	C	D
Natural	1	1	3	1
Dried Fruit	2	2	1	2
Winy	3	3	2	3
Fruity		4	6	5
Tropical Fruit			5	6
Spicy				4
Lemony			7	
Mangga Kweni				7
Acetic Acid	7			
Citric Acid		5		
Very Salty			4	
Very Acid	4			
Sourish	5			
Not Balance	6			

The cumulative score or final score of all sensory attributes determines the specificity grade rating, the minimum value for specialty grade is 80. Observing the final score obtained at each altitude, it can be said that it is classified as a specialty grade except at an altitude of 1000-1200 m.asl (namely A), and the final score tends to increase with the altitude of the place. Compilation of the results of sensory attribute analysis and interpretation of image data can be mapped for coffee land zoning that has the potential to produce coffee classified as specialty grade, presented in Figure 3.

Each altitude has a different sensory attribute characteristic value, the distribution pattern of sensory attributes from each altitude is presented in Figure 4.

Looking at Figure 4 shows that the pattern of distribution of sensory attributes is different for each altitude, but for uniformity, clean cup, and sweetness it achieves the highest score of 10 or excellent. Meanwhile, fragrance/aroma, aftertaste, flavor, acidity, body, overall, and balance tend to increase with altitude. Referring to the existing sensory attributes and taking into account Table 2, it can be said that

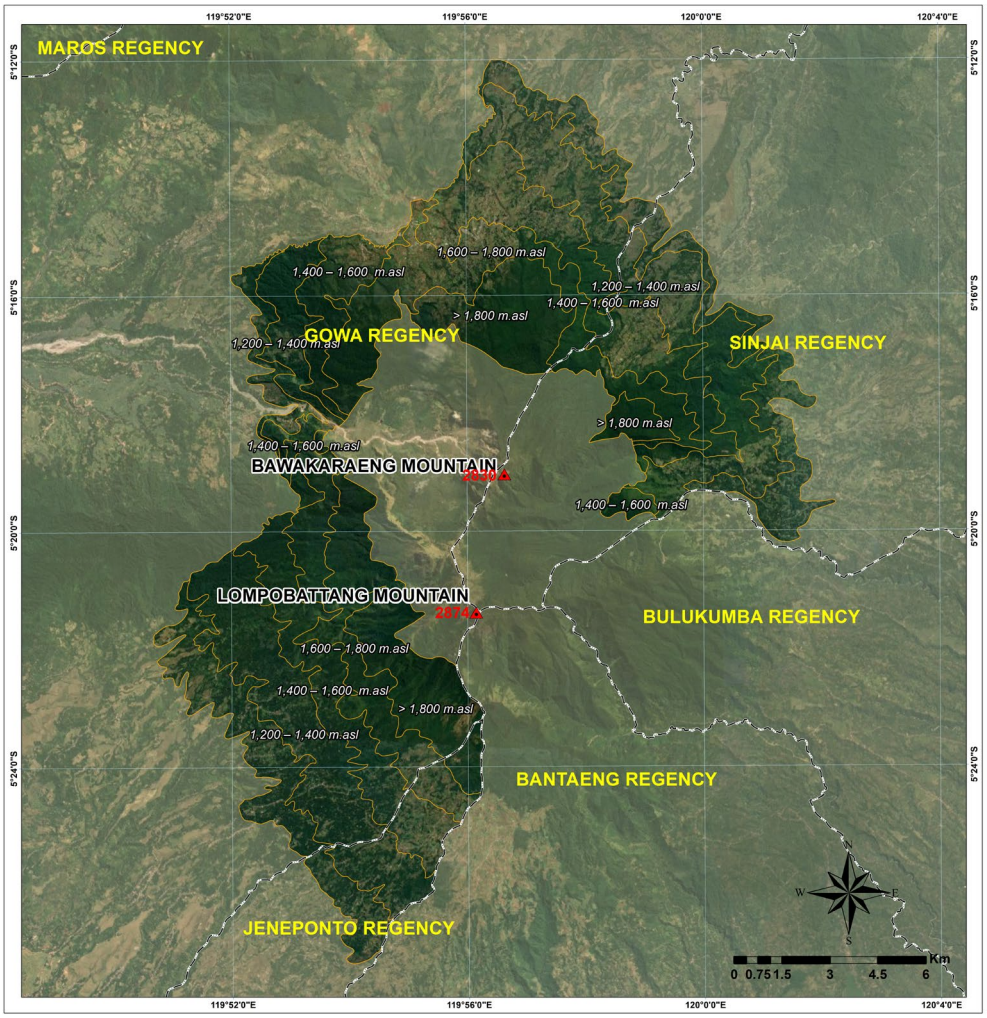

Figure 3: Map of coffee land zoning with potential specialty grade.

the organoleptic characteristics of Natural, Dried Fruit, and Winy are the basic characteristics of the research location because all altitudes have them.

Overall, it can be said that the difference in altitude will give the unique aroma and taste of coffee wine that is different too. However, it can be seen that the higher the altitude, the better or optimal the aroma and taste of coffee wine tends to be and can be written D > B > C > A. These differences present a complex taste sensation with many alternative choices to choose or determine the characteristics of the desired wine coffee product. On the other hand, Lambot et al. (2017) argue that Green coffee quality and by consequence coffee sensory attributes are influenced by many factors in which environmental parameters and technical practices to cultivate coffee plays a significant role, and shading trees on the production system and the coffee quality, and it is also stated that fertilization is a key technique to increase and optimize the yield in the production system. Therefore, it is very possible to obtain variations because the processing procedures (land processing and plant maintenance) in each region are different, apart from differences in altitude. The overall results obtained from the characteristics of sensory attributes and from organoleptic characteristics can be mapped by zoning coffee fields that have different levels of coffee wine taste, as presented in Figure 5.

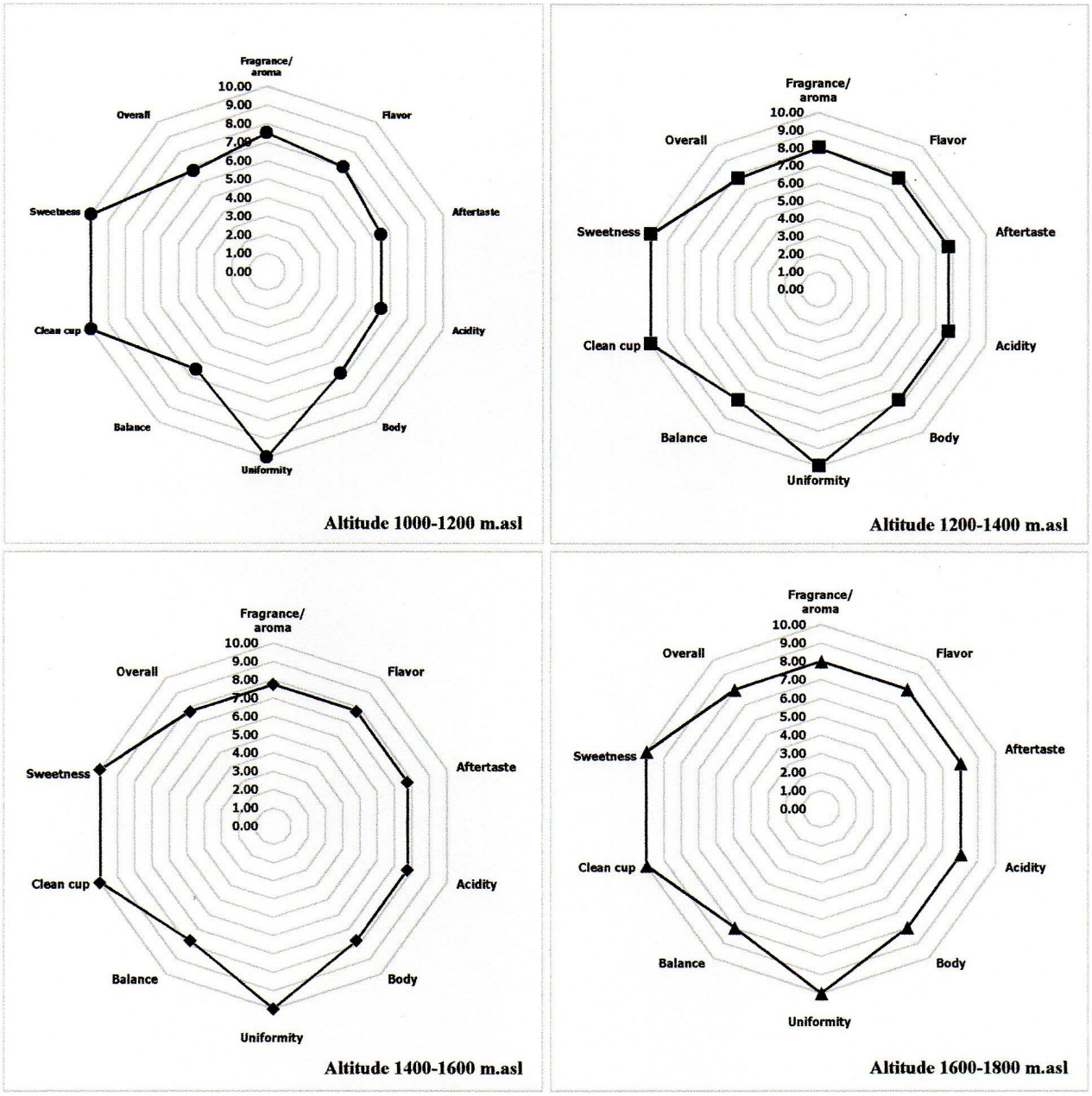

Figure 4: Distribution pattern of sensory attributes from each altitude.

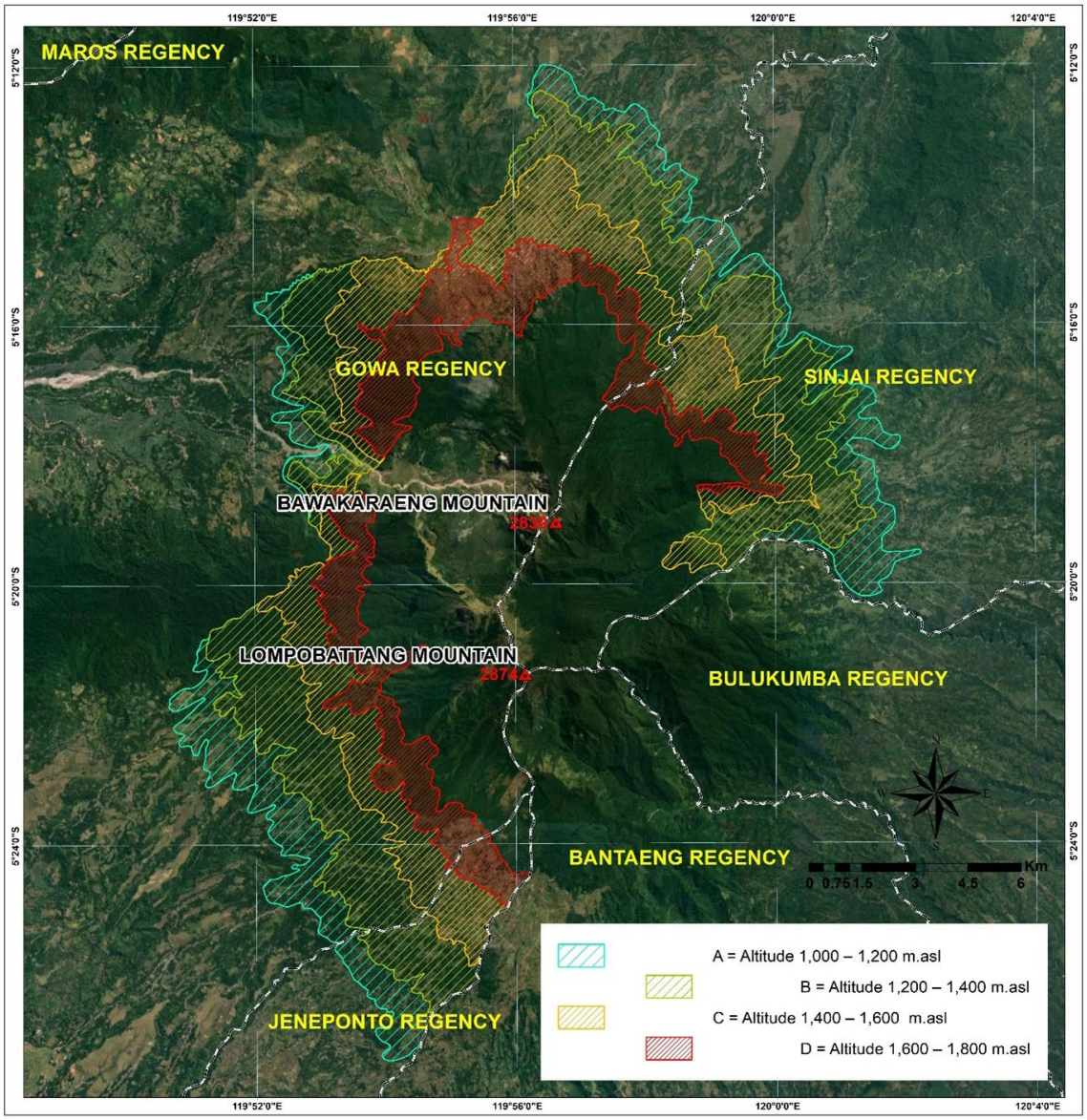

Figure 5: Zoning of coffee fields that have different wine flavors according to the altitude.

5 CONCLUSIONS

The results of the study can be concluded that the difference in altitude also results in differences in the characteristics of the coffee wine taste. In particular, from the results of data compilation and satellite imagery, the area of coffee land with the potential to be a specialty grade is 20,025 ha or 2.00% of the total research area of 1,011,693 ha.

Also, from the results of data compilation from the characteristics of organoleptic sensory attributes and interpretation of satellite imagery, it can be mapped the differences in land zoning based on the altitude of the place with a different taste of coffee wine, namely altitude 1000-1200 m.asl (A) covering an area of 3552.10 ha, altitude 1200- 1400 m.asl (B) covering an area of 5738.53 ha, altitude 1400–1600 m.asl (C) covering an area of 4381.27 ha; and altitude 1600–1800 m.asl (D) covering an area of 3351.60 ha.

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7 AUTHORS' CONTRIBUTION

ZC wrote the manuscript and conducted the experiment, SL supervised the experiment and co-worked the manuscript, MI analyzed the satellite imagery data and drew the map, KH conducted an analysis of the quality of the coffee, SH reviewed and approved the final version of the work, and TKH supervised the trial results.

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