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EVALUATION OF LAND SUITABILITY FOR ORANGE PLANTS (*Citrus Sinensis L.*) AFTER ERUPTION OF MOUNT SINABUNG, KARO DISTRICT, NORTH SUMATERA

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Abstract. The eruption of Mount Sinabung produced volcanic ash that cover agricultural land in its vicinity, causing a decrease in agricultural production. One of the agricultural products around Mount Sinabung is orange, which is cultivated in the vast area. This study aimed to evaluate the land suitability for orange plants (*Citrus sinensis L.*) after the eruption of Mount Sinabung. Soil samples were taken based on 4 cardinal directions (North, East, South, and West), each at a radius of 3-5 km, 5-7 km, and 7-10 km. Soil samples were taken from the depth of 0-20 cm and 20-40 cm. The soil was analyzed for soil texture, soil pH, CEC, organic C, total N, available P, and exchangeable bases (Ca, Mg, K, and Na). Evaluation of land suitability was done by 2 methods, the qualitative and quantitative methods by applying rating for each parameter. Results show that the Land evaluation range from S2 (Suitable), S3 (Marginally Suitable), and N (Not Suitable) with limiting factors such as slope, soil depth, soil texture, soil pH, and soil fertility. The land suitability evaluation using these two methods has some different results they have different land suitability criteria. Overall, the suitability area of the S2 class is 7,929.79 hectares located in Kuta Gugung, Kurbakti, and Kuta Mbaru, the area of the S3 conformity class is 13,038.29 hectares located in Namanteran, Sukandebi, Beganding, and Tiganderket and the area of the suitability class N is 7,207.49 hectares in Kuta Kepar, Kuta Tonggal, and Payung.

Keywords: Mount Sinabung, volcanic ash, orange plants, land suitability

1 Introduction

Mount Sinabung is a strato-type volcano in Karo Regency, North Sumatra, Indonesia. Until 2010, this mountain had never been recorded to erupt since 1600 so this mountain is classified as a type B volcano. However, this mountain changed to type A when it erupted on 27 August 2010 with a phreatic eruption type [1]. The Center for Volcanology, Disaster Mitigation, and Geology recorded seismic activity from 2012 to 2013. A large eruption occurred on September 15, 2013, so that approximately 6,000 residents had to be evacuated from a 3 km radius [2]. The volcanic activity of Mount Sinabung was monitored again from January to October 2014 [3]. The National Disaster Management Agency reported an eruption on January 3, 2015, which was bigger than the previous eruption which occurred almost every day [4].

The result of the volcanic eruption was in the form of thick black smoke accompanied by a rain of sand and volcanic ash, the material covered thousands of hectares of farmers' crops which were under a radius of six kilometers [5]. The material from the eruption damaged residents' plants around Mount Sinabung from a radius of 0 to 5 km (which is a disaster-prone red zone).

One of the agricultural products around Mount Sinabung is orange. Orange production in Karo Regency reached 66.29 tons ha^{-1} in 2009, with total production reaching 927,862 tons in a harvested area of 13,997 ha [6]. Besides being marketed in the regions, oranges from Karo Regency are also marketed to other provinces so that oranges are one of the major sources of economic income in Karo Regency. However, after the eruption, citrus plantations around Mount Sinabung were damaged and yields decreased.

Given that oranges are a source of income for residents, especially in the area around Mount Sinabung, it is necessary to evaluate the land for orange plants after the eruption of Mount Sinabung, because most of the agricultural land around Mount Sinabung is covered with volcanic ash from the eruption.

2 Materials and Methods

2.1 Materials

Mount Sinabung is administratively located in several sub-districts, namely Naman Teran District, Simpang Empat District, Payung District and Tiganderket District, Karo Regency, North Sumatra Province. The research location is geographically located at 03º6'17.3" to 03º15'4.2" North Latitude and 98º19'17.2" to 98º27'27.1" East Longitude. Sampling was carried out in Naman Teran, Payung, Kaban Jahe, Munthe, Tiganderket, Simpang Empat, and Merdeka districts, which are part of Karo Regency (Table 3). Meanwhile, two sub-districts, namely Kuta Mbaru District and Sei Bingai District, are part of the Langkat Regency.

Fig. 1. South, 3 km from the peak of Mount Sinabung

Fig. 2. North, 3 km from the peak of Mount Sinabung

Before taking soil samples, observations of the physical condition of the land and observations of the surrounding topography were carried out, namely measuring the slope of the land, rock outcrops, surrounding vegetation, and so on. Soil samples were taken at a depth of 0 – 20 cm and 20 – 40 cm. Soil samples taken were disturbed soil samples (drill samples) and intact soil samples (ring samples). Determination of the location or sampling area is determined based on locations that represent the 4 cardinal directions, namely West, East, South, and North at a radius of 3 - 5 km, 5 - 7 km, and 7 - 10 km from the peak of Mount Sinabung, respectively. The number of samples taken is 12 samples. In addition to drill samples, the land evaluation process also uses several soil profiles in the form of secondary data sourced from previous research.

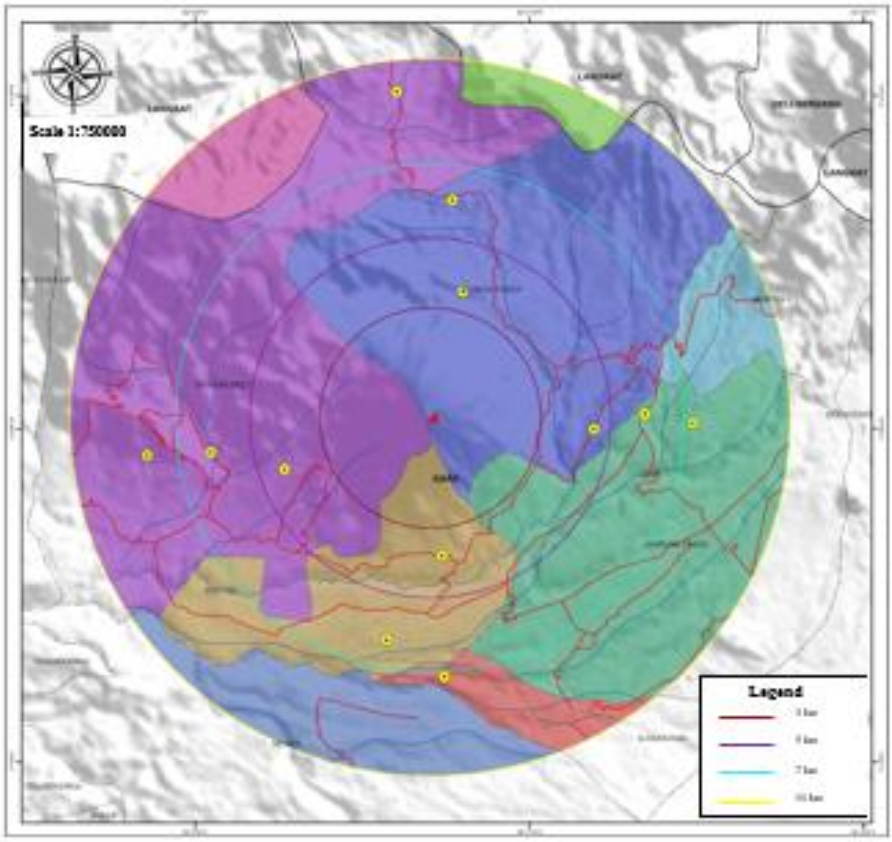

Fig. 3. Administration Map of Mount Sinabung

2.2 Methods

Analysis of the chemical and physical properties of the soil was carried out at the Laboratory of the Department of Soil Science, Faculty of Agriculture, Andalas University. The physical and chemical properties of this soil are based on the table of land suitability criteria for orange plants, namely soil texture (pipette and sieve), pH (electromagnetic method), CEC, base saturation, base cations, N-total (Kjeldahl), C-organic (Walkey). and black), and P-available (Bray II). After the analysis, the land evaluation is carried out. The data needed in the land suitability assessment are climate data, soil environmental data, and soil characteristics data. Climatic data in the form of rainfall, average temperature, average minimum air temperature (Tmin ^{0}C), total monthly rainfall (P, mm), and the number of dry months. Then the soil environmental data such as soil drainage, effective soil depth, flood period, land slope, rock on the surface (Rock outcrop). Then the data on soil characteristics, namely the physical and chemical properties of the soil, have been analyzed in the laboratory.

Evaluation of land suitability was carried out using qualitative and quantitative methods. The qualitative method was carried out by comparing the land characteristics obtained with semi-detailed land suitability criteria for orange plants sourced from PPT and Agroklimat [7]. The quantitative land evaluation was carried out by comparing climate and land characteristics with the conditions for growing sweet orange plants according to Sys and Van Ranst [8] which had a limit on the assessment score for each characteristic. In this quantitative land suitability class classification, the rating method is carried out with the storie method and the square root method. These two methods have the following formula:

1. Storie Method:

$$\mathrm{I} = A \times \frac{A}{100} \times \frac{\mathrm{B}}{100} \times \frac{\mathrm{C}}{100} \times \ldots. \quad (1)$$

Where I = specified index and A, B, C… = different ratings given for each property.

2. Square Root Method:

$$I = \mathrm{Rmin} \sqrt{\frac{A}{100} \times \frac{\mathrm{B}}{100}} \times \ldots. \quad (2)$$

In which Rmin = the minimum rank.

Table 1. Index Value for Land Suitability Class

Index	Land Suitability class
75-100	S1, Very Suitable
50-75	S2, Suitable
25-50	S3, Marginally Suitable
0-25	N, Not Suitable

Resource : Van Ranst, et al [8].

The results of the land suitability evaluation that have been obtained are then mapped using GIS software.

3 Results and Discussion

3.1 Climate Condition

Depending on the species, orange require 5 to 9 wet months. Wet months are needed for flower and citrus fruit development to keep the soil moist. Rainfall is 1000-2000 mm/yr which is evenly distributed throughout the year. However, the optimal rainfall is 1,520-3,800 millimeters per year with 2 dry months. As for the wet months (5-12 months), the rainfall is above 100 mm/year, and for the dry months (0-5) the rainfall is below 60 mm/month [9]. Rainfall data is needed in the development of agricultural resources because rainfall is one of the most influential factors in agriculture.

The classification of Schmidt and Ferguson [10] distinguishes climate types based on rainfall, namely wet months (months with rainfall >100 mm/month) and dry months (months with rainfall <60 mm/month). Rainfall around Karo Regency is included in the criteria with high rainfall, with an average monthly rainfall of around 141.47 mm. The climate in this research location has type B.

Temperature is one of the climatic elements that is very important to know in evaluating land suitability for a plant. The temperature data used in this study is Karo Regency temperature data for the last 10 years, namely from 2006 to 2016. Based on Table 5, the average annual temperature is 20.3 ºC where the lowest temperature is in 2014 with a value of 19.63 ºC and the highest temperature in 2016 with a value of 21.07 ºC. During the last 10 years, the highest monthly average temperature was in June, which is the middle of the dry season with the lowest average monthly rainfall. While the lowest monthly average temperature is in December which is the middle of the rainy season.

3.2 Land evaluation qualitative methods

Evaluation of land suitability for orange plants (*Citrus sinensis L.*) after the eruption of Mount Sinabung with the matching method referring to FAO [11] obtained two types of classes, namely S2 and S3 classes. This land suitability evaluation is carried out up to the sub-class level with the results of the evaluation of actual land suitability and potential land suitability. Qualitative evaluation of the land suitability consists of the determination of the land use for particular applications regardless of yield fulfillment and socio-economic issues [12]. Actual land suitability is land suitability class in natural condition, not considering improvement efforts and level of management that can be done to overcome obstacles or limiting factors that exist in each map unit. Meanwhile, potential land suitability is land suitability that will be achieved after land improvement efforts have been carried out by Harjowigeno [13].

Actual land suitability class for orange plants (*Citrus sinensis L.*) after the eruption of Mount Sinabung obtained class S2 (quite suitable) and class S3 (marginally appropriate) where class S2 is located at locations East 5-7 km and East 7-10 km, class S3 is located at locations North 5-7 km, South 3-5 km, South 5-7 km, South 7-10 km, West 3-5 km, West 5-7 km, and West 7-10 km, while class N1 (not suitable) is located at locations North 3-5, North 7-10 km and East 3-5 km. The actual land suitability classes and subclasses can be seen in Table 2.

Table 2. Actual Land Suitability for Orange (*Citrus sinensis* L.) after the eruption of Mount Sinabung

Sample Location	North 3-5 km	North 5-7 km	North 7-10 km	East 3-5 km	East 5-7 km	East 7-10 km
Class	N1	S3	N1	N1	S2	S2
Sub-Class	N1f	S3ne	N1f	N1f	S2	S2

Table 2. Actual Land Suitability for Orange (*Citrus sinensis* L.) after the eruption of Mount Sinabung (continue)

Sample Location	South 3-5 km	South 5-7 km	South 7-10 km	West 3-5 km	West 5-7 km	West 7-10 km
Class	S3	S3	S3	S3	S3	S3
Sub-Class	S3e	S3r	S3f	S3e	S3e	S3r

Most of the land suitability subclasses obtained have the same limiting factor, namely the level of erosion hazard (e) with the limiting factor of slope because the location of this study is an area with hilly and wavy topography on Mount Sinabung.

In addition, the next limiting factor is the rooting medium (r), in the form of effective root depth at location South 5-7 km and soil texture at location west 7-10 km. Other limiting factors are available nutrients (n) with low available P values (locations North 5-7 km and South 3-5 km) and low K-dd (North 3-5 km) and nutrient retention (f) with low soil pH (locations North 5-7 km and North 7-10 km).

Referring to the results of the actual land suitability evaluation, it is known that several limiting factors can be used as references to do several improvement efforts to produce potential land suitability classes. However, some limiting factors are absolute so that no improvement efforts can be made.

Table 3. Potential Land Suitability for Orange Plants (*Citrus sinensis L.*) after eruption of Mount Sinabung

No	Sample Location	Actual Land Suitability	Limiting Factor	Land Improvement Attempt	Potential Land Suitability
1	North, 3-5 km	S3e	Land Slope	Contour parallel planting, planting ground cover crops.	S2
2	North, 5-7 km	S3ne	Low available P, and Land slope	Addition of organic matter, Contour parallel planting, planting ground cover crops.	S2
3	North, 7-10 km	S2		No need for a land improvement attempt	S2
4	East, 3-5 km	S3e	Land Slope	Contour parallel planting, planting ground cover crops.	S2
5	East, 5-7 km	S2		No need for a land improvement attempt	S2
6	East, 7-10 km	S2		No need for a land improvement attempt	S2
7	South, 3-5 km	S3e	Land Slope	Contour parallel planting, planting ground cover crops.	S2
8	South, 5-7 km	S3r	Roots effective depth	No land improvement attempt can be done	S3
9	South, 7-10 km	S3f	Low Soil pH	addition of organic matter	S2
10	West, 3-5 km	S3e	Land Slope	Contour parallel planting, planting ground cover crops.	S2
11	West, 5-7 km	S3e	Land Slope	Contour parallel planting, planting ground cover crops.	S2
12	West, 7-10 km	S3r	Clay soil texture	No land improvement attempt can be done	S3

The resulting potential land suitability class is class S2 (quite suitable) at 10 sampling locations and S3 at sample locations South 5-7 km and West 7-10 km. S3 class (marginally appropriate) at these two sample locations was since no improvement could be made to the absolute limiting factor, namely (r) in the form of shallow effective root depth (location South 3-5 km) and clay texture (location West 7-10 km). In detail, each potential land suitability class can be seen in Table. 3 which also shows the limiting factors and improvement efforts that can be made at all sampling locations.

3.3 Land Evaluation Quantitative methods

Evaluation of land suitability with the rating method has a separate climate criteria table from the land criteria table. According to Van Ranst and Verdoodt [14], which explains that in the parametric method, the maximum number of soil characteristics that can be considered is up to the number 8. Therefore, this method recommends conducting a climate evaluation. Climatic characteristics are divided into several groups, namely radiation, temperature, rainfall, and relative humidity.

Table 4. Climate Suitability Class Based on Parametric Approach for Orange Plants (*Citrus sinensis L*) after eruption of Mount Sinabung

Climate Caracteristic	Score	Limiting Factor	Rate	Class
Rainfall	1770.3	0	96.69	S1
Dry month <100 mm/month	3	0	95	S1
Average Temperature	20.43	1	86.44	S1
Total Month with temperature >38 C	0	0	100	S1
Total Month with temperature <13 C	0	0	100	S1
Minimum Temperature	15.04	0	100	S1
Index Storie Method		79.40		
Index Square root Method		82.85		
Climate Suitability Class		S1		

The research location around Mount Sinabung has the same climatic characteristics in each cardinal direction and each radius. The climate suitability for citrus plants at the study site was obtained in class S1 with a storie land index of 79.40 and a square root index of 82.85. The highest rating value obtained is 100 and the lowest rating value is 86.44. Based on Table. 4, it can be seen that overall, the climate characteristics in the research location have a class S1 (very suitable).

The results of land suitability for orange (*Citrus sinensis L.*) after the eruption of Mount Sinabung with a parametric approach obtained several classes, namely class S2 (quite suitable) at locations North 5-7 km, East 7-10 km, South 3-5 km, and West 3-5 km with a limiting factor value of 2, class S3 (marginally appropriate) at sample locations North 3-5, East 5-7 km, South 7-10 km, West 5-7 km, and West 7-10 km with each limiting factor value of 3 on the soil depth parameter, and class N (not suitable) at sampling locations North 7-10 km, East 3-5 km, and South 5-7 km. The results of the evaluation of the land suitability of the rating method can be seen in Table 5.

Table 5. Soil Suitability Class Based on Parametric Approach for Orange Plants (*Citrus sinensis L.*) after eruption of Mount Sinabung

Sample Location	North 3-5 km	North 5-7 km	North 7-10 km	East 3-5 km	East 5-7 km	East 7-10 km
Land Index Storie	15.36	24.21	14.82	11.87	21.06	48.34
Land Index Square Root	24.78	37.41	24.35	22.46	30.79	54.08
Land Suitability class	S3	S3	N	N	S3	S2

Table 5. Soil Suitability Class Based on Parametric Approach for Orange Plants (*Citrus sinensis L.*.) after eruption of Mount Sinabung (continue)

Sample Location	South 3-5 km	South 5-7 km	South 7-10 km	West 3-5 km	West 5-7 km	West 7-10 km
Land Index Storie	21.45	19.11	19.71	40,83	27,19	39,99
Land Index Square Root	30.19	21.86	28.08	37,46	33,39	49,10
Land Suitability class	S3	N	S3	S2	S3	S3

Based on the table, it can be seen that the lowest storie index and Square root were obtained in sample east 3-5 km with a Storie index value of 11.87 and a Square root index value of 22.46. This is caused by the low soil pH (limiting factor 4, rating value 40, and class N) and shallow soil depth (limiting factor 3, rating value 42.5, and suitability class S3). Meanwhile, the highest index was found in the soil sample location II with a storie index value of 52.14 and a square-root index value of 68.50. In this sample, the lowest rating value is found in the soil depth parameter with a limiting factor of 2.

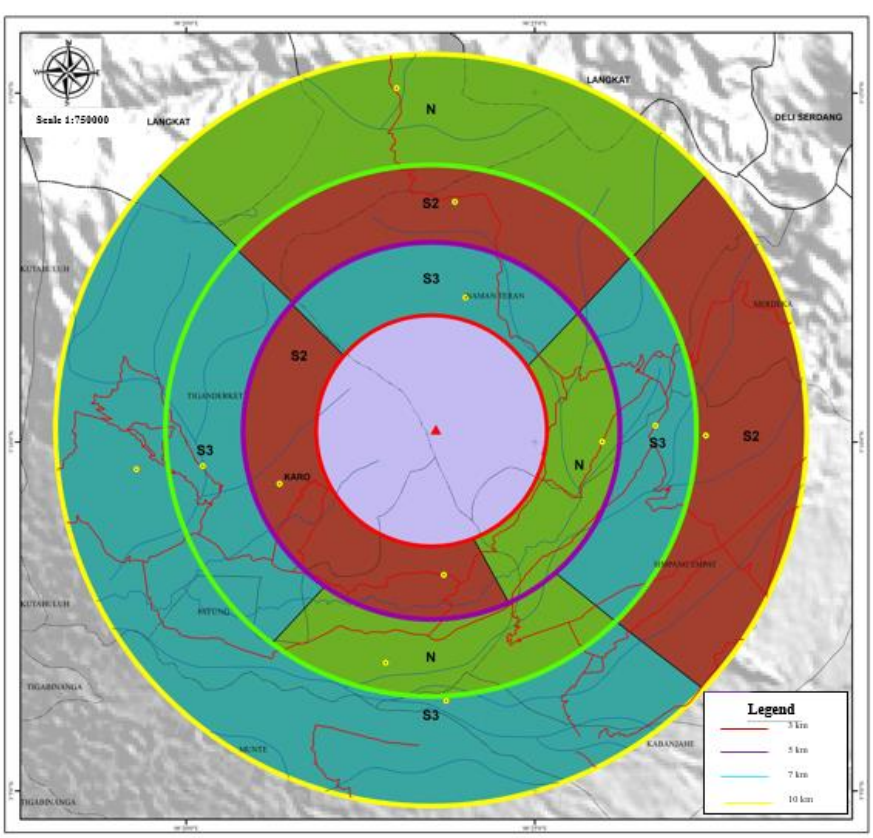

Fig. 4. Map of Land Suitability Class for Orange Plant After Eruption of Mount Sinabung

4 Conclusion

Based on the results of the research that has been done, it can be concluded that the land suitability class for orange (*Citrus sinensis L.*) after the eruption of Mount Sinabung with 2 evaluation methods obtained several land suitability classes, both actual and potential. The matching method gets the results of the S2 suitability class in the Sukandebi and Kurbakti areas. S3 compatibility classes are located in the areas of Kuta Gugung, Guru Kinayan, Payung, Beganding, Kutambaru, Susuk, and Nari Gunung Dua. The suitability class N1 is found in the Kuta Kepar and Kuta Tonggal areas. The limiting factors in the matcing method and the rating method are slopes, soil texture, low pH and low available P. While the rating method obtains the results of S2 land suitability class with a land index value range of 50 – 75 (in the Kuta Gugung, Kurbakti, Susuk, and Nari Gunung Dua areas) S3 with a land index value range of 25 – 50, and N (in the Kuta Kepar, Kuta Tonggal, and Sukandebi) with a range of land index values 0 – 25. Overall, the area of the S2 suitability class is 7,929.79 ha, the area of the S3 suitability class is 13,038.29 ha, and the area of the N suitability class is 7,207.49 ha.

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