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Abstract. Decreasing productivity of pepper has become one of the problems of pepper commodities development in West Lampung Regency, as the second-largest pepper developer area. This condition made the fall in the price of pepper which greatly affects the income of the farmers. In order to increase production and develop pepper in West Lampung Regency, it is necessary to know the location and land suitability of the pepper first to facilitate giving directions and recommendations. Thus, this research is studying the spatial distribution of pepper and its characteristics, as well as the land suitability in West Lampung Regency. The results showed the spatial distribution of pepper commodity based on supervised classification is mostly located in the east of West Lampung Regency. Regarding the suitability, West Lampung Regency is categorized into land suitability class moderately suitable (S2fns) and marginally suitable (S3fns, S3ns, S3d, S3f, S3s, S3fs) with the biggest limiting factors are slope and nutrient retention. Land suitability with limiting factor conditions such as available nutrients, nutrient retention, and drainage can still be improved by providing lime, organic matter, fertilizers, and construction of irrigation systems.

1. Introduction

As one of the plantation export products that have an important role, pepper can improve the Indonesian economy apart from palm oil, rubber, and coffee. Pepper is also a commodity that canbe used to improve Indonesia's export performance [1]. The export of pepper in 2016 was 33,645 tonnes, and it contributed more than 400 million [2][3]. d However, the commodity of pepper has recently faced obstacles in its development, such as being planted in unsuitable land, lack of availability of superior seeds, lack of human resources to grow pepper, and low consumption of pepper in Indonesia. [4]. The selling price of pepper, which often fluctuates and tends to decline, makes it difficult for small and medium-sized farmers to survive because farmers do not have suitable storage or warehouse to wait for the selling price to rise.

In this regard, the Ministry of Agriculture [5] states that the intensification of pepper is a step to increase pepper productivity. However, this effort must also be supported by an analysis of land capability and land suitability to make it easier to formulate directions and apply technological innovations to increase its productivity. In the current agricultural era, pepper development also must be in line with community development and regional development that involves various factors, both social, economic, cultural, and technological factors, which all interact with each other in the development process [6].

Lampung is the second-largest province for pepper production after the islands of Bangka Belitung Islands. The total area of the pepper commodity in Lampung Province in 2015 was 45,863 ha, with a production of 4,860 tonnes and a productivity of 0.324 tonnes per hectare [5]. West Lampung is one of the regencies in Lampung Province that develops pepper, but as is well known, the pepper commodity's productivity has decreased. Therefore, research is needed in order to establish a pepper commodity in West Lampung Regency. So, the objectives of this research is to determine the spatial distribution of pepper and its characteristics and analysing the land suitability for pepper as an effort to increase the pepper productivity

2. Materials and method

2.1. Research area

This research was conducted in West Lampung Regency, which is located the southernmost Sumatra Island, Indonesia. Geographically, West Lampung Regency is located at the position of 4º 47' - 5º 56' South Latitude, and 103º 35' - 104º 33' East Longitude. The total area of West Lampung Regency is 2141.57 km² consisting of 15 sub-districts [7]. The research area has an altitude that varies from 200 masl to > 2,000 masl. The landform in West Lampung Regency is dominated by Old Volcanic Mountains (V.33) around 26.1% and followed by Old Volcanic Hills (V.32) around 20.2%. West Lampung Regency has a climate type B, according to Oldeman, which has the number of wet months 7-9 months with rainfall ranging from 2500-3000 mm/year or 140-221 mm/month. The research location area is presented in figure 1.
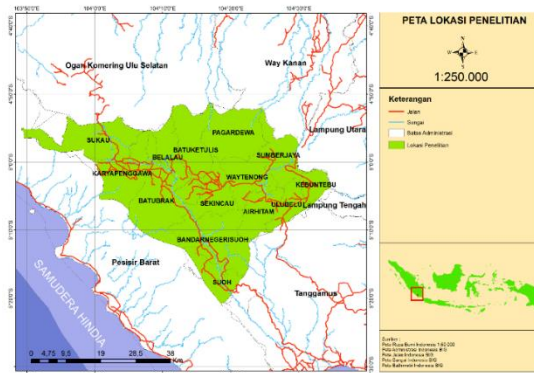

Figure 1. Study area

2.2. Analysis of distribution and spatial characteristics of pepper commodities

This analysis begins with the field survey, conducted in August 2020, using GPS to record the coordinate points of the pepper plantations' location. Then, the points are imported into Google Earth for reference in making training sample polygons. With these points and field surveys, the characteristic of pepper in satellite imagery can be identified, so it will make the classification process easier.

Sentinel-2 imagery (5 March 2019) was used as a base map for supervised classification. Supervised classification is the procedure most often used for quantitative analysis of remote sensing image data. This classification is based on the idea that a user can select sample pixels in an image that represents specific classes and then direct the image processing software to use these training sites as references for the classification of all other pixels in the image [8]. Supervised Maximum Likelihood Classification (MLC) has been used for classification. MLC is a robust technique, and there are significantly few

chances of misclassification [9]. The purpose of this analysis is to produce a map of spatial distribution and characteristics of pepper commodities in West Lampung Regency.

2.3. Analysis of land suitability
Land suitability evaluation is the process of assessing land resources for specific purposes using a proven approach or method. The results are in the form of directives and information about land use following existing land conditions [10]. Based on The Ministry of Agriculture No. 79 of 2013, land suitability is assessed for current conditions or after improvements have been made. More specifically, land suitability is viewed from the physical characteristics of the environment according to the type of commodity.

The level of land suitability for pepper commodities is classified as suitable (S1), quite suitable (S2), less appropriate (S3), and inappropriate (N). The assessment is based on agroclimatic conditions, physical and chemical characteristics of the soil. The determination of the land suitability class is obtained from the limiting factors found in the land by matching with the Land Mapping Unit (LMU). For example, LMU 5 has pH, slope, Cation Exchange Capacity (CEC), and drainage values in the S1 category and a base saturation value in the S2 category, thus the LMU is assigned to the S2n category or S2 class with limiting factor nutrient retention. The land suitability criteria for pepper, according to [9], are presented in table 1. The expected output in this analysis is to produce a land suitability map of pepper in West Lampung Regency to facilitate the direction-making in pepper commodities development.

Table 1. Land suitability criteria for pepper

| Growing condition criteria	Class of land suitability			
	S1	S2	S3	N
Daily temperature average (C)	23 - 32	20 – 23 32 - 34		< 20 > 34
Rainfall (mm)	2000 – 2500	2500 – 3000	3000 – 4000 1500 – 2000	< 1500 > 4000
Drainage	Good, Intermediate	Rather hampered	Hampered, rather quick	Very hampered, quick
Soil depth	> 75	50 – 75	30 – 50	< 30
Soil CEC (cmol+/kg)	> 16	5 – 16	< 5	
Base saturation (%)	> 50	35 – 50	< 35	
pH	5,0 – 7,0	4,0 – 5,0 7,0 -8,0	< 4,0 > 8,0	
C-organic	>0,4	<0,4		
Total N (%)	Moderate	Low	Very low	
P_2O_5 (mg/100g)	Moderate	Low	Very low	
K_2O	Moderate	Low	Very low	
Slope (%)	< 8	8 - 15	15 - 30	> 30

3. Results and discussion

3.1. Distribution and spatial characteristics of pepper commodities
Figure 3 shows the Sentinel imagery 2019 and land use map of West Lampung Regency. Based on the result of the land use map, the research area is mostly dominated by forest and other plantations with a total area of 69,153 ha and 56,089 ha (table 2). The forest areas consist of the National Park of Bukit Barisan (52,261 ha) and protected forest (16,890 ha), whereas the other plantation consists of coffee plantation and cacao plantation.

Table 2. Total area for each land-use category in West Lampung Regency

Land use	Area (ha)	%
Agriculture	16,866	8.51
Cloud	3,560	1.79
Forest	69,153	34.92
Other plantation	56,088	28.32
Pepper	47,339	23.90
Urban	5,022	2.53
Total	198,029.30	100

Regarding the pepper commodities, table 2 shows that the entire area of pepper commodities is 47,339 ha or 28.32 % of the total area. This figure is very high and different compared to the statistical data from the Plantation and Livestock Service Office of West Lampung Regency. In fact, pepper is the second-largest plantation after coffee. As indicated by the purple colour in figure 3, pepper is mostly found on the east side of West Lampung, to be precise, in the sub-districts of Way Tenong, Air Hitam, and Gedung Surian. These three sub-districts are the centers of pepper development in West Lampung Regency.
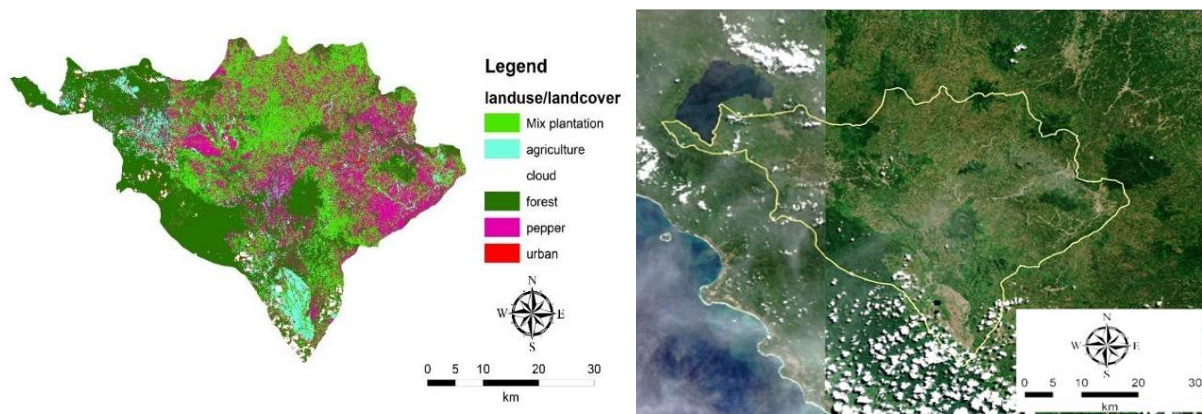
Figure 2. Sentinel-2 imagery 2019 and land use map of west Lampung regency

Based on field observation, most farmers plant pepper intercropping with coffee plants with have an average plant ratio of coffee and pepper is 4:1 (figure 4a, 4b). Pepper farmers in West Lampung use support plants as "*tajar hidup*" for pepper cultivation. While back then 2007, almost all farmers used dadap trees (*Erythrina variegate*), but this tree was exposed to large pests, so after that, farmers started using Gamal trees (*Gliricidia maculate*). Besides the intercropping method, there is also pepper monoculture, such as in the Gedung Surian sub-district, as shown in Figure 4c.
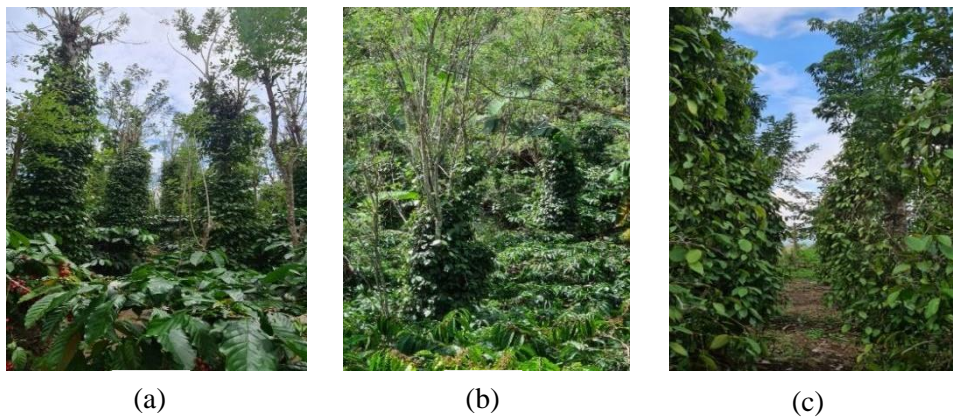
(a)   (b)   (c)

Figure 3. Characteristic pepper plantation in West Lampung Regency

3.2. *Land suitability of pepper commodities*

The LMU data at scale 1:100000is obtained from the Centre for Research and Development of Agricultural Land Resources [9], showed that West Lampung regency is divided into 32 LMU. LMU is a unit that has information about the physical properties of the soil and environmental characteristics per land unit. Soil physical properties include data on parent material, slope, landform, and chemical content. while environmental characteristics include rainfall and climate.. The distribution of soil type is presented in figure 5.
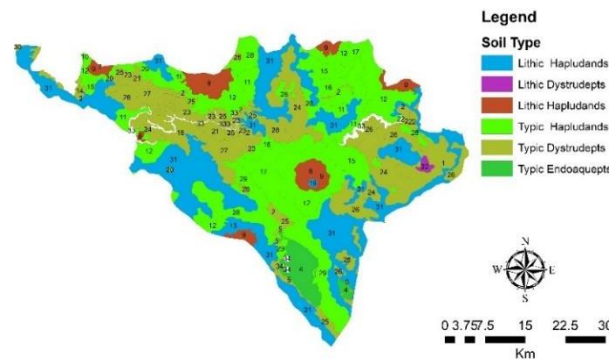

Figure 4. Distribution of soil type in West Lampung Regency

Table 3. The Total area of soil type in West Lampung Regency

No	Soil	Land Mapping Unit	Area	
			ha	%
1	Lithic Hapludands	13, 19, 31	56.918	27.41
2	Lithic Dystrudepts	32	556	0.27
3	Lithic Hapludands	6, 7, 8, 9	10.324	4.97
4	Typic Hapludands	10, 11, 12, 15, 16, 17, 28, 29	75.429	36.32
5	Typic Dystrudepts	1, 2, 3, 5, 14, 18, 20, 21, 22, 23, 24, 25, 26, 27, 30	58.274	28.06
6	Typic Endoaquepts	4	6.163	2.97
	Total		207.664	100

Based on figure 5, the most dominated soil type in West Lampung Regency is Typic Hapludands and Typic Dystrudepts, with a total area of 75.429 ha and 58.274 ha, respectively (Table 3). Typic Hapludands is soil type with Andisols order. Andisol is a soil developing in volcanic ejecta (such as volcanic ash, pumice, cinders, and lava) and/or in volcaniclastic materials, the colloidal fraction of which is dominated by short-range order minerals or Al-humus complexes. The dominant processes in most Andisols are weathering and mineral transformation. Translocation within the soils and accumulation of the translocated compounds [11]. While Typic Dystrudepts is soil type with Inceptisols order. Inceptisols are immature or young soils whose soil development still weaker than mature soils and much resembles the properties of the parent material, which has a udic moisture regime. Because of its amorphous phase, generally, this soil is relatively fertile [11].
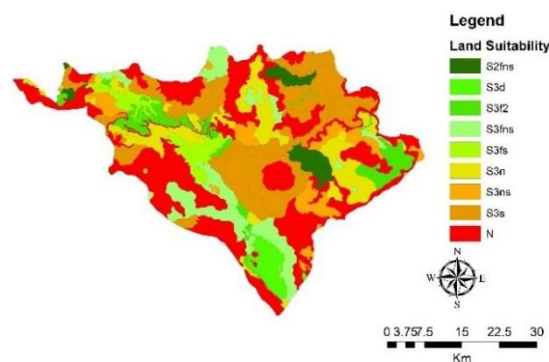

Figure 5. Land suitability map in West Lampung Regency

After got the LMU map, the next is to perform table matching with a limiting factor to produce a land suitability map, which is presented in figure 6. The results showed in West Lampung regency, there was 6,819 ha or 3.4% of the land was class S2 with limiting factor available nutrient, nutrient retention, and slope (table 4). Then class S3 is 127,326 ha or 64 % of the total area (Table 4). The limiting factors that led to S2 and S3 land suitability include land quality of slope (s), nutrients available (f), nutrient retention (n), drainage (d), either individually or in combination. In condition of the West Lampung regency, the main limiting factor is slope because the topography is a mountainous area.

Table 4. The total area of land suitability in West Lampung Regency

Land Suitability	LMU	Area (ha)		%
S2fns	10, 15	6.820	6.819	3.4
S3d	1, 2, 3, 5, 14, 23	5.530		
S3n	28, 29	23.615		
S3fns	27	19.706		
S3ns	4	11.772		
S3f	18, 20, 21, 22, 24, 25	12.389		
S3fs	11, 12, 16, 17	7.924		
S3s	26	46.390	127.326	64.3
N	6, 7, 8, 9, 13, 19, 30, 31, 32, 33, 34	63.915	63.915	32.3
Total			198060	

The actual suitability map on pepper shows that there are several limiting factors belonging to the S2 and S3 class categories. The limiting factor in the S2 land suitability class category is not as severe as for the S3 class. Limiting factors of the suitability map can be improved according to its characteristic

of the limiting factor. After improvements and upgrades are made, the actual land suitability can be intensified to potential land suitability.
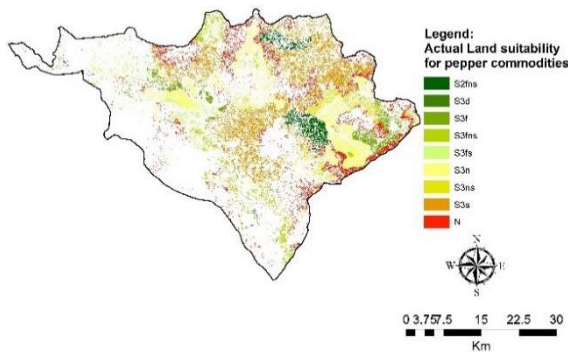

Figure 6. Actual land suitability of pepper commodities map in West Lampung Regency
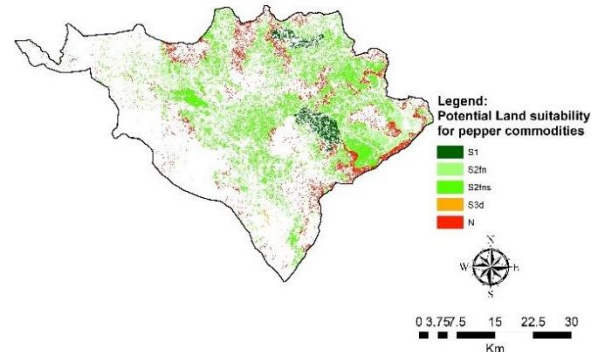

Figure 7. Potential land suitability for pepper commodities in West Lampung Regency

Based on figure 7, the suitability class for pepper is dominated by the S3 suitability class covering 34,508 ha or 73% of the total area (table 5). While for S2 class has 2,875 ha or 6% of the total land area. The dominant pepper plant is in the S3s land suitability class of 14,050 ha (table 5). As previously explained, West Lampung Regency is dominated by a mountainous area so that it has land with steep slopes. For some limiting factors on land, it can be improved by giving several treatments to the land. For example, the limiting factor of a slope can be minimized by the farmers' habit of using annual plants as support for pepper plants. For limiting factors of available nutrients, it can be improved by adding organic material and adding lime to increase soil acidity. While for limiting factor of nutrients retention, it can be improved by applying N, P, K fertilizers to increase the available nutrients according to the nutrient deficiency in the land.

Table 5. The total area of land suitability of current pepper commodities in West Lampung Regency

Land Suitability	LMU	Area (ha)		%
S2fns	10, 15	2,875	2.875	6.1
S3d	4	153		
S3f	1, 2, 3, 5, 14, 24	3,614		
S3fns	28, 29	3,830		
S3fs	27	1,552		
S3n	18, 20, 21, 22, 24, 25	8,323		
S3ns	26	2,986		
S3s	11, 12, 16, 17	14,050	34.508	72.9
N	6, 8, 9, 13, 19, 31, 32, 33, 34	9,949	9.949	21
Total		47,333		

After the provision is made, the potential land suitability map (figure 8) shows that the S1 land suitability class becomes 2,875 ha (table 6). This land is highly recommended for pepper development in terms of increasing production. However, the improvement of the limiting factors should be more concerned first. So, the utilization of land use can be maximized.

Table 6. The total area of potential land suitability of current pepper commodities in West Lampung regency

Land Suitability	LMU	Area (ha)	
S1	10, 15	2,875	2,875
S2fn	2, 3, 4, 6, 14, 23	3,614	34,354
S2fns	11, 12, 16, 17, 18, 20, 21, 22, 24, 25, 26, 27, 28, 29	30,741	
S3d	5	153	
N	1, 7, 8, 9, 13, 19, 30, 31, 32, 33	9,956	9,956
Total		47,339	

Regarding the S2 land suitability class, table 6 shows that the total area is 34,354 ha. This could be the next recommended land but still paying attention to the costs and efforts that need to be done. Considering that there are still many limiting factors that can reduce the production of pepper commodities. General suggested provisions for cultivated pepper have already been given by the Ministry of Agriculture [13], which consists of production, certification, circulation, and supervision of pepper commodities.

4. Conclusion

West Lampung Regency is categorized into land suitability actual class moderately suitable (S2fns) and marginally suitable (S3fns, S3ns, S3d, S3f, S3s, S3fs) with the biggest limiting factors are slope and nutrient retention. The pepper existing area in West Lampung Regency is 47,332 ha, which is dominated by intercropping cultivation. Pepper commodities needs for intensification through the provision of inputs and some treatment specific for the land. There is 2,875 ha of pepper areas that can be improved to S1 class with provision. Information from the results of this study is expected to help the West Lampung district government in improving and developing the commodity of pepper, both in terms of productivity and the selling value of pepper. The results of this study are the first steps of further detailed research on the commodity of pepper.

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