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Modification of land requirements (soil and climate) for specific growth of pepper (*Piper nigrum* L.) in East Luwu Regency

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Abstract. Efforts to increase the productivity of the pepper plant in East Luwu Regency as a leading plantation commodity efficiently can be done through the development of the pepper commodity on suitable lands to achieve optimal productivity. The land suitability criteria for modified pepper plants was based on the Indonesian Center for Agricultural Land Resources Development and Research. This study aims to modify the land suitability criteria for specific locations in East Luwu Regency. The method used in determining the range of land suitability criteria is the deductive method. The location points were determined by purposive sampling technique, namely at locations with high, medium, and low pepper production. The results showed that the range of location climatic characteristics criteria, among others, rainfall (mm) >2.000 were classified as S1 (very suitable), <2,000 and >3,000 were classified as unsuitable (N). The daily mean temperature of 22.6-32.1°C classified as very suitable (S1), and >34°C classified as unsuitable (N). The characteristics of the landscape and soil include 3-8% slope, good and moderate drainage, medium texture, slightly fine and fine, coarse fragments <5%, soil depth >100 cm, pH H₂O 5.6-<6 and C-organic >1.9% is classified as very suitable (S1), while slope > 30% with very inhibited and fast drainage, coarse texture, coarse fragments > 5%, soil depth <50 cm, pH H₂O <5.2 and >8.0, with content c-organic <0.4% is classified as unsuitable (N).

1. Introduction

Pepper (*Piper nigrum* L.) is a spice plant that plays an important role in the Indonesian economy as a leading commodity in the plantation sector because of its high economic value, making pepper a source of foreign exchange. Pepper is a potential export commodity in Indonesia. In 2017, pepper production in Indonesia ranked second in the world after Vietnam [1]. Pepper production in 2017 reached 6,790 tons [2]. East Luwu Regency ranks first as the largest pepper producer in South Sulawesi with a production contribution of 4,323.92 tons/year with an area of 5,871.30 ha of pepper plantations [3]. The highest production of pepper in East Luwu Regency located in Towuti District with a land area of 4,061.34 hectares with a total production of 2,843.17 tons/year [3].

Pepper is a high nutrient-demanding crop [4]. More attention has paid to secure high yield and good quality of sweet pepper affecting its productivity [4]. Successful cultivation of pepper plant is affected by various environmental factors like temperature and light intensity [5].

Efforts to increase the productivity of pepper plants in East Luwu Regency as a superior plantation commodity can carry out efficiently on suitable lands. Selection of suitable land to achieve optimal productivity can be done through the land evaluation stage based on the land requirements (soil and



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climate) for growth and production [6]. The available land (soil and climate) requirements will greatly assist in increasing pepper crop production. However, the information currently available (Requirements for Pepper Crops) by BBSDLP [7] is still general and not site-specific. For this reason, it is necessary to rearrange more specific land suitability criteria for pepper plants so that the determination of land suitability for pepper in the East Luwu region is more precise.

2. Methods

The research was conducted in three sub-districts: Towuti, Burau, and Mangkutana, East Luwu Regency (figure 1). The selection of research locations based on pepper production with high, medium, and low production categories. Soil sample analysis (table 1) was carried out at the Laboratory of Chemistry and Soil Fertility, Department of Soil Science, Faculty of Agriculture, Hasanuddin University, Makassar.

The stages of this research are 1) Determination of observation points by purposive sampling method based on locations that have pepper plants, 2) laboratory analysis, 3) determination of the range of land suitability criteria using deductive methods, namely based on the results of pepper production in three districts, namely Towuti District with high productivity, Burau Subdistrict with medium productivity, and Mangkutana with low productivity, 4) Modification of the characteristics of the climate and land for pepper plants based on land requirements by the Indonesian Center for Agricultural Land Resources Development and Research (BBSDLP) [7,8].

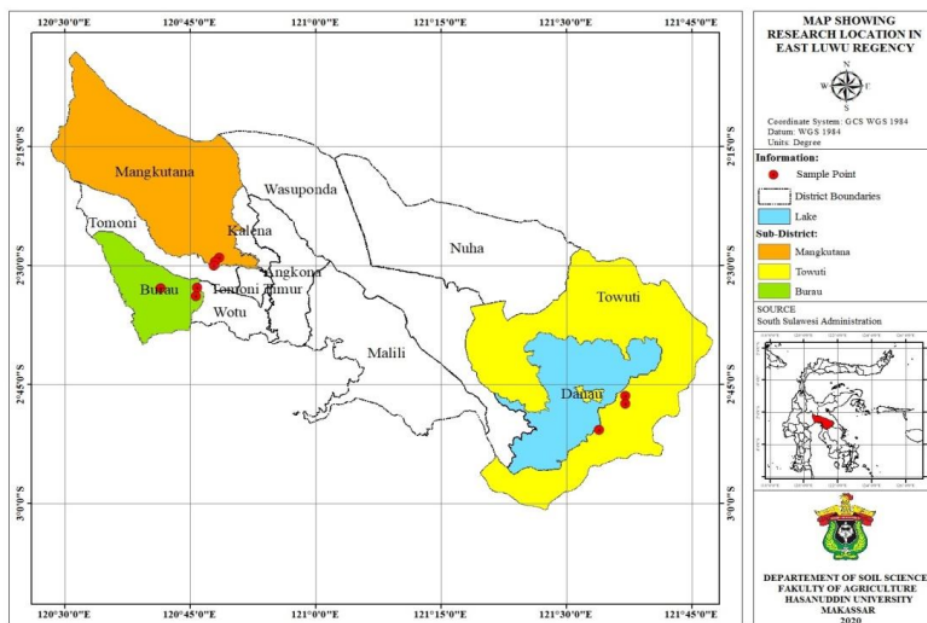


Figure 1. Work map of the research location.

Table 1. Parameters and methods of soil analysis in the laboratory.

Parameters	Methods
Texture	Hydrometer
pH (H ₂ O)	pH meter
C-organic	Walkey and Black
CEC, K, Na, Ca, Mg	Extraction NH ₄ Oac 1N pH 7.0

3. Results and discussion

3.1. The relationship between climate characteristics and pepper productivity

The relationship between annual rainfall and pepper productivity was showed that in 2,000-2,500 mm/year of rainfall can provide high pepper productivity with the highest average yield of 2.63 tons/ha found in Towuti District. The rainfall >2,500-2,600 mm/year gives moderate pepper productivity with an average yield of 1.53 tons/ha located in Burau District. Meanwhile, the highest rainfall around >2,600-3,000 mm/year with low productivity of pepper with an average yield of 1 ton/ha located in Mangkutana District.

Based on data, the annual average air temperature at the study location is 26.8 °C. The temperature was suitable for pepper plant growth in the range of 20-34 °C. The temperature in the morning was generally 21-27 °C, during the day 26-32 °C, and in the afternoon 24-30 °C [9]. The relative humidity of the study site was 82.6%. According to BBSDLP [7], the required relative humidity for pepper plants ranges from 60-80%.

3.2. Relationship between soil characteristics and pepper productivity

3.2.1. *Topography (slopes)*. Based on field observations, the research location has varying slopes, namely flat to slightly flat with a 0-8% slope. Towuti district classified as somewhat flat with a slope of 3-8% (T3P1, T3P2, T3P3) with the highest productivity of pepper, Burau district with moderate productivity is categorized as flat (T1P2, T1P3) to slightly flat (T1P1) with slopes of 0-3% and 5-8%, and Mangkutana District with the lowest pepper productivity categorized as r data (T2P2, T2P3) to slightly flat (T2P1) with slopes of 0-3% and 3-8%.

3.2.2. *Soil moisture*. Soil moisture shows the availability of water in the soil, especially during the dry season. Based on field observations, the soil profile of the research location has moist soil conditions, with a slightly wet (medium) category. This is in line with the results of research by [10], which states that the combination of soil moisture levels is highly dependent on the phase of plant growth and the type of plant. Thus, the pepper plant can categorize as an annual plant that can grow optimally in relatively moist soil conditions [11].

3.2.3. *Texture*. Soil texture shows the coarseness of the soil. Based on the ratio between the amount of sand (2 mm - 50 μ), dust (2 μ - 50 μ), and clay (<2 μ). The relationship between soil texture and pepper productivity at the study site showed that the soil texture with dusty clay gives high pepper productivity of around 2.3 to 3 tonnes/ha, compared to the clay texture class with lower productivity of about 0.8 to 1.7 tonnes/ha. The clay and dusty texture classes found in Towuti District with high pepper productivity are around 2.3 to 3 tonnes/ha. In comparison, the clay texture class found in Burau and Mangkutana Districts with moderate pepper productivity of 0.8 to 1.7 tonnes/ha and low 0.8 to 1.1 ton/ha.

3.2.4. *Soil depth*. Based on the results of the correlation analysis between soil depth and pepper productivity, there is no correlation. This relationship indicated by the value of $r = 0.316$, which means that the increase in pepper productivity is not influenced by soil depth. Soil depth is one of the characteristics that used as a growing requirement in the evaluation of annual crop areas, where annual plants with a soil depth of <50 cm are categorized as shallow and included if the depth is >100 cm. Based on the results in the field, the soil depth for the pepper plant in the research location for optimal depth > 100 cm and marginal <50 cm. The soil depth of about 120 to 150 cm in Towuti District tends to provide high pepper productivity of around 2.3 to 3 tons/ha, while Burau District with soil depths of 110 to 150 cm with moderate pepper productivity of about 0.8 to 1.7 tons/ha. Meanwhile, soil depth of 150 cm with low pepper productivity of about 0.8 to 1.1 tonnes/ha found in Mangkutana district.

3.2.5. *Rock*. Based on the results of observations on the coarse fragments of the research location, it was found in Burau District that the internal coarse fragments were around 5%, while in the Towuti and Mangkutana Districts, there were no coarse fragments found.

3.2.6. *pH H₂O*. Based on the results of the correlation analysis between pH H₂O and pepper productivity, there was a positive correlation. It showed that the correlation value indicated by the value of $r = 0.829$, which means that the productivity of pepper follows an increase in the pH value of H₂O. According to BBSDLP [7], pepper plants can grow at a pH of 5.0 to 7.0. The data on the distribution of H₂O pH at the research location can be seen in Table 2. Soil reactions (pH H₂O) around 5.5 to 5.8 can provide high pepper productivity, around 2.3 to 3 tonnes/ha found in the Towuti district. The pH values of 5.1 to 5.4 with moderate pepper productivity of around 0.8 to 1.7 tonnes/ha were found in Burau District, while pH 5.1 to 5.3 provide low pepper productivity, which is around 0.8 to 1.1 tonnes/ha in Mangkutana District.

3.2.7. *C-organic*. The percentage of C-organic topsoil can indicate the accumulation of organic matter in different environments [12]. Based on the results of the correlation analysis of the relationship between soil organic C and pepper productivity, it can be seen that there is a weak correlation between organic C and pepper productivity. This relationship is indicated by the value of $r = 0.488$, which means that the paper productivity follows the increase in C-organic. The C-organic content is around 1.63 to 2.16%, with high pepper productivity of around 2.3 to 3 tonnes/ha found in Towuti District. The C-organic content is around 1.74 to 2.1%, with moderate pepper productivity of about 0.8 to 1.7 tonnes/ha in Burau District. While the C-organic content of around 1.41 to 2.01% gave the lowest pepper productivity, which was around 0.8 to 1.1 tonnes/ha, found in Mangkutana District.

3.3. *Determination of land suitability criteria range for pepper*

Determination of the range of land suitability criteria was carried out using deductive methods, namely based on the results of pepper productivity in the three sub-districts. The optimal criteria were high and marginal productivity of pepper with low productivity of pepper. The observed land characteristics were based on general land characteristics by Sys [8] and associated with pepper productivity. Each land characteristic is given a range of values based on data obtained from the field and laboratory associated with the productivity of pepper in the three sub-districts.

3.4. *Modification of pepper land requirements*

The land requirements for pepper plants based on BBSDLP [7] was presented in table 2. Sys [8] have presented general land requirements in table 3, and for modification of land requirements, namely climate and soil, can be seen in table 4.

Modification of land requirements is based on general land characteristics by Sys [8] and land characteristics by BBSDLP [7], so that this modification of land requirements is a combination of land characteristics by Sys [8] and BBSDLP [7]. Modified land characteristics such as rainfall (mm), coarse fragments (%), soil depth (cm), pH H₂O, C-Organic, and slopes are characteristics of the land that have a different range of values between Towuti, Burau, and Mangkutana Districts. The range of values contained in the land requirements by BBSDLP [7] as well as data obtained from the field and laboratory are used as a comparison in determining the range of values to the modified land requirements for specific location pepper plants.

Other climatic characteristics that are not modified are air humidity (%) and dry period (months). This is because the research locations, namely Towuti, Burau, and Mangkutana Districts, have uniform air humidity data. In addition, the three research locations only had a wet month (BW) and a wet month (BL) without a dry month (BK), so that the dry period (months) did not meet the requirements in the characteristics to be modified. Other soil characteristics that are not modified are drainage, texture, CEC, and base saturation. This is because the research location has relatively the same texture, drainage, CEC, and base saturation classes so that the value range on these soil characteristics in the modified land

requirements for pepper plants in East Luwu Regency still uses the value range from the BBSDLP land requirements [7].

Table 2. Land requirements for pepper.

Requirements for use / land characteristics	Land suitability class			
	S1	S2	S3	N
Temperature (tc)				
Average daily temperature (°C)	23-32	20-23 32-34		>34 <20
Water availability (wa)				
Rainfall (mm)	2,000-2,500	2,500-3,000	3,000-4,000 1,500-2,000	<1,500 >4,000
Humidity (%)	60-80	-	-	<50 >100
Duration of dry period (months)	<2	<3	3-4	>5
Availability of oxygen (OA)				
Drainage	Fine, moderate	Somewhat hampered	Stuck, rather fast	Very hampered, fast
Root Media (rc)				
Texture	Medium, slightly fine, fine	Rather rough	Coarse, very smooth	Rough
Coarse material (%)	<15	15-35	35-55	>55
Soil depth (cm)	>75	50-75	30-50	<30
Nutrient retention (nr)				
CEC clay (cmol)	>16	5-16	<5	
Base saturation (%)	>50	35-50	<35	
pH H ₂ O	5.0-7.0	4.0-5.0 7.0-8.0	<4.0 >8.0	
C-organic (%)	>0.4	≤0.4		
Available Nutrient (na)				
N total (%)	Moderate	Low	Very low	-
P ₂ O ₅ (mg/100 g)	Moderate	Low	Very low	-
K ₂ O (mg/100 g)	Moderate	Low	Very low	-
Toxicity (xc)				
Salinity (dS / m)	<5	5-8	8-10	>10
Sodicity (xn)				
Alkalinity / ESP (%)	<10	10-15	15-20	>20
Sulfidic hazard (xs)				
Depth of sulfidic (cm)	>100	75-100	40-75	<40
Erosion hazard (eh)				
Slope (%)	<8	8-15	15-30	>30
Erosion hazard	Very light	Low-medium	Weight	Very heavy
Danger of flooding (fh)				
- Height (cm)	-	-	25	>25
- Length (days)	-	-	<7	≥7
Land preparation (lp)				
Surface rock (%)	<5	5-15	15-40	>40
Rock outcrop (%)	<5	5-15	15-25	>25

Source: Wahid and Suparman [9].

Table 3. Land characteristics of research sites.

Land Characteristics	Research sites		
	Towuti	Burau	Mangkutana
Temperature (tc)			
Average daily temperature (°C)	22.6 – 32.1	22.6 – 32.1	22.6 – 32.1
Water availability (wa)			
Rainfall (mm)	2,000 – 2,500	>2,500 – 2,600	>2,600 – 3,000
Duration of dry period (months)	0	0	0
Availability of oxygen (OA)			
Drainage	Good	Good	Good
Root Media (rc)			
Texture	Medium, slightly fine, fine	Very smooth	Very smooth
Coarse fragment (%)	-	5%	-
Soil depth (cm)	133.3	130	150
Nutrient retention (nr)			
pH H ₂ O	5.6	5.3	5.2
C-organic (%)	1.9	1.9	1.7
CEC (cmol/kg clay)	14.3	30.2	15.7
Base saturation (%)	55.7	35.9	50.9
Sum of base cations (cmol/kg of soil)	3.7	3.9	3.9
Topography (t)			
Slope	3 – 8	0-3 5-8	0-3 3-8

Table 4. Land requirements for pepper plants in East Luwu Regency.

Requirements for use / land characteristics	Land Class			
	S1	S2	S3	N
Temperatur (tc)				
Average daily temperature (°C)	22.6 – 32.1	20 – 22.6 32.1 – 34		<20 >34
Water availability (wa)				
Rainfall (mm)	2,000 – 2,500	>2,500 – 2,600	>2,600 – 3,000	<2,000 >3,000
Humidity (%)	60-80	-	-	<50 >100
Duration of dry period (months)	<2	<3	3-4	>5
Availability of oxygen (OA)				
Drainage	Fine, moderate	Somewhat hampered	Stuck, rather fast	Very hampered, fast
Root Media (rc)				
Texture	Medium, slightly fine, fine	Rather rough	Coarse, very smooth	Rough
Crude fragment (%)	<5	5%		>5%
Soil depth (cm)	>100	75 – 100	50 – 75	<50
Nutrient retention (nr)				
pH H ₂ O	5.6 – <6	5.2 – 5.6 >6.8		<5.2 >8
C-organic (%)	>1.9	1.7-1.9	0.4-1.7	<0.4
CEC (cmol/kg clay)	>16	5-16	<5	
Base saturation (%)	>50	35-50	<35	
Toxicity (xc)				
Salinity (dS / m)	<5	5-8	8-10	>10
Sodicity (xn)				
Alkalinity / ESP (%)	<10	10-15	15-20	>20
Topography (t)				
Slope (%)	3 – 8	0-3 8-15	15-30	>30

4. Conclusions

Based on data in the field, the climatic characteristics considered appropriate in the evaluation of land suitability for specific pepper plants in East Luwu Regency include rainfall of 2,000 – 3,000 mm / year with a daily average temperature of 20-34 °C. Rainfall <2,000 mm and >3,000 mm and daily mean temperature <20 °C and > 34 °C were considered unsuitable based on the productivity of pepper. The characteristics of the terrain and soil that are considered suitable for pepper plants include slopes of 0-15%, with good drainage, medium, slightly fine, and fine texture, coarse fragments <5%, soil depth > 75 cm, pH (H₂O) 5.6, - <6 and C-organic >1.7%. Slopes >30%, drainage is very hampered, coarse texture, coarse fragments >5% and <50, soil depth <50 cm, pH (H₂O) <5.2 and >8 and C-organic <0.4% are considered unsuitable based on pepper productivity.

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