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Land Suitability for Chili and Tomato Crops in Wayamiga Village East Bacan Sub-District South Halmahera District, Indonesia

Efendi Umar [a,b++], Ramli Hadun [c*], Adnan Sofyan [c] and Amiruddin Teapon [d]

[a] Department of Agriculture, Universitas Khairun Ternate, Indonesia.
[b] Regional Secretary, Staff South Halmahera District, Indonesia.
[c] Agriculture Studies Program, Postgraduate at Universitas Khairun, Ternate, Indonesia.
[d] Faculty of Agriculture, Soil Science Study Program, Universitas Khairun, Ternate, Indonesia.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Chili (*Capsicum annum* L.) and tomato (*Solanum lycopersicum*) crops are two vegetable horticultural commodities with high economic value and market demand and it's becomes extremely important to consider land suitability and environmental sustainability factors to reduce losses and increase the probability of success. This research aimed to identify land suitability, land limiting factors, and land management for the development of chili and tomato crops in Wayamiga Village East Bacan Sub-district. The research uses a land survey method with a free survey observation distance system. The land characteristics identification employs the Boring Technique on 13 land units and land sampling of 7 samples. Land suitability analysis refers to the FAO's land suitability classification system (1976) up to the sub-class of land suitability using a matching

[++] Graduate Student;
**Corresponding author: Email: ramlihadun@gmail.com;*

method. The research results indicate that the land is actually suitable for chili in Wayamiga Village with the analysis result suggesting a suitable land and S3(write this in full since it is the first time it appears) for chili and tomato is 1.940,7 ha (42,1%) and not suitable (N) is 2.666,3 ha (57,9%). Suitable land for chili and tomato crops is usually moderately suitable land (S2) (do same as foe S3) and marginally suitable land (S3). The land limiting factors that affect the land suitability for chili and tomato crops include rainfall during the growth period, humidity, soil drainage, base saturation, soil pH, organic C, soil salinity, total nitrogen nutrients (N-total), phosphorus (P_2O_5), potassium (K_2O), flood hazard class, land average temperature, soil effective depth, surface rocks, and slope. Land management applied to maintain the sustainability of chili and tomato farming in Wayamiga Desa consists of the improvement of environmental humidity conditions, tillage, construction of drainage channels, application of lime and organic fertilizers, application of nitrogen, phosphorus, and potassium fertilizers, and flood prevention.

Keywords: Land suitability; land limiting factors; land management; chili and tomato crops.

1. INTRODUCTION

Chili (*Capsicum annum* L.) is a vegetable horticultural commodity that has a high economic value. Demand for chili is increasing every year for cooking ingredients, food industry, and medicine. This is a potential and opportunity that farmers can grab to make a fortune [1]. Likewise, tomato (*Solanum lycopersicum*) as a horticultural commodity has a high economic value and demand in the world market [2]. Tomato, besides being consumed fresh and as a cooking ingredient, can be further processed as a raw material for the food industry, such as fruit juices and sauce [3]. With the substantial economic value and potential benefits of chili and tomato, it is necessary to weigh the development of both horticultural commodities to improve farmers' economy and maintain the availability of the products in the market.

Agricultural development, especially horticultural commodity, need to be based on regional potential and capabilities to guarantee plant productivity and land sustainability [4,5,6]. The potential of an area or region for agricultural development depends on the suitability between land quality and characteristics and the plant agroecological requirements since each agricultural commodity requires specific land properties for optimum growth and production [7]. Agricultural commodity development that is suitable to plant agroecological requirements along with appropriate land management can produce optimum yield and maintain land productivity sustainably [8].

A land resource survey and land suitability evaluation can be used to identify land potential for the development of horticultural commodities including chili and tomato. Land suitability evaluation is a process of assessing the potential of land for specific uses [9]. Land suitability is the acceptable level of land condition for a particular use or for a type of plant. It can be assessed for current land conditions and future conditions after the application of land improvement efforts [10] Missing in reference list); [11].

Wayamiga Village East Bacan Sub-district has an area of ± 4.631 Ha. It is a potential area for the development of horticultural commodities in the South Halmahera district. The common commodities developed and the source of farmers' income are chili (*Capsicum annum* L.) and tomato (*Solanum lycopersicum*). However, the productivity of chili and tomato crops, on average, is lower compared to the crops' national productivity. At the regional level, which is South Halmahera District, chili crop productivity is only 2 tons.ha^{-1} and tomato is 3 tons.ha^{-1} [12] (Missing in reference list). The low productivity of chili and tomato crops is related to land suitability, planting area, land management, and pest and disease issues.

Based on the aforementioned, it is imperative to carry out research to identify the land suitability for chili and tomato crops and the limiting factors that affect land suitability and to determine land management efforts to improve land productivity and sustainability of horticultural farming in Wayamiga Village East Bacan sub-district.

2. MATERIALS AND METHODS

The research took place from January to March 2023. The research location is administratively located at Wayamiga Village East Bacan Sub-district South Halmahera District and geographically situated between 00°33'58.22" south latitude and 00°42'10.34" south latitude and between 127°31'44.71" east longitude and 127°34'33.11" east longitude. The location of the research site is illustrated in Fig. 1. Tools and

materials used consisted of a global positioning system (GPS), soil drill, Munsell soil color chart book, soil description card, sample bags, fieldwork map on a scale of 1: 50.000, and soil samples in the research area. The research employed an analytical approach by dividing the landscape in Wayamiga village into homogenous land units through an overlay process between a landform map, geology, topography, and soil. There were a total of 13 homogenous land units and 7 soil profile samples in the research. Homogenous land units are the analysis units (population) in the land suitability evaluation study where land characteristics and area are used n the assessment of land potential [8].

The soil sample analysis consisted of soil structure, soil pH, cation-exchange capacity, N-total, P_2O_5, K_2O, Organic C, and soil salinity. Evaluation of land suitability referred to the FAO's land suitability classification system (1976) using a matching method by comparing land characteristic data to land suitability criteria for chili and tomato crops.

Class and sub-class determination used guidelines from FAO, 1976 by setting minimum limiting factors in classes and subclasses. There were 5 land suitability classes, namely S1 (highly suitable), S2 (moderately suitable) S3 (marginally suitable), N1 (currently not-suitable), and N2 (permanently not suitable). The determination of actual suitability was the current suitability and had not considered improvement efforts and management levels to address the land limiting factors of each land unit. Whereas, potential land suitability was the land suitability to be achieved if land improvement efforts were implemented with certain management level against the land limiting factors so that land productivity levels and production per unit can be estimated [13,4,14].

This section can be improved by indicating how classifications of this study were done and also potential suitability was done.

Further what guided the limiting factor selection

Author to present a section of FAO land suitability classification.

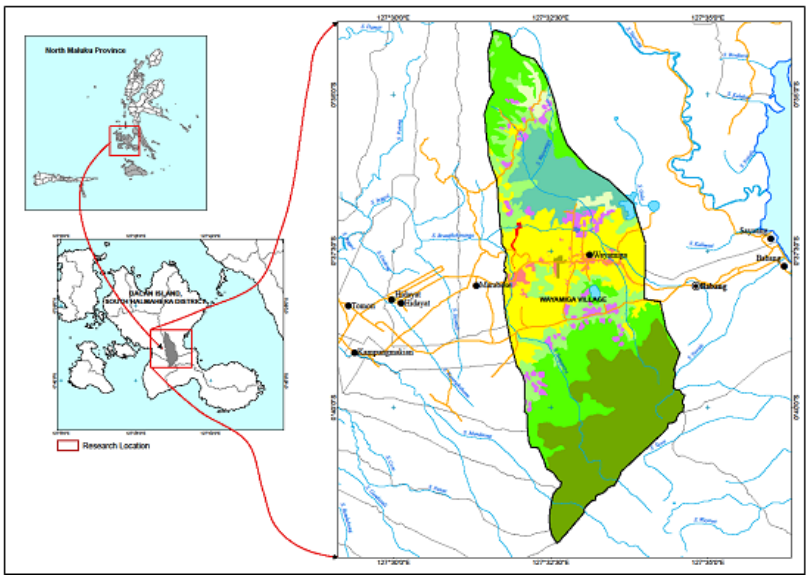

Fig. 1. Map of research location in South Halmahera District

3. RESULTS AND DISCUSSION

3.1 Land Physical Condition

Land is a physical environment consisting of soil, climate, relief, hydrology, and vegetation that affect its utilization potential [15,16]. Climatologically, the research area is in the agro-climatic zone D2 with an average wet month (CH>200 mm) is 4 months and an average dry month (CK<100 mm) is 3 months. The annual rainfall in the area is 1,916.9 mm/year with a temperature of 26.4^{o}C, annual humidity is 84.3% and annual sunshine is 64.5%. The village topography is dominated by a steep

topographic class (>45%) of 1.984,8 ha (42.9%). The appropriate topographic class for the development of horticultural crops of chili and tomato is 2,056.2 ha (44.4%). The soil in the village, according to the national soil classification system [17] and equivalent to the soil taxonomy system [18] comprises 5 types, namely Umbrisol (Lithic Udorthents), District Gleysol (Typic Endoaquepts), Lytic Cambisol (Lithic Dystrudepts), Gleyic Cambisol (*Aquic Dystrudepts*), and District Cambisol (*Typic Dystrusepts*). The mapping result indicates types of district cambisol (*Typic Dystrusepts*) soil is the dominant type of soil in Wayamiga Village with a distribution area of 3,052.5 ha (65.9%). The district cambisol (*Typic Dystrusepts*) soil in dry land is mostly used by the villagers in the Wayamiga Village for chili and tomato cultivation.

3.2 Actual Land Suitability for Chili

The actual land suitability for chili in the Wayamiga village based on the analysis result is that land in the suitable order (S) was 1,940.7 ha (42.1%) and not suitable (N) was 2,666.3 ha (57.9%). The suitable order land was divided into three classes: moderately suitable (S2) of 961.1 ha (20.9%) and marginally suitable (S3) of 979.6 ha (21.3%). Whereas, the not suitable order (N) comprised currently not-suitable class (N1) of 192.5 ha (4.2%) and permanently not suitable (N2) of 2,473.8 ha (53.7%). Table 1 presents the result of the actual land suitability analysis for chili.

Give a comprehensive description of what each label/abbrevation represents. What guided this categorization of different classes and also how where the limiting factors arrived at?

For example, what does N, N1, N2, S, S2rfn, LMU e.t.c. stand for. This can be done under research methods.
The actual land suitability for chili in the sub-class categories of land suitability varied, especially in the moderately suitable (S2) and marginally suitable (S3) classes. The analysis resulted in three sub-classes in the moderately suitable land (S2), namely S2rfn, S2fnb, and S2fne sub-classes. Likewise, three sub-classes were found in the marginally suitable class (S3) including S3rb, S3rp, and S3e. Whereas, only one sub-class was found in the currently not-suitable class (N1), which was sub-class N1e, and two sub-classes in the permanently not-suitable class (N2), which were N2p and N2e.

3.3 Actual Land Suitability for Tomato

The analysis of the actual land suitability for tomato in Wayamiga Village resulted in land in the suitable order (S) of 1,940.7 ha (42.1%) and not suitable (N) of 2,666.3 ha (57.9%). The suitable land order was divided into moderately suitable class (S2) of 961.1 ha (20,9%) and marginally suitable class (S3) of 979.6 ha (21,3%). Whereas, the not-suitable order (N) comprised a currently not suitable class (N1) of 192.5 ha (4.2%) and a permanently not-suitable class (N2) of 2,473.8 ha (53.7%). Table 2 presents the result of the actual land suitability analysis for tomato.

The actual land suitability for tomato in the sub-class categories of land suitability varied in the moderately suitable (S2) and marginally suitable (S3) classes. The analysis resulted in three sub-classes in the moderately suitable land (S2), namely S2twrfn, S2twfnb, and S2twfne. Likewise, three sub-classes were found in the marginally suitable class (S3) including S3rb, S3rp, and S3e. Whereas, only one sub-class was found in the currently not suitable class (N1), which was N1e, and two sub-classes in the permanently not suitable (N2), which were N2p and N2e. Fig. 2 illustrates the spatial distribution of the actual land suitability sub-classes for chili and tomato.

3.4 Potential Land Suitability for Chili

How did you calculate potentials and what factors were they based on. The author can discuss this under research methods.

The result of the potential land suitability analysis for chili in Wayamiga Village obtained the land with a highly suitable class (S1) of 869.5 ha (18.9%), moderately suitable class (S2) of 525.1 ha (11.4%), and marginally suitable class (S3) of 546.1 ha (11.9%). The currently and permanently not suitable land (N1) did not change due to hurdles in improving the existing limiting factors. Table 3 indicates the results of the potential land suitability analysis for chili.

The potential land suitability sub-classes for chili (Table 3) in the moderately suitable class land (S2) from the analysis result consisted of two types, namely S2rb which comes from actual sub-class S3rb, and S2e which comes from actual sub-class S2wfne. The marginally suitable (S3) subclasses, namely S3rp and S3e, did not change due to difficulties in addressing the existing limiting factors. The limiting factors of the

Table 1. Actual land suitability for chili in Wayamiga Village

No	Land Suitability		Limiting Factors	LMU	Area	
	Class	Sub-class			Ha	%
1	S2	S2rfn	Rooting media (r), nutrient retention (f), available nutrients (n)	2	292.9	6.4
		S2fnb	Nutrient retention (f), available nutrients (n), flood hazard (b)	1B	576.6	12.5
		S2fne	Nutrient retention (f), available nutrients (n), erosion hazard (e)	8	91.6	2.0
2	S3	S3rb	Rooting media (r), flood hazard (b)	1A	433.5	9.4
		S3rp	Rooting media (r), land preparation (p)	3,5	428.8	9.3
		S3e	Erosion hazard (e) (slope 8-15%)	6	117.3	2.5
3	N1	N1e	Erosion hazard (e) (slope 15-30%)	7,10	192.5	4.2
4	N2	N2p	Land preparation (p)	4	115.5	2.5
		N2e	Erosion hazard (e) (slope >30%)	9,11,12	2,358.3	51.2
Total					**4,607.0**	**100**

Source: Results of land suitability analysis 2023

Table 2. Actual land suitability for tomato in Wayamiga Village

No	Land Suitability		Limiting Factors	LMU	Area	
	Class	Sub-class			Ha	%
1	S2	S2twrfn	Temperature (t), water availability (w), rooting media (r), nutrient retention (f), available nutrients (n)	2	292.9	6.4
		S2twfnb	Temperature (t), water availability (w), nutrient retention (f), available nutrients (n), flood hazard (b)	1B	576.6	12.5
		S2twfne	Temperature (t), water availability (w), nutrient retention (f), available nutrients (n), flood hazard (e)	8	91.6	2.0
2	S3	S3rb	Rooting media (r), flood hazard (b)	1A	433.5	9.4
		S3rp	Rooting media (r), land preparation (p)	3,5	428.8	9.3
		S3e	Erosion hazard (e) (slope 8-15%)	6	117.3	2.5
3	N1	N1e	Erosion hazard (e) (slope 15-30%)	7,10	192.5	4.2
4	N2	N2p	Land preparation (p)	4	115.5	2.5
		N2e	Erosion hazard (e) (slope>30%)	9,11,12	2,358.3	51.2
Total					**4,607.0**	**100**

Source: Results of land suitability analysis 2023
(Author to see suggestion under suitability)

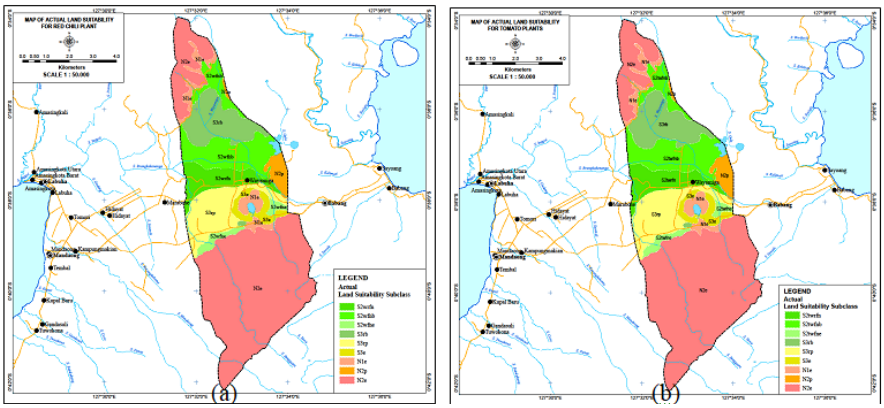

Fig. 2. Actual Land Suitability Map: a) for chili and b) for tomato in Wayamiga Village
The can try make the maps more clear

Table 3. Potential land suitability for chili in Wayamiga Village

No	Land Suitability		Limiting Factors	LMU	Area	
	Class	Sub-class			Ha	%
1	S1	-	-	1B,2	869.5	18.9
2	S2	S2rb	Rooting media (r), flood hazard (b)	1A	433.5	9.4
		S2e	Erosion hazard (e) (slope 3-8%)	8	91.6	2.0
3	S3	S3rp	Rooting media (r), land preparation (p)	3,5	428.8	9.3
		S3e	Erosion hazard (e) (slope 8-15%)	6	117.3	2.5
4	N1	N1e	Erosion hazard (e) (slope 15-30%)	7,10	192.5	4.2
5	N2	N2p	Penyiapan lahan (p)	4	115.5	2.5
		N2e	Bahaya erosi (e) (lereng >30%)	9,11,12	2,358.3	51.2
Total					**4,607.0**	**100**

Source: Results of land suitability analysis 2023
Give explanations for your labels

sub-class S3rp comprised rooting media (r) with shallow soil depth conditions and land preparation (p) with large quantities of surface rock distribution. The limiting factor in the sub-class S3e was primarily erosion hazard (e) with a slope condition of 8-15%. The sub-class of the currently not suitable land (N1), which is N1e, had a permanent limiting factor of the slope of 15-30% that is difficult to repair. Moreover, in the permanently not suitable sub-class of N2p, the limiting factor was the large quantities of surface rock, whereas in the sub-class N2e, the limiting factor was the slope of >30%, which is also difficult to repair.

3.5 Potential Land Suitability for Tomato

The result of the potential land suitability analysis for tomato in Wayamiga Village indicated an increase in land area in the moderately suitable (S2) land of 1.394,6 ha (30,3%), whereas the marginally suitable (S3) land decreased by 546.1 ha (11.9%). Table 4 indicates the results of the potential land suitability analysis for tomato.

The potential land suitability classes for tomato did not increase to the highly suitable class (S1) due to limiting factors in the moderately suitable class (S2) land such as temperature, water availability (humidity), and erosion hazard (slope 8-15%) that are difficult to repair. Land improvement efforts only reduce land-limiting factors. Therefore, the moderately suitable (S2) sub-classes, namely S2tw and S2twe, still exist. The sub-class S2twrb, in particular, is a sub-class that resulted from land improvement in the marginally suitable subclass S3rb.

The currently not suitable class (N1) land for tomato with subclass N1e (limiting factors include erosion hazard and slope of 15-30%) and the permanently not suitable class (N2) with subclass N2p (limiting factor includes a large quantity of surface rock) and subclass N2e (limiting factor includes the slope of >30%) are lands with land limiting factors that are difficult to address; thus, the classes and their sub-classes did not change. Fig. 3 illustrates the spatial distribution of the potential land suitability sub-classes for chili and tomato.

3.6 Minimum Land Limiting Factors

Land limiting factors are part of the land quality or characteristics that are in a minimum or limited condition that affect land suitability classes. There are two minimum limiting factors based on their properties, namely permanent limiting factors that are impossible to repair and economically unprofitable and limiting factors that are repairable and economically profitable.

The minimum land limiting factors for chili and tomato in Wayamiga Village that are repairable include rainfall during the growth period (w2), soil drainage (r1), base saturation (f2), soil pH (f3), organic C (f4), total nitrogen nutrients (n1), phosphorus (P_2O_5) (n2), potassium (K_2O) (n3), and flood hazard classes (b). Whereas, the minimum limiting factors that are difficult to repair consist of average temperature (t), humidity (w3), the effective depth of soil (r4), surface rocks (p1), and slope (e2). Zhang & He [19], Sudjus & Hadun [13], and Suheri et al. [20] suggest that liming and applying organic matter can enhance base saturation (f2), soil pH (f3), and organic matter content (f4).

3.7 Land Management for Chili and Tomato Crops

Land management for the development of chili and tomato crops in Wayamiga Village aims to improve land quality and characteristics so that the land can produce sustainably. Moreover, it aims to improve the minimum limiting factors that are repairable, such as rainfall during the growth period, humidity, soil drainage, base saturation, soil pH, organic C, total nitrogen nutrients, phosphorus (P_2O_5), potassium (K_2O), and flood hazard classes. Table 5 lists the types of land management for each limiting factor.

Table 4. Potential land suitability for tomato in Wayamiga Village

No	Land Suitability		Limiting Factors	LMU	Area	
	Class	Sub-class			Ha	%
1	S2	S2tw	Temperature (t), water availability (w)	1B,2	869.5	18.9
		S2twrb	Temperature (t), water availability (w), rooting media (r), flood hazard (b)	1A	433.5	9.4
		S2twe	Temperature (t), water availability (w), erosion hazard (e) (slope 3-8%)	8	91.6	2.0
2	S3	S3rp	Rooting media (r), land preparation (p)	3,5	428.8	9.3
		S3e	Erosion hazard (e) (slope 8-15%)	6	117.3	2.5
3	N1	N1e	Erosion hazard (e) (slope 15-30%)	7,10	192.5	4.2
4	N2	N2p	Land preparation (p)	4	115.5	2.5
		N2e	Erosion hazard (e) (slope >30%)	9,11,12	2,358.3	51.2
Total					**4,607.0**	**100**

Source: Results of land suitability analysis 2023

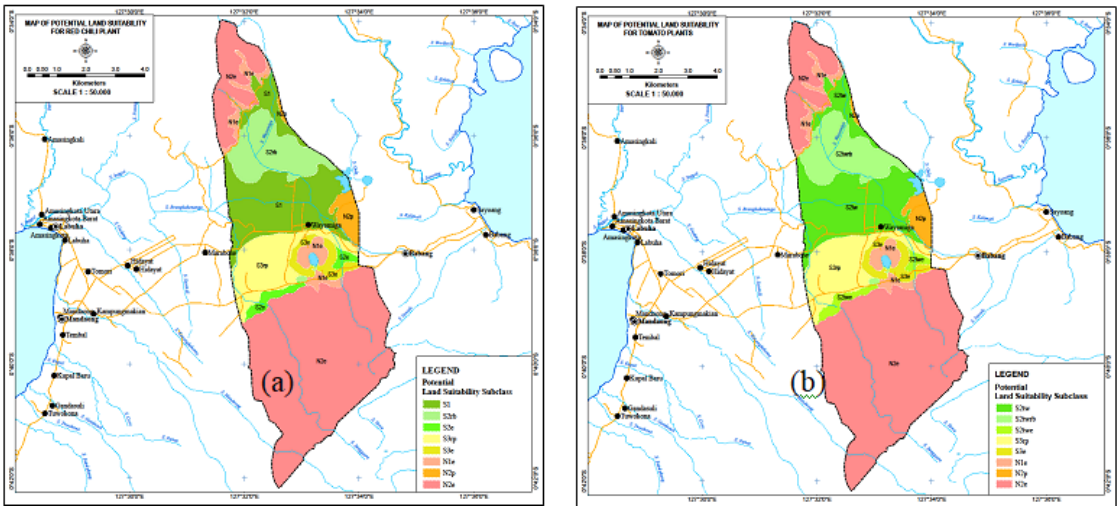

Fig. 3. Potential land suitability map: (a) for chili and (b) or tomato in Wayamiga Village

Table 5. Types of land management for chili and tomato in Wayamiga Village

Class	Minimum Limiting Factors	Type of Land Management	Type of Horticultural Crop
S2,S3	Rainfall	Reduction of environmental humidity, tillage	Tomato
S2,S3	Humidity	Reduction of environmental humidity, tillage	Tomato
S2,S3	Soil drainage	Construction of drainage channels and tillage	Chili and tomato
S2,S3	Base saturation	Application of lime	Chili and tomato
S2	Soil pH	Application of lime	Chili and tomato
S2	Organic C	Application of organic fertilizers	Chili and tomato
S2	Total N	Fertilization with urea fertilizer	Chili and tomato
S2	P_2O_5	Fertilization with SP36 fertilizer	Chili and tomato
S2	K_2O	Fertilization with KCL fertilizer	Chili and tomato
S2,S3,N1	Flood hazard	Construction of drainage channels and flood protection structures	Chili and tomato

Source: Results of data analysis 2023

The paper can be enhanced by author explaining what the findings mean and linking the findings to other authors.

The results of land suitability evaluation for chili and tomato crops in Wayamiga Village East Bacan sub-district indicate that land characteristics that became the main limiting factors were rainfall, humidity, soil drainage, base saturation, soil pH, Organic- C, total N, P_2O_5, and K_2O [20,13]. These limiting factors are the primary factors in areas with fairly high rainfall (>200 mm for 4 months) and easily leached soil conditions. The land unit that was unsuitable to their primary limiting factors was erosion where most of the area, which is 1.984,8 ha (42,9%), has steep topographic class (>45%). Rainfall and erosion are the primary limiting factors in island areas in agricultural development.

4. CONCLUSION

Land potential suitable for the development of chili and tomato crops in Wayamiga village consists of moderately suitable class (S2) of 961.1 ha (20.9%) and marginally suitable class (S3) of 979.6 ha (21.3%). The development of chili and tomato in the suitable land requires land management of the land limiting factors of rainfall during the growth period, soil drainage, base saturation, soil pH, organic C, nitrogen nutrient element, phosphorus, and potassium, and flood hazard threats.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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