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LAND SUITABILITY ASSESSMENT FOR *JARAK TOWO* CASSAVA DEVELOPMENT (CASE STUDIES IN TAWANGMANGU AND NGARGOYOSO SUB-DISTRICTS, KARANGANYAR REGENCY, INDONESIA)

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ABSTRACT

Jarak towo is one of the local varieties of cassava that has uniqueness and characteristics, including a fluffier and more savory taste, a more expensive price and better market opportunities compared to other types of cassava. However, this cassava requires special land criteria to produce abundant and quality tubers. This is related to the land suitability factor. This study aimed to assess land suitability to obtain potential land for the development of jarak towo. It was carried out in Tawangmangu and Ngargoyoso Sub-districts, Karanganyar Regency. This research was explorative-descriptive with a land survey approach. The survey was carried out in four land map units (LMU) based on land use and altitude. The altitude of each area is 1,400 masl (LMU 1), 1,200 masl (LMU 2), 1,000 masl (LMU 3) and 800 masl (LMU 4). Land suitability was obtained by matching soil and land characteristics with the optimum growth requirements of *jarak towo* cassava. The results showed that not all land in the Ngargoyoso and Tawangmangu Sub-district was suitable for the development of jarak towo. Some land and soil parameters were at a marginal level, making them a limiting factor for land suitability and affect the growth, quantity and quality of cassava tubers. The limiting factor will reduce production or double the required input. Land in the study area was marginally suitable (S3) and not suitable (N) for jarak towo. The limiting parameters for cassava cultivation were low temperature, low organic C, steep slopes, low P_2O_5 and K_2O and shallow soil. Several locations that had the potential for the development of *jarak towo* cassava were LMU 2, 3, and 4 in Tawangmangu and LMU 3 and 4 in Ngargoyoso with additional improvement efforts. Improvements that could be made were the application of a well-constructed bench terrace and the addition of organic fertilizers combined with P and K fertilizers.

Key words: land evaluation, limiting factors, potential land, jarak towo, land map units, terraces

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INTRODUCTION

Cassava is one of the food commodities produced from dryland farming to improve food security [1-3]. Consumption of cassava-based products is an increasing trend in Indonesia, as indicated by the increasing number of cassava imports from year to year. This condition is inversely proportional to the declining trend in national production and harvested area. The average national growth rate has decreased by 0.89% every year, as indicated by the reduction in harvested area from 1.41 million hectares in 1980 to 0.87 million hectares in 2016. In a shorter period, the last 5 years, the growth rate of harvested area for cassava was even lower, at 5.37% per year. Meanwhile, import growth from 2000 to 2015 reached 76.32% [4].

Karanganyar Regency is one of the cassava producing areas in Central Java Province, Indonesia [5]. Many varieties of cassava are cultivated in this area, including *jarak towo* cassava. This cassava variety has its own uniqueness and characteristics; morphologically fluffier and savorier and has a higher selling price than other varieties. Tawangmangu and Ngargoyoso sub-districts have mountainous topography located on the western slope of Mount Lawu and produce cassava jarak towo. Production has not been able to meet the high demand for *jarak towo* cassava, due to the limited suitable land for cassava cultivation [6]. An understanding of land suitability criteria is needed to find the right producing areas to increase production and cassava quality [7]. This is in line with the Regulation of the Ministryof Agriculture of the Republic of Indonesia Number: 07/Permentan/OT.140/2/2012 concerning the technical guidelines for criteria and requirements for sustainable land use, agricultural land and food, and agricultural reserve land [8].

Cassava has the potential to be developed in dry land because it is drought tolerant and has high adaptability to tropical climate conditions in Indonesia [9-10]. Improper management of cassava farming causes an increase in production costs which is not in line with the increase in cassava production and quality [11]. On the other hand, *jarak towo* cassava is highly prospective as a source of raw material for the food processing industry with high economic value.

The unsuccessful *jarak towo* cassava cultivation lies in the unsuitability of land. Yields may have the same quantity but different quality than that grown on the appropriate land. Different microclimate will also contribute to dissimilar crop yields [12]. Similarly, different microelements in the soil will have an impact on crop yields. However, the addition of microelements through fertilization can increase crop yields [13]. According to Irianto *et al.* [6], the development of sustainable *jarak towo* cassava farming as a source of raw materials for the food processing industry is based on land suitability. Therefore, this study aims to assess the suitability of land for the development of *jarak towo* cassava as a recommendation for farmers in their farming practices.

MATERIALS AND METHODS

This research was a case study on *jarak towo* cassava farming in Tawangmangu and Ngargoyoso sub-districts, Karanganyar Regency. The research design was exploratory-descriptive with a land survey, and land as the unit of analysisand supported by soil analysis in the laboratory. The data were collected using observation, recording and documentation.

Land survey was conducted based on a land map unit (LMU), where each sub-district had 4 LMUs determined based on land use and altitude. The average altitudes were 1,400 masl (LMU 1), 1,200 masl (LMU 2), 1,000 masl (LMU 3), and 800 masl (LMU 4) [14-15]. Determination of soil sampling point was carried out by purposive sampling on farmers' land planted with *jarak towo* cassava and its surroundings, which were estimated to have the potential to be developed as production centers.

For each LMU, four soil sampling points were taken (Figure 1). Soil sampling points in Tawangmangu were points T1-T4 for LMU 1, points T5-T8 for LMU 2, points T9-T12 for LMU 3, and points T13-T16 for LMU 4. While the sampling points in Ngargoyoso were points N1- N4 for LMU 1, points N5-N8 for LMU 2, points N9-N12 for LMU 3, and points N13-N16 for LMU 4. Soil samples were taken by drilling holes as deep as 30 cm. Soil samples were air-dried and sieved for analysis in the laboratory.

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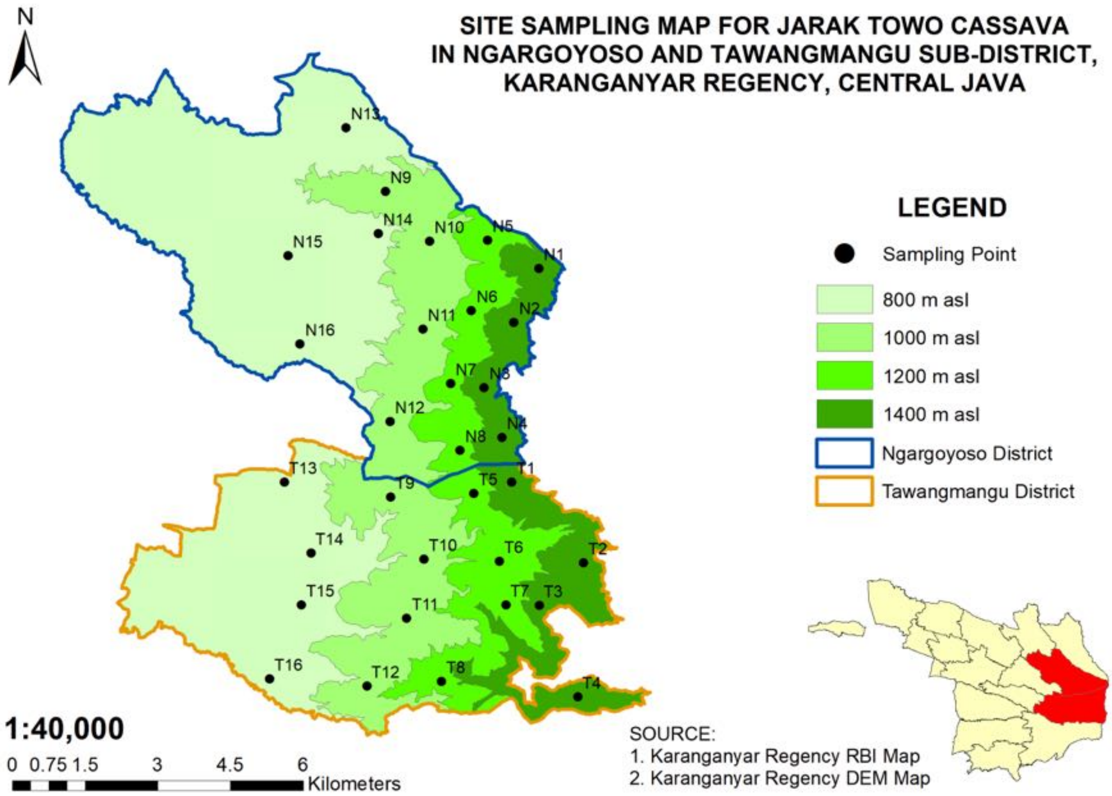

Figure 1: Soil sampling areas

Determination of land suitability was carried out by matching soil and land characteristics with optimum growing requirements for *jarak towo* cassava. The requirements for optimum growth of cassava were based on those recommended by the Center for Research and Development of Agricultural Land Resources, Ministry of Agriculture [16] with modifications. Modifications were made with the consideration that *jarak towo* can produce high quality tuber if planted at an altitude of ±1000 masl [6]. Soil and land characteristics used as parameters for determining land suitability were temperature (tc), water availability (wa), oxygen availability (oa), root capacity (rc), nutrient retention (nr), nutrient availability (na), erosion hazards (eh) and land preparation (lp) [16-17]. The observed parameters along with land suitability classifications are listed in Table 1. Land suitability consists of four classes ranging from very suitable (S1), moderately suitable (S2), marginally suitable (S3) and not suitable (N), modified from [15, 16, 18].

RESULTS AND DISCUSSION

Optimal, directed and efficient use of land resources requires data and information on soil, climate and other physical environmental characteristics, as well as plant growth requirements [16]. Optimal sustainable land use of available land resources

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entails land suitability analysis [19-21]. Land suitability is the fitness of specific land use in a particular type of land. The land suitability class of an area can vary, depending on the potential and limitation of the concerned land resources [22]. The type of soil in the two sub-districts is andisols, which is formed from weathering and transformation processes so that it tends to contain high levels of organic matter. The texture can be smooth like clay and a little rough like loam, depending on the need of the cassava plant [23]. The condition of the land suitability for *jarak towo* cassava plant in Tawangmangu is presented in Table 2 and Ngargoyoso is displayed in Table 3.

The physiology and chemistry of cassava is influenced by temperature and water availability [24]. Temperature is one of the factors causing differences in plant height and above-ground biomass [24]. According to Ezui *et al.* [25], the optimal temperature in cassava cultivation is 27° C; however, as found in the study areas, *jarak towo* cassava plant could not grow and produce tubers properly at that temperature. Table 2 and Table 3 show that *jarak towo* cassava plant can grow well at temperatures of 18-21° C and the most appropriate temperature for growing this cassava is 18.98° C. This is in line with the results of research by Zulhaedar and Nazar [23]. If the temperature becomes a serious obstacle that is difficult to overcome, the land is considered not suitable [26]. Interaction between water availability and temperature has the highest contribution to tuber yields and the chemical properties of leaves and tubers. Water availability will affect the size of cassava leaves and root storage [27]. Cassava plants that experience drought will have fewer leaves by 45% and lower tuber yields by 83% than cassava plants that are well watered [28]. Drought can cause yield losses of between 9% and 59% of potential production [25]. In the research areas, water availability obtained from rainfalls between 3,500 and 4,000 mm/year, fulfilled the requirements for the growth of *jarak towo* cassava leaves and tubers; and therefore, this aspect was not considered a limiting factor.

Soils with slightly obstructed or well-drained are highly suitable for cassava plants (Table 2 and Table 3). Drainage is related to oxygen supply (aeration) to cassava plants. Surface water that contains a lot of oxygen can enter the soil through vertical percolation. Too low reduction potential is prevented with oxygen supply so that cassava plants are protected from iron and manganese, a particular organic acid or sulfide poisoning. Oxygen availability was not a limiting factor in *jarak towo* cassava cultivation.

The most dominant component of root capacity (rc) in the study area (Tables 2 and 3) was the soil texture, which was classified as medium to fine with a coarse

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material content of ≤ 15% and 15% - 35%, respectively. Soil depth varied from 40 cm to 120 cm. Shallow soil causes inhibition of plant root development while deep soil will have good aeration and drainage, can support root and plant development well. Root capacity was not a dominant limiting factor in the development of *jarak towo* cassava farming.

Nutrient retention (nr) was measured by the parameters of cation exchange capacity (CEC), base saturation (BS), soil pH and organic carbon. Cation Exchange Capacity describes the number or size of cations being exchanged. High CEC means that more cations are exchanged so that the availability of nutrients for plants will increase. The results of the research presented in Table 2 and Table 3 show that the CEC of 13.68 - 21.23 cmol+/ kg in the suitability of land for *jarak towo* cassava was moderately suitable. Soils with high BS can be classified as fertile soils because there has never been serious soil leaching. On the other hand, low BS indicates that the soil is acidic and can inhibit the absorption of nutrients by plant roots.

Table 2 and Table 3 show that the base saturation is quite high and belongs to a fairly appropriate class. Soil pH in Tawangmangu District varied between 5.92 – 6.3 (slightly acidic), while soil pH in Ngargoyoso District ranged from 5.57 – 6.49 (slightly acidic). Slightly acidic soil pH is suitable for cassava, which requires a slightly acidic - neutral pH. Soil acidity is very important because it becomes the basis of consideration for fertilization (including liming) and improving the chemical and physical properties of the soil. Soil pH affects the efficiency of plant growth, the availability of plant nutrients, and the activity of microorganisms in the soil [11]. Organic carbon parameters ranged from 0.5% (very low) to 8.48% (very high) and the average organic carbon content was high and suitable for jarak towo. Even though the organic carbon content is high, its availability still needs to be maintained with regular application of organic matter every growing season. Organic matter contains several essential nutrients for plant growth. The role of organic matter in providing soil nutrients cannot be separated from the mineralization process which is the final stage of the transformation of organic matter. Organic matter has a role in providing Nitrogen, Phosphor, and Sulfur nutrients for plants.

Nutrient availability (na) was measured by parameters of total nitrogen, P_2O_5, and K_2O. Table 2 and Table 3 present that the total-N value in the two sub-districts ranged from 0.24% to 0.94%, which were considered moderately suitable to highly suitable for jarak towo. The P_2O_5 value is very low, so it becomes a limiting factor. Available P is related to soil pH, where the highest availability is at pH 6.8-7.2 and this is in line with research [29]. The relationship between P availability and pH can be used as a soil fertility management strategy. The K_2O value is very low and belongs to the marginally appropriate class. This is due to the depletion of nutrients in the soil after planting cassava. Cassava is a root crop that requires high K_2O for its growth.

Cassava can be planted well without tillage that is usually required by other plant to grow well and provide optimal yields, as well as maintain the physical properties of soil [30]. On the other hand, conventional tillage provides the greatest soil vulnerability to erosion compared to no-tillage and minimum tillage. In the study areas, the erosion hazards were light even though the slope was steep (average 15-30 %) because farmers had applied no-tillage and minimum tillage cultivation in addition to making terraces. The slope is an important factor affecting runoff and erosion. Based on the inclination of the slopes, almost all slopes in the study areas inclined more than 15% (Table 2 and Table 3). Areas with steep slopes of more than 15% inclination generally experience soil erosion that puts an effect on soil formation [7]. This was a limiting factor in the development of *jarak towo* cassava farming. Making bench terraces with good construction is a strategy that can be applied to minimize the erosion hazards.

Land preparation was performed by measurement using the parameters of surface rocks and rock outcrops since these two parameters influence the land preparation activities. If more surface rock and rock outcrops are found, the soil surface will be more covered, making soil processing and planting more difficult. Table 2 and Table 3 show that the surface rock was <0.1% and the outcrop was between 0% and 1 - 10%. This was not a limiting factor in land suitability.

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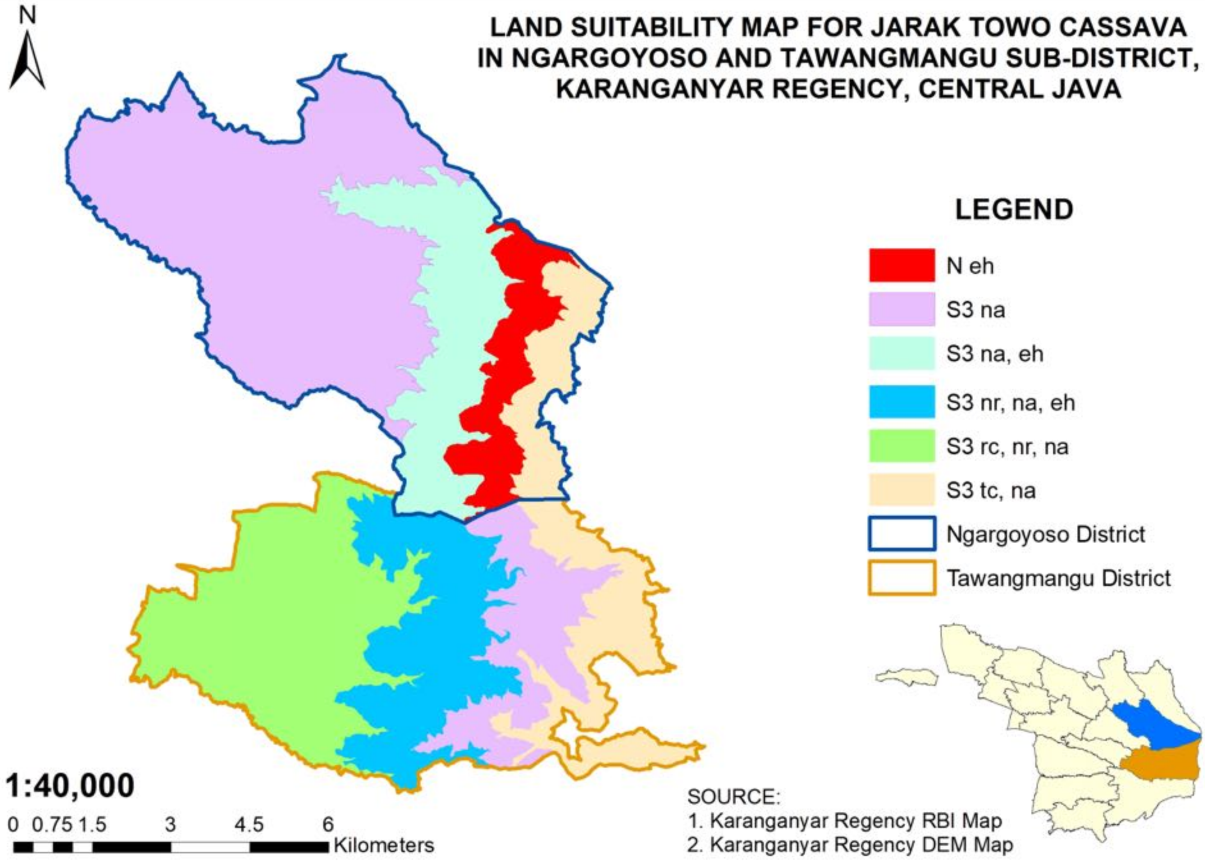

Figure 2: Map of land suitability for *jarak towo* cassava in Tawangmangu and Ngargoyoso Sub-districts

Table 2 and Table 3 show that not all land is suitable for *jarak towo* cassava cultivation. Several parameters are included in the marginal level and become a limiting factor and affect the growth, quantity and quality of cassava tubers. The results of some research studies show that cassava production is influenced by land suitability and land management that minimizes the limiting factor of land suitability [31,32]. The limiting factor will reduce production or double the required input. In particular, the improvement of land suitability in the production of *jarak towo* cassava is carried out by making the following improvement efforts:
Tawangmangu Sub-district (See Figure 3)

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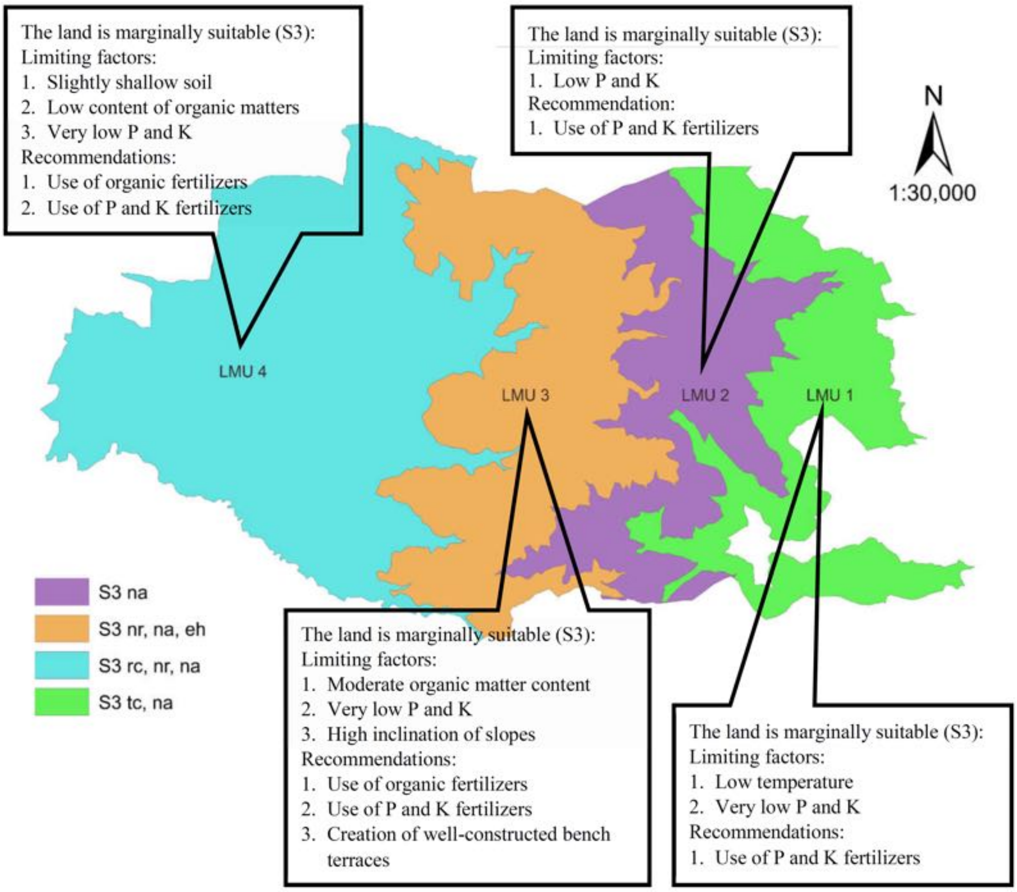

Figure 3: Development of *jarak towo* cassava in Tawangmangu Sub-district

1) LMU 1

This land suitability class was S3, which was marginally suitable but required more inputs from land classified as S2. The limiting factors in this land unit were temperature and nutrient availability.

Improvement efforts:

a) The efforts to improve temperature cannot be made.

b) The nutrient availability can be maintained by increasing the use of P and K fertilizers that are tailored to the needs of the plant [11].

2) LMU 2

The suitability of this land belonged to S3 class, which was marginally suitable but required more inputs from land classified as S2. The limiting factor for this land unit was nutrient availability.

Improvement effort:

The availability of nutrients can be maintained by increasing the use of P and K fertilizers that are tailored to the needs of the plant [11].

3) LMU 3
   The suitability class of this land was S3, which was marginally suitable but required more inputs from land belonging to the S2 class. Nutrient retention, nutrient availability, and erosion hazards were the limiting factors.
   Improvement efforts:
   a) Nutrient retention can be improved by liming or adding organic matters [33].
   b) The availability of nutrients can be enriched by increasing the use of P and K fertilizers that are tailored to the needs of the plant [11].
   c) Erosion hazards, particularly the inclination of the slope, can be managed through improvement efforts by making terraces [34-35], planting parallel to the contour [36], and planting groundcovers [37].

4) LMU 4
   This land suitability belonged to S3 class, which was marginally suitable but more inputs from land classified as S2 were required. The limiting factors in this land unit were root capacity, nutrient retention and nutrient availability.
   Improvement efforts:
   a) Root capacity, particularly soil depth, generally cannot be improved, except for soft and thin layers of soil by dismantling it when cultivating the soil.
   b) Nutrient retention can be improved by liming or adding organic matters [33].
   c) The availability of nutrients can be maintained by increasing the use of P and K fertilizers that are tailored to the needs of the plant [11].

Ngargoyoso Sub-district (See Figure 4)

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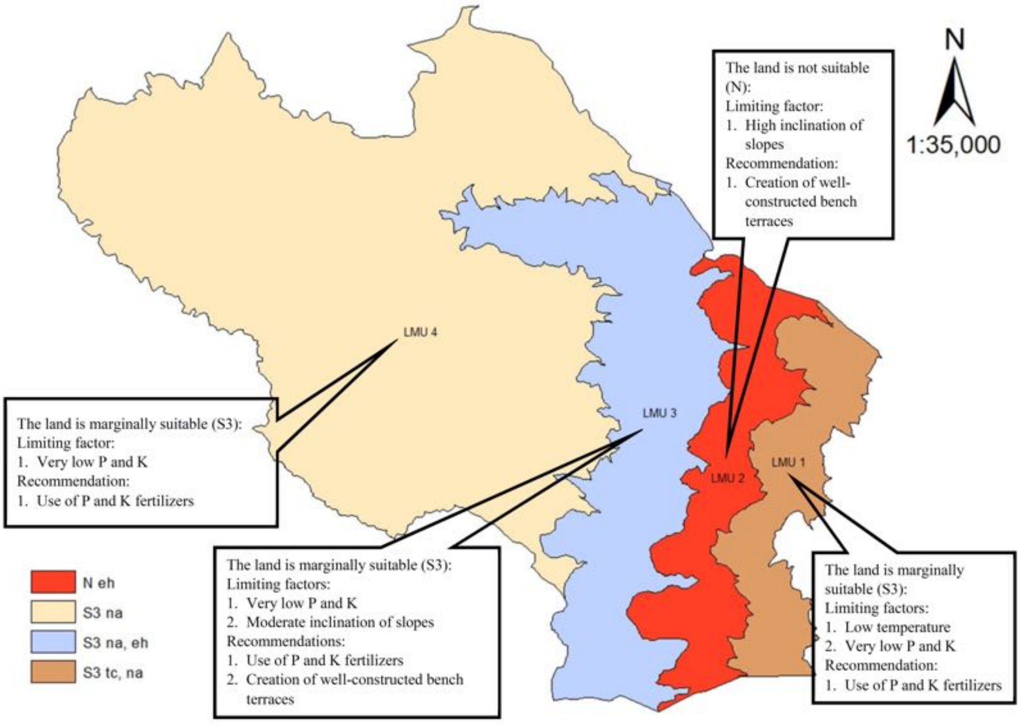

Figure 4: Development of *jarak towo* cassava in Ngargoyoso Sub-district

1) LMU 1
   This land suitability was categorized into S3, which was marginally suitable. However, more inputs from land categorized into S2 were necessary. The limiting factors in this land unit included temperature and nutrient availability.
   Improvement efforts:
   a) The efforts to improve temperature cannot be made.
   b) The nutrient availability can be maintained by increasing the use of P and K fertilizers that are tailored to the needs of the plant [11].

2) LMU 2
   This land was considered not suitable land (N) since it had a limiting factor, which was erosion hazards, that was very difficult to overcome.
   Improvement effort: Erosion hazards, particularly the inclination of the slope, can be managed through improvement efforts by making terraces [34-35], planting parallel to the contour [36] and planting groundcovers [37].

3) LMU 3

This land belonged to S3 class, which was marginally suitable but still required more inputs from land belonging to the S2 class. The limiting factors of this land unit covered nutrient availability and the danger of erosion.

Improvement efforts:

a) The availability of nutrients can be maintained by increasing the use of P and K fertilizers that are tailored to the needs of the plant [11].
b) Erosion hazards, particularly the inclination of the slope, can be managed through improvement efforts by making terraces [34-35], planting parallel to the contour [36] and planting groundcovers [37].

4) LMU 4

This land was classified into the S3 class, which was marginally suitable. However, this land still required more inputs from the S2 land unit. Nutrient retention was the limiting factor of this land unit.

Improvement effort: The availability of nutrients can be maintained by increasing the use of P and K fertilizers that are tailored to the needs of the plant [11].

CONCLUSION

Land suitability for cassava towo cultivation in Tawangmangu and Ngargoyoso sub-districts is marginally suitable (S3) and not suitable (N). In these two sub-districts, LMU 1 which has a limiting factor of low temperature is not recommended as a location for the development of *jarak towo* cassava farming, while LMU 2, 3 and 4 in Tawangmangu and LMU 3 and 4 in Ngargoyoso are recommended. Land management efforts that can be done to improve land suitability for cassava farming are the construction of well-constructed bench terraces and the application of organic fertilizers combined with P and K chemical fertilizers. Land Map Units 2 in Ngargoyoso is perhaps recommended as long as agricultural practices pay attention to land conservation.

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Table 1: Modification land suitability classification for *jarak towo* cassava

Soil and land characteristics	S1	S2	S3	N
Temperature (tc)				
Average temperature (°C)	18-20	20-22	16-18 22-24	> 24 < 16
Water availability (wa)				
Rainfall (mm/year)	3,000-4,000	2,000-3,000 4,000-4,500	1,000-2,000 4,500-5,000	< 1,000 > 5,000
Oxygen availability (oa)				
Drainage	well-drained, slightly well-drained, slightly obstructed	somewhat excessively drained	obstructed	very obstructed excessively drained
Root capacity (rc)				
Texture	slightly fine, medium, slightly coarse	fine	very fine	coarse
Coarse material (%)	< 15	15-35	35-55	> 55
Soil depth (cm)	> 75	50-75	20-50	< 20
Nutrient retention (nr)				
CEC (cmol+/kg)	> 27	16- 27	< 16	-
Base saturation (%)	> 52	< 52		
pH H2O	5.9-7.0	5.5-5.9 7.0-7.6	< 5.5 > 7.6	-
Organic carbon (%)	> 2.5	2.0-2.5	< 2.0	-
Nutrient availability (na)				
Total-N (%)	> 0.21	0.10-0.20	< 0.10	-
P_2O_5 (mg/100g)	> 21	15-20	< 15	-
K_2O (mg/100g)	> 21	10-20	< 10	-
Erosion hazards (eh)				
Slope (%)	0-15	15-30	30-45	> 45
Erosion hazards	very light, light	medium	Heavy	very heavy
Land preparation (lp)				
Rock surface (%)	< 0.1	0.1-3.0	3.0-25.0	> 25.0
Rock outcrop (%)	< 0	1-10	10-20	> 20

S1: Highly Suitable; S2: Moderately Suitable; S3: Marginally Suitable; N: Not Suitable

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Table 2: Land suitability of *jarak towo* cassava cultivation in Tawangmangu Sub-district

Land Characteristics	LMU 1		LMU 2		LMU 3		LMU 4	
	Value	Class	Value	Class	Value	Class	Value	Class
Temperature (tc)								
Average temperature (°C)	17.76	S3	18.98	S1	20.2	S2	21.42	S2
Water availability (wa)								
Rainfall (mm/year)	3,500-4,000	S1	3,500-4,000	S1	3,500-4,000	S1	3,500-4,000	S1
Oxygen availability (oa)								
Drainage	slightly obstructed	S1	slightly obstructed	S1	slightly obstructed	S1	slightly obstructed	S1
Root capacity (rc)								
Texture	medium	S1	slightly fine	S1	Medium	S1	fine	S2
Coarse material (%)	15-35	S2	15-35	S2	<15	S1	<15	S1
Soil depth (cm)	60	S2	70	S2	120	S1	40	S3
Nutrient retention (nr)								
CEC (cmol+/kg)	21.23	S2	14.44	S2	18.09	S2	14.64	S2
Base saturation (%)	0.41	S2	1.63	S2	1.71	S2	0.62	S2
pH H_2O	6.10	S1	6.08	S1	6.30	S1	5.92	S1
Organic carbon (%)	4.65	S1	6.08	S1	2.36	S3	0.50	S3
Nutrient availability (na)								
Total-N (%)	0.79	S1	0.74	S1	0.45	S1	0.24	S1
P_2O_5 (mg/100g)	2.53	S3	2.04	S3	1.87	S3	2.55	S3
K_2O (mg/100g)	0.97	S3	1.02	S3	1.02	S3	1.06	S3
Erosion hazards (eh)								
Slope (%)	15-30	S2	15-30	S2	30-45	S3	15-30	S2
Erosion hazards	light	S1	light	S1	Light	S1	light	S1
Land preparation (lp)								
Rock surface (%)	<0.1	S1	<0.1	S1	<0.1	S1	<0.1	S1
Rock outcrop (%)	0	S1	1-10	S2	0	S1	1-10	S2

Data source: Laboratory Analysis, 2020

S1: Highly Suitable; S2: Moderately Suitable; S3: Marginally Suitable; N: Not Suitable

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Table 3: Land suitability of *jarak towo* cassava cultivation in Ngargoyoso Sub-district

Land Characteristics	LMU 1		LMU 2		LMU 3		LMU 4	
	Value	**Class**	**Value**	**Class**	**Value**	**Class**	**Value**	**Class**
Temperature (tc)								
Average temperature (°C)	17.76	S3	18.98	S1	20.2	S2	21.42	S2
Water availability (wa)								
Rainfall (mm/year)	4,000-4,500	S2	3,500-4,000	S1	4,000-4,500	S2	3,500-4,000	S1
Oxygen availability (oa)								
Drainage	slightly well-drained	S1	slightly well-drained	S1	slightly well-drained	S1	slightly obstructed	S1
Root capacity (rc)								
Texture	medium	S1	medium	S1	slightly coarse	S1	slightly coarse	S1
Coarse material (%)	<15	S1	<15	S1	<15	S1	<15	S1
Soil depth (cm)	70	S2	90	S1	60	S2	75	S2
Nutrient retention (nr)								
CEC(me/100gr)	18.38	S2	18.5	S2	13.68	S2	14.32	S2
Base saturation (%)	0.78	S2	0.63	S2	2.25	S2	1.23	S2
pH H_2O	6.15	S1	6.35	S1	6.49	S1	5.57	S2
Organic carbon (%)	8.48	S1	6.71	S1	4.58	S1	2.42	S3
Nutrient availability (na)								
Total-N (%)	0.94	S1	0.89	S1	0.42	S1	0.46	S1
P_2O_5 (mg/100g)	1.97	S3	2.27	S3	1.87	S3	1.82	S3
K_2O (mg/100g)	0.86	S3	0.8	S3	0.98	S3	0.85	S3
Erosion hazards (eh)								
Slope (%)	15-30	S2	45-65	N	30-45	S3	8-15	S1
Erosion hazards	light	S1	light	S1	Light	S1	light	S1
Land preparation (lp)								
Rock surface (%)	<0.1	S1	<0.1	S1	<0.1	S1	<0.1	S1
Rock outcrop (%)	0	S1	0	S1	1-10	S2	0	S1

Data source: Laboratory Analysis, 2020
S1: Highly Suitable; S2: Moderately Suitable; S3: Marginally Suitable; N: Not Suitable

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