Vol. 12, No. 4 (2023) : 957 - 967
DOI : http://dx.doi.org/10.23960/jtep-l.v12i4.957-967
JURNAL TEKNIK PERTANIAN LAMPUNG
ISSN 2302-559X (print) / 2549-0818 (online)
Journal homepage : https://jurnal.fp.unila.ac.id/index.php/JTP

Land Suitability Assessments for The Palm Plantation (*Arenga pinnata* L.) As Non-Timber Forest Product Using Geographic Information System

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Article History :

Received : 7 March 2023
Received in revised form : 12 June 2023
Accepted : 30 May 2023

Keywords :
Agroforestry,
Conservation,
Cultivated,
Palm sugar,
Social Forestry

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ABSTRACT

The use of sugar palm plants as a producer of palm sugar, which is a non-timber forest product (NTFP) is considered not optimal and has the potential to be cultivated. Assessing land suitability is necessary for assessing the potential of land resources to provide information and production values. This study aims to analyze land suitability for sugar palm plantations as measured by climate, land physical properties, and a combination of these parameters. The research was conducted in Baru Ranji Village, Merbau Mataram District, South Lampung Regency, using spatial analysis methods through the use of overlay, matching, and scoring techniques through the Geographic Information System (GIS). The results showed that climatic parameters become limiting factors and only shift the level of land suitability and when combined with the physical parameters, the land was suitable for sugar palm cultivation. The use of agroforestry system in social forestry for sugar palm cultivation can increase economic and environmental conservation value.

1. INTRODUCTION

Forest resources are essential for the survival and improvement of the living conditions of millions of people in various regions throughout the world. The use of forest resources in providing quality products has to maintain environmental sustainability in accordance with the principles of conservation and sustainability. The global community encourages the implementation of sustainable forest management which includes poverty alleviation, livelihood provision for communities who depend on forests, and the tenure rights of local communities and/or indigenous communities over forests (Vogt *et al*., 2006). Forests can contribute significantly in economic aspects for providing various environmental products and services and ecological aspects in protecting the environment. However, the challenge is how current forest regeneration can continue to produce benefits without sacrificing future benefits and options (MacDicken *et al.,* 2015). This idea is the core of the view of sustainable forest management that can be encouraged by social forestry policies. Social

forestry is set to achieve three major goals in managing natural resources in the form of alleviating poverty in communities around the forest, providing opportunities for communities to provide access to the use of natural resources through empowerment, and increasing capacity and improving forest conditions (Maryudi *et al*., 2012).

In improving livelihood and improving the condition of natural resources, non-timber forest products (NTFPs) are important and have greater potential in the future. Sugar palm (*Arenga pinnata* L.) is a local commodity that can be managed in forest areas using an agroforestry pattern. Sugar palm trees that produce sap can be used to produce brown sugar, which is one of the NTFPs that can be developed. However, sugar palm is still used traditionally and in a limited way, so the people who use it are still very dependent on nature and not many people cultivate it. Sugar palm is a plantation commodity that has agro-climatic suitability for various conditions in Indonesia and has high economic value (Nuraini & Atmaja, 2019). Many people around the forest use sugar palm plants and become a source of income to provide food for their families. A sustainable model for the development and management of sugar palm production and its derivative products has been reported by Malamassam (2020) in Hasanudin University's educational forest where its development requires a community empowerment program. Apart from having economic value in every part and product produced, sugar palm plants actually also function as a conservation effort through deep roots to prevent erosion of the land (Mulyanie, 2018). The various benefits that can be obtained from sugar palm plants will provide opportunities for planting and cultivating sugar palm plants in the future.

In order to realize sustainable forest management for the use of NTFPs using sugar palm, this research will focus on analyzing the suitability of land at the research location for sugar palm plantation. Land suitability can be interpreted as the level of land appropriateness for a particular plant cultivation and/or use (Primawan & Indrianawati, 2020). Sustainability of production can be measured in term of climatic and physical parameters of the land for cultivation (Wintgens, 2008). Land suitability evaluation is needed to assess the potential of land resources so that it can provide information and the value of the production obtained. Land use planning requires computer-based technology such as geographic information systems (GIS) to be able to analyze, manipulate and present information in tabular and spatial form (Wirosoedarmo *et al.,* 2012). In analyzing land suitability carried out by Primawan & Indrianawati (2020) on plantation resources for prospective commodities in West Java Province, it was carried out using a GIS-based weighing method.

Therefore, the aim of this research is to analyze the suitability of sugar palm plants as measured based on climatic parameters, land physical parameters, and combining these two parameters to support productive and sustainable land use planning using GIS. It is expected that this research can improve sugar palm management at the research location and that its use will be more effective while still prioritizing environmental sustainability.

2. MATERIALS AND METHODS

2.1. Research Location

This research was conducted in Baru Ranji Village, Merbau Mataram District, South Lampung Regency, Lampung Province (Figure 1). Based on its astronomical position, Baru Ranji Village is located at 105° – 105°45' East Longitude and 5°15' – 6° South Latitude. Baru Ranji Village was designated as a research location with the

consideration that it is one of the holders of approval for social forestry management with a community forest scheme and has a palm sugar Social Forestry Business Group (KUPS). Baru Ranji Village has an area of ±1,364 Ha. The location was chosen based on the management of sugar palm that has been carried out by the community where there is a Forest Farmers Group (KTH) which uses sugar palm plants as one of the non-timber forest product commodities, namely KTH Hutan Tua which is the holder of approval for community forest management in protected forest areas. The community forest managed by KTH Hutan Tua covers an area of ±243 Ha. In relation to sugar palm plants used in community forests, land suitability evaluation can assess the potential for sugar palm tree development. Land suitability certainly has an important role in the development of sugar palm, especially in encouraging the productivity of sugar palm plants (Sebayang, 2016).

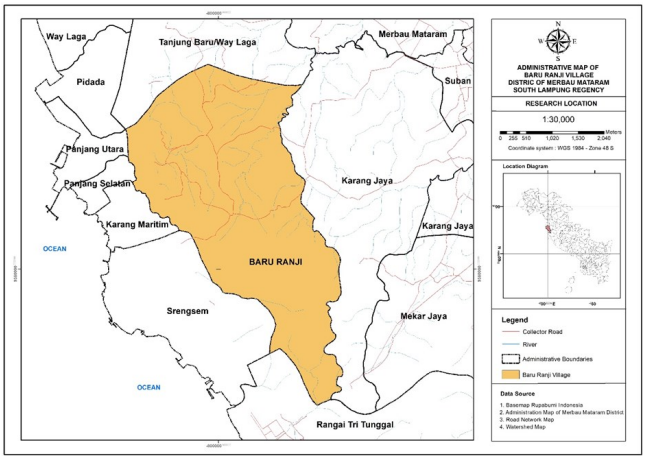

Figure 1. Research location: Baru Ranji Village, District of Merbau Mataram, South Lampung Regency

2.2. Materials and Equipments

The equipment used in this research included Arc GIS 10.5 Software, E.R Mapper 12.0 Software, and Microsoft 2019 Software. The data used in this research comes from institutional/agency documentation as a reference in assessing the suitability of sugar palm land. The parameters used in the research are climate and land physical parameters. Based on Parker *et al.,* (2019) the climate parameters used can be annual average temperature, annual rainfall, and number of dry months. Then, to measure the physical parameters of the land, you can use slope, texture, drainage, soil depth, soil pH and salinity. The data sources based on climate parameters and physical land parameters can be seen in Table 1.

2.3. Data Analysis

Climatic and physical land data processing was carried out through overlaying maps that have been created. In the case of data processing, land suitability classification for sugar palm trees was analyzed using matching and scoring methods. Then the satellite imagery was downloaded as consideration for interpretation purposes in drawing land suitability maps. In Ritung *et al*. (2007) the FAO conformity classification structure was differentiated based on order, class, subclass, and unit levels. At the level of land suitability order, a distinction was made between land that is classified as suitable (S = Suitable) and land that is not suitable (N = Not Suitable). This research will use order level land suitability as in Table 2.

Sugar palm plants can grow based on certain land use characteristics. Regarding land suitability requirements for sugar palm plants, it can be seen in Table 3.

Table 1. Required data for land suitability assessment

Data name	Source	Scale type
1. Climatic parameters		
* Average annual temperature	BMKG and Landsystem map (Scale 1 : 500,000)	Interval
* Average annual rainfall	CHIRPS Resolution = 0.05° x 0.05°	Interval
* Number of dry month	Landsystem map (Scale 1 : 500,000)	Interval
2. Physical land parameters		
* Land slope	DEMNAS SRTM 30m	Interval
* Soil texture	Geoportal Lampung, FAO-UNESCO Digital Soil Map	Nominal
* Drainage	Landsystem map (Scale 1 : 500,000)	Nominal
* Soil depth	Landsystem map (Scale 1 : 500,000)	Nominal
* Soil pH	Landsystem map (Scale 1 : 500,000)	Nominal
* Salinity	Landsystem map (Scale 1 : 500,000)	Nominal

Table 2. Land suitability class

Code	Class	Note
S1	Highly suitable	Land that does not have significant limitations to agricultural productivity
S2	Fairly suitable	Land has some severe limitations to sustainable productivity
S3	Slightly suitable	Land with major limitations for sustainable agricultural productivity
N	Unsuitable	Land with extreme limitations to agricultural productivity

Source: Ritung *et al*. (2007)

Table 3. Suitability requirements for sugar palm plantation (Hardjowigeno & Widiatmaka, 2015)

Requirements or Land characteristic	Land Suitability Class			
	S1	S2	S3	N
Temperature (tc)				
Average annual temperature (°C)	25 – 28	>28 – 32 23 – <25	>32 – 35 20 – <23	Td
Water availability (wa)				
Average annual rainfall (mm/year)	2.000 – 3.000	>3.000 – 4.000 1.300<2.000	>4.000 – 5.000 1.000 - <3.000	Td
Number of dry month (<100 mm/ month)	<2	2-3	>3 -4	>3
Rooting media (rc)				
Soil drainage	Good	Fair, Slightly fast	Fast, Slightly fast	Inhibited
Texture	LS, SCL, SiL, Si, SiCL, L	SC, SiC, C	S, Str C	Td
Soil depth (cm)	>100	75-100	50 - <75	--
Nutrient retention (nr)				
Soil pH	5.5 – 7	>7 – 7,5 5 - <5,5	>7,5 – 8,5 4,5 - <5	4 - <4,5
Toksisity (xc)				
Salinity (dS/m)	<2	2 – 4	>4 – 8	--
Slope (%)	<8	8 - 15	>15 - 25	--

Note: C = Clay; S = Sand; Si = Silt; L = Loam; LS = Loamy sand; SC = Sandy clay; SCL = Sandy clayey loam; SiC = Silty clay; SiCL = Silty clayey loam; SiL = Silty loam; Str C = structured clay; Td = Not applicable.

The results of the classification of land suitability for sugar palm plants for each land suitability parameter was converted into a score range and accumulated. The highest accumulative value for climate parameters was 12 and the lowest was 3. Meanwhile for land physical parameters the highest was 24 and the lowest was 6. The combination of the two has the highest accumulative value of 36 and the lowest is 9 as shown in Table 4.

Table 4. Score range for land suitability class

No.	Suitability parameter	Number of parameter	Range of total score
1.	Climate	3	3 – 12
2.	Land physical properties	6	6 – 24
3.	Climate and land physical properties	9	9 – 36

The score for each land suitability parameter will be classified based on four land suitability classes. Based on the resulting total score, land suitability classification can be made based on a range of 4 intervals at each level to represent land suitability. The following is the land suitability classification score for sugar palm plantations in Table 5.

Table 5. Land suitability classification

No.	Suitability parameter	S1	S2	S3	N
1.	Climate	10 - 12	7 - 9	4 - 6	< 4
2.	Land physical properties	19 - 24	13 - 18	7 - 12	<7
3.	Climate and land physical properties	28 - 36	19 - 27	10 - 18	<10

3. RESULTS AND DISCUSSION

Realizing sustainable forest management by utilizing non-timber forest products can be optimized by assessing the suitability of sugar palm plantations. Land suitability assessed in this research is the level of land suitability for sugar palm plants. In general, this research carries out land suitability analysis which is measured through climate and land physical parameters which then combines these two parameters. There are at least 3 parameters for climate and 6 parameters for land physical properties used in this research. The results obtained in this research are as follows:

3.1. Climatic Suitability

Climatic parameters can influence land suitability as assessed by annual rainfall, annual average temperature, maximum and minimum temperatures, and the number of dry months. Figure 1 presents the overlay results for each climate parameter. In general, sugar palm plants are more suitable for sloping soil with various agro-climatic conditions, such as mountainous areas with high rainfall with a sandy clay texture. The growth of sugar palm plants can also be influenced by the levels of clay and dust where they grow (Widarawati *et al*., 2017). The height above sea level will determine the air temperature and the intensity of light received by plants, including sugar palm plants. The higher a place, the lower the temperature at that place. Likewise, the intensity of

the sun will decrease. The length of light and the intensity of light will be used to classify plants that are suitable for the highlands or lowlands (Guslim, 2007; Novita *et al.*, 2013).

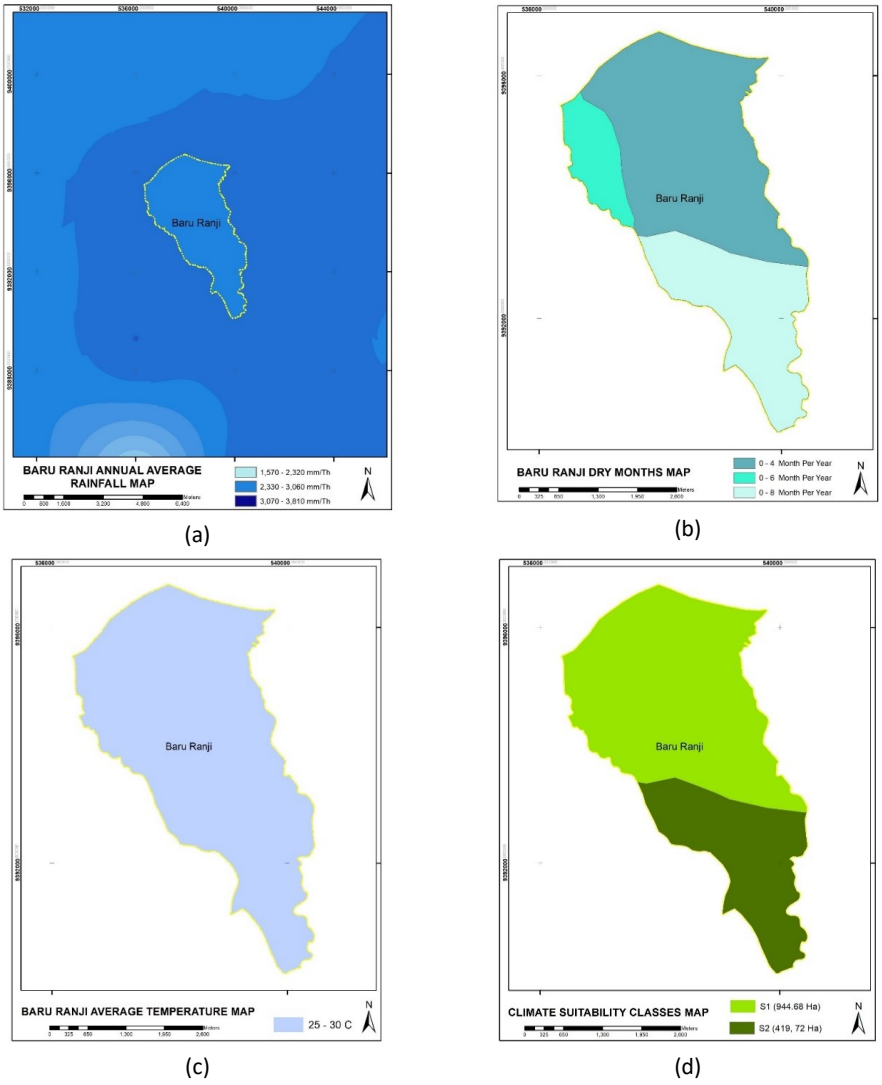

Figure 2. Map resulted from spatial analysis: a) Annual rainfall; b) Number of dry months; c) Annual Temperature; d) Land suitability for climate parameters

Based on calculation, the highest cumulative score is 8 and the lowest is 6. The higher the total score of the climate suitability parameters used for each commodity, the higher the current level of land suitability. The level of land suitability based on the climatic factors is fairly suitable (S2) with an area of 944.68 Ha and the land suitability class is slightly suitable (S3) with an area of 419.72 Ha. The formation of two classes of sugar palm land suitability based on climatic factor indications is due to the existence of differentiating factors that can limit the suitability of the land. In classes S2 and S3, the weighing factor is the number of dry months. In class S2 the length of the dry months is 0 – 5 months, while in class S3 the length of the dry months is 0 – 8 months. Meanwhile, the annual rainfall and temperature parameters are relatively the same for Baru Ranji village.

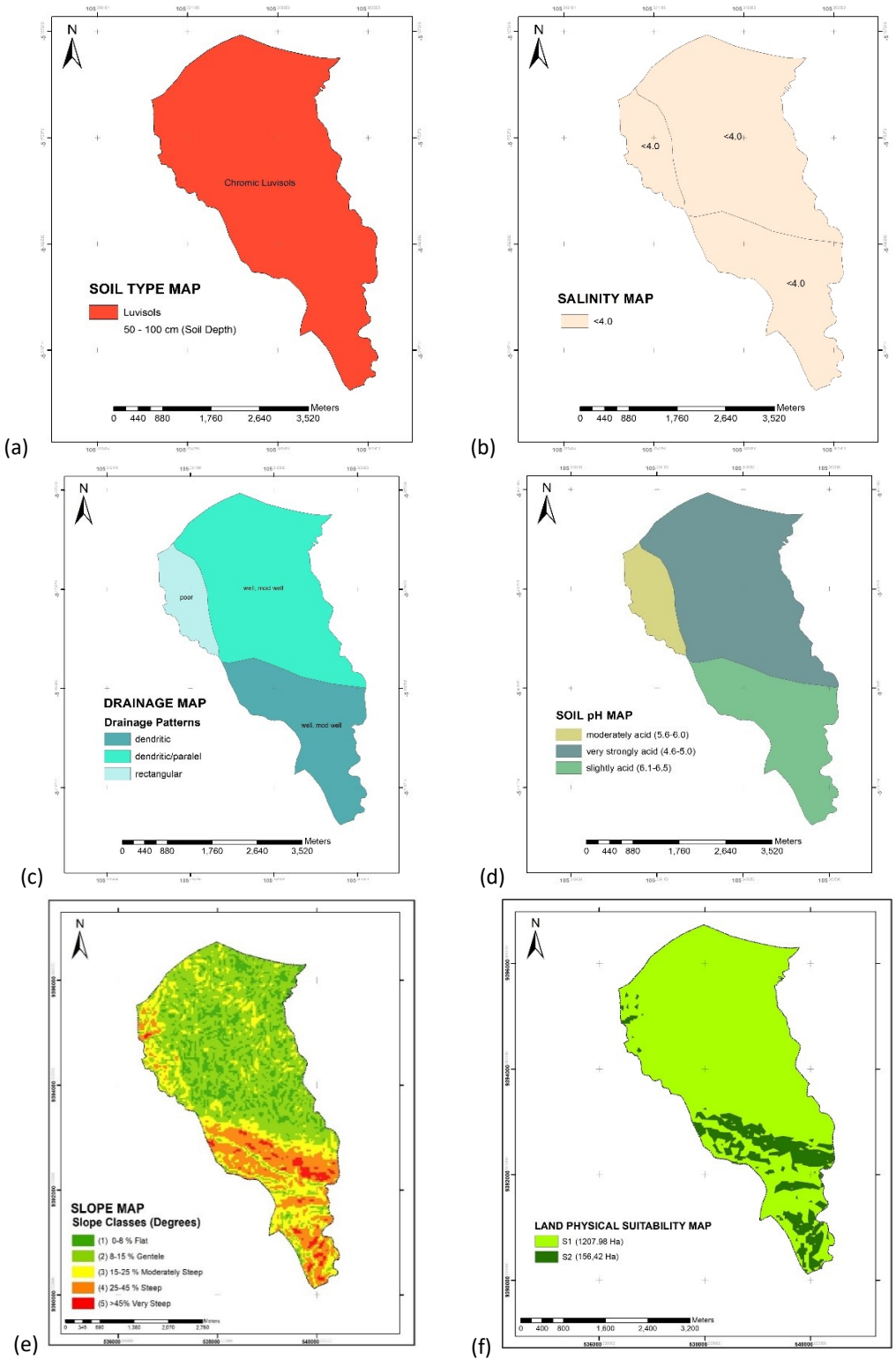

Figure 3. Map resulted from spatial analysis: a) soil type and depth, b) soil salinity, c) drainage, d) soil pH, e) slope, and f) physical land suitability

3.2. Physical Land Suitability

The physical condition of the land needs to be taken into account when developing sugar palm plants which include slope and soil characteristics such as soil texture and

type, drainage, soil depth, pH, and salinity. The results obtained based on the physical suitability of the land are presented in Figure 2.

Regarding to the physical properties of the land which is one of the determining factors for sugar palm growth, basically sugar palm can grow well among other trees or bushes, in plains, hills, valleys up to an altitude of 1,400 masl (meter above sea level) (Mulyanie, 2018). However, optimally sugar palm plants can thrive at an altitude of 500 – 800 masl (Rafi'i, 2010; Harahap, 2017). The slope influences the quality of the land and is one of the parameters in determining the suitability level of land for sugar palm plantations. The morphological characteristics of land are closely related to slope characteristics. Land with flat topography to gentle slope will have strong soil aggregates because it is rich in organic material. In contrast, in land with sloping and steep topography, soil aggregates will increasingly disappear and soil stability will be very weak, resulting in increasing surface flow and elimination of soil organic matter (Wirosoedarmo *et al*., 2012). Apart from that, the importance of several aspects related to soil properties and soil conditions that are sufficiently well-drained are also needed. Sugar palm plants actually do not require special soil conditions so they can grow in clay and sandy soil. Soil pH that is too acidic is not good for sugar palm growth (Mulyanie, 2018). The soil chosen for sugar palm plantation must be a well-drained type of soil such as loose soil, volcanic soil on mountain slopes and sandy clay soil along river banks. Land suitability scoring based on land physical parameters is carried out on the seven elements according to the basis of classification in this research.

The physical condition of the land greatly influences the growth of sugar palm plants. This can be seen from the physical characteristics of the suitability of the land where sugar palm plants grow which can be seen from the physical factors of the land such as the texture of sandy clay and silty clayey loam, shallow soil depth ranging from 50 - 100 cm, good soil drainage, slightly acid soil (pH 6.1 – 6.5), slightly acid to highly acid. Salinity is classified as marginally low with a conductivity of 2-4 ds/m, and land slope ranges from 15-25%.

The total score of land physical parameters for sugar palm plants obtained that a maximum value is 20 and a minimum value is 16. The land suitability level based on the physical factors of the land is very suitable (S1) with an area of 1207.98 Ha and the land suitability class is fairly suitable (S2) with an area of 156.42 Ha. The formation of two classes of sugar palm land suitability for the physical parameters of the land is due to the existence of differentiating factors that can limit the suitability of the land. In classes S1 and S2 the weighting factors are slope and height, in class S1 the slope is more than 45° while in class S2 it is less than 45°. Meanwhile the drainage, texture, depth, salinity and soil pH parameters are relatively the same for Baru Ranji Village.

3.3. Suitability of Existing Land

The suitability of existing land for sugar palm trees is obtained from combining land suitability based on climatic parameters and physical properties of the land. The parameters that have been determined are then combined by adding them to obtain a value or score for the two parameters. The suitability of land for sugar palm trees in Baru Ranji Village is presented in Figure 4. Based on this data, in general 88.54% or 1207.98 Ha of the land in Baru Ranji Village are classified as very suitable for developing sugar palm plants, and 11.46% or 156.42 Ha of the land is in fairly suitable condition for sugar palm. This is related to the physical factors of the land which are very supportive for developing sugar palm plants. The challenge for the future is how sugar palm plants can be cultivated, where currently farmers are still very dependent on sugar palm plants that live and grow wild in nature. Sugar palm plants can be

cultivated in an agroforestry manner to support increasing the productivity of the sap produced and also maintain the sugar palm plant population available in nature. Sugar palm plants that are suitable for the land in Baru Ranji Village not only can improve the economy of sugar palm farmers in the village, but also balance the environment as conservation plants in preventing soil erosion.

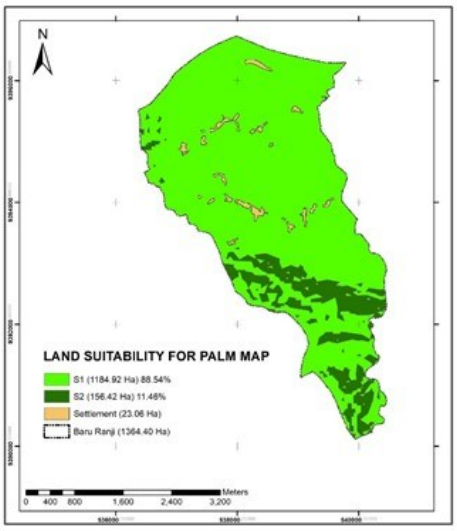

Figure 4. Map of land suitability for sugar palm plantation

The suitability of the land for sugar palm plants at the research location as measured by climatic and physical land parameters strengthens the understanding conveyed by Wintgens (2008) where these two parameters can be used as considerations in cultivating a plant. Sustainable management of sugar palm plants really needs to be supported by various parties. Limited knowledge, product development, technology, institutions, finance, and marketing have become obstacles in the development of a business, especially for micro, small and medium enterprises in obtaining optimal benefits both in social, economic, and environmental aspects (Creech *et al*., 2014). It is known that agroforestry has contributed extraordinary benefits through social, economic, and environmental aspects. The main advantage of implementing agroforestry is the diversification of production which is the best strategy, especially for small farmers because their livelihoods depend on the agricultural system (Jiru, 2019). With favorable climatic and physical land conditions, especially sugar palm plants that can grow between trees, the application of agroforestry can certainly be a solution in land use, including in the development of non-timber forest products. Of course, the use and management of non-timber forest products can also be a means of preserving biodiversity while protecting the environment and prioritizing the principles of sustainable forest management.

4. CONCLUSION

Based on the results of this research, it was concluded that there were differences in the area of the two parameters used in assessing land suitability for sugar palm plants. Based on climatic parameters, the land suitability level in Baru Ranji Village are classified was classified as fairly suitable (S2) with an area of 944,682 Ha, and slightly suitable (S3) with an area of 419,723 Ha. Meanwhile, based on the land physical factors, land suitability level are differentiated as very suitable land (S1) with an area of

1207,987 Ha, and fairly suitable (S2) with an area of 156,418 Ha. When these two parameters are combined, the land in Baru Ranji Village as a whole is suitable for sugar palm cultivation with highly suitable class (S1) of 88.54% of the land, and fairly suitable (S2) of 11.46% of the land. Directed and efficient use of land resources is very necessary. The use of agricultural land needs to be managed and planned according to its function and the use is based on the characteristics of the land and also considering the availability of space and the possibility of climate changes that may occur.

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