Research Article

Land Potential for Cacao (*Theobroma cacao.* L) Development in Banggai Regency

Potensi Lahan untuk Pengembangan Tanaman Kakao (Theobroma cacao. L) di Kabupaten Banggai

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Abstract: Seeing the bright prospects of cacao plants with the available land potential in Banggai Regency, it is necessary to assess land suitability in the development of cacao plants to know the actual potential land suitability level and the limiting factors that affect the potential for cacao plant development, apart from that it can optimize land use in the area, Banggai Regency. The approach used as an indicator for determining the land suitability class for cacao plantations in Banggai Regency is to take an FAO parametric index land quality based on land characteristics that match the requirements for land use for cacao plants, then tabulated into land map units. The results show that the actual land suitability class of Banggai Regency is N = not suitable and S3 = marginally suitable, with the limiting factor of water availability, root media, nutrient retention, available nutrients, and erosion hazard. So that land improvement efforts are needed to increase the land suitability class by considering the existing potential. Improvement efforts that can be done include adding lime, fertilizer, and organic matter, making mound terraces, bench terraces, credit terraces, and erosion-retaining plants. So that the results of the potential land suitability class are S1 = very suitable, S2 = suitable, S3 = marginally suitable, with an area of land that can be developed for cacao plants in Banggai Regency, namely 419,236.9 ha.

Keywords: Limiting factors, land area, development, cacao.

Abstrak: Melihat prospek cerah tanaman kakao dengan potensi lahan yang tersedia di Kabupaten Banggai, maka perlu adanya penilaian kesesuaian lahan dalam pengembangan tanaman kakao dengan tujuan mengetahui tingkat kesesuaian lahan aktual potensial dan faktor pembatas yang mempengaruhi potensi pengembangan tanaman kakao, selain dari itu dapat mengoptimalkan penggunaan lahan di Kabupaten Banggai. Adapun pendekatan yang digunakan sebagai indicator penentruan kelas kesesuaian lahan tanaman kakao Kabupaten Banggai yaitu memperhitungkan suatu kualitas lahan indeks parametric FAO berdasarkan karakteristik lahan yang matching dengan persyaratan penggunaan lahan tanaman kakao. Kemudian ditabulasikan kedalam satuan peta lahan (SPL). Hasil menunjukkan kelas kesesuaian lahan aktual Kabupaten Banggai yaitu N=tidak sesuai dan S3 = marginal, dengan faktor pembatas ketersediaan air; media perakaran; retensi hara; hara tersedia dan bahaya erosi. sehingga perlu adanya upaya perbaikan lahan untuk meningkatkan kelas kesesuain lahan dengan mempertimbangkan potensi yang ada. Upaya perbaikan yang dapat dilakukan yaitu Penambahan kapur, pupuk dan bahan organik, pembuatan teras guludan, teras bangku dan teras kredit serta tanaman penahan erosi. sehinggah diperoleh hasil kelas kesesuaiana lahan potensial S1= sangat sesuai, S2= cukup sesuai, S3= marginal, dengan luas lahan yang dapat dikembangkan untuk tanaman kakao Kabupaten Banggai yaitu 419.236,9 ha.

Kata kunci: Faktor pembatas, luas lahan, pengembangan, kakao.

INTRODUCTION

Cacao (*Theobroma cacao* L.) is one of the plantation commodities widely cultivated in Indonesia, with good quality products, so it is in great demand by other countries (Kiranta & Meydianawathi, 2014). The demand for cacao continues to grow due to global political

instability and growth in chocolate consumption worldwide (Amos, 2007). Therefore, to balance and overcome the ever-increasing demand, it is necessary to increase cacao production from the soil/land perspective.

The available lands often aren't in their best condition, resulting in the need to be adjusted within the accepted criteria for sustaining optimum cacao production (Liyanda et al., 2012; Jayanti et al., 2013). Land suitability is one of the decision-making components in land use planning (Pereira & Duckstein, 1993; Sharifi & Van Keulen, 1994; Baja et al., 2006). The widely used Indonesian land suitability is based on FAO land suitability that involves soil-climate characteristics (FAO, 1976; Ritung et al., 2011; *e.g.,* Rahmawaty et al., 2020), whereas neglecting other production constraints, *i.e.,* infrastructure, accessibility, and socio-political components (Ritung et al., 2011). The study of land suitability can help to find a location suitable for cacao plants, as well as to optimize the production of the existing cacao site in the Banggai Regency, which is currently minimally published.

Physically, the land in Banggai Regency is considered to have the potential to develop cacao plants (Pamanyo et al., 2021). In developing this commodity, there needs to be careful planning in using the land. Cacao-based land use planning is one solution to overcome problems related to increasing production because, with land use planning, development directions will be known according to their designation (Anglaaere et al., 2011; Jumiyati et al., 2021). Planning is needed in making decisions based on the suitability of plant commodities to obtain optimal and sustainable production (FAO, 2007; Suryawan et al., 2020), leading to land use with cacao commodities that are more productive, economically profitable, and acceptable to the community. Welang et al., (2016) stated that land suitability is the level of suitability of a plot of land for a particular use. Furthermore, land suitability can also be assessed from the current state (actual land suitability) or after improvements have been made (potential land suitability). This approach had successfully implemented in assessing cacao suitability in Indonesian soils, *e.g.,* Bulukumba (Aini et al., 2020), East Barito (Nael and Papilaya, 2019), Jayapura (Malik et al., 2021), and post-tsunami soil of Aceh Barat (Wahyunto et al., 2008).

This study aimed to assess the cocoa suitability of the Banggai regency using Indonesian land suitability criteria, as well as to identify the major limiting factors for sustaining cocoa production in this area. The result of this study is expected to raise more significant concerns in developing cacao plantations in Banggai Regency.

MATERIALS AND METHODS

Study Location and Field Campaign

The research was conducted in Banggai Regency at 0°30'-2°20' and 122°23'-124°20' consisting of the entire districts and villages, from February to June 2021. The research location is presented in Figure 1. The data used in this study comprised primary and secondary data. Primary data were obtained from direct observations and interviews. The secondary data consisted of climate data, administrative map, slope map, RTRW map, soil map, and landform map. The administrative and RTRW maps were derived from the Banggai government. A national-sourced digital elevation model (DEMNAS) from the Indonesian Geospatial Agency (BIG) was used to generate slope and landform maps. With limited resources to carry out all observations site across the study area, soil maps supplied with field observation data were purchased from Indonesian Center for Agricultural Land Resources Research and Development/ICALRD to fill most of the gaps.
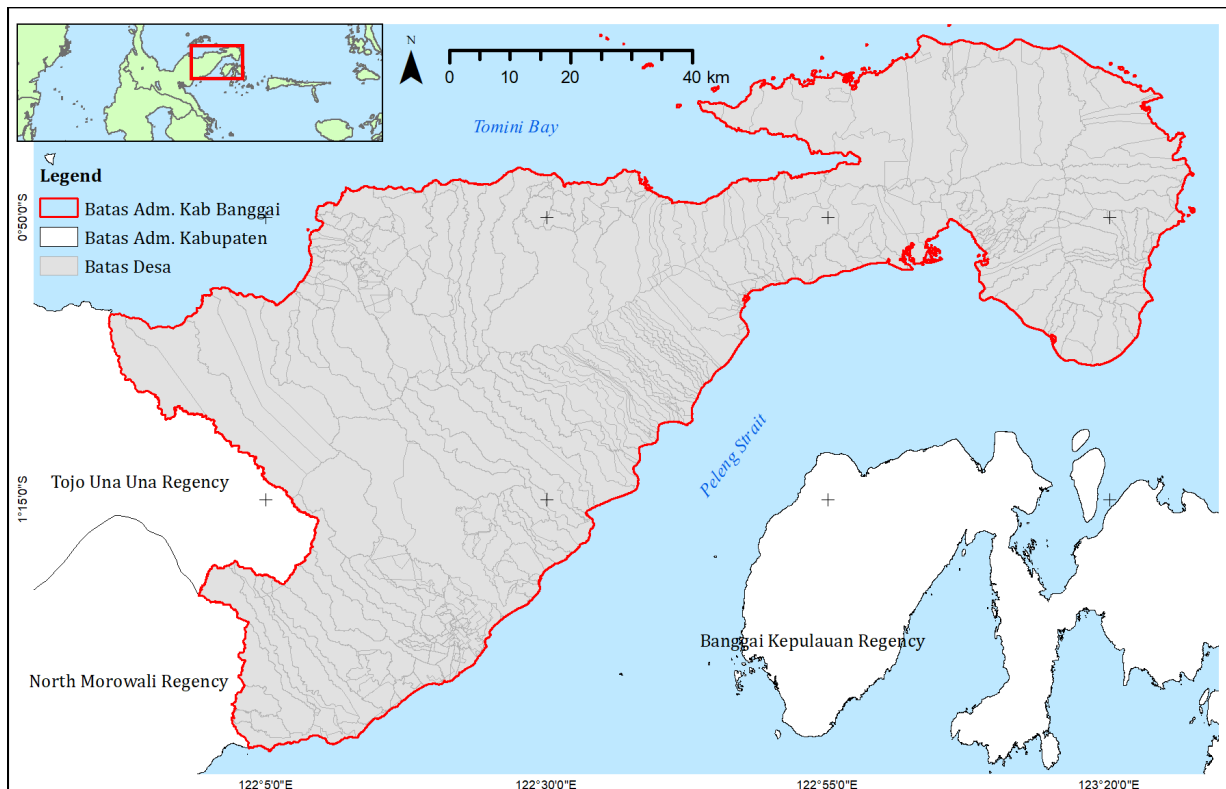
Figure 1. The location of the study area within red thick line

Cacao Suitability Assessment

To attain a land unit map, the entire input maps were overlaid and digitized using ArcGIS 10.4.1. Each land unit was matched to the cacao plants' suitability criteria as shown in Tables 1 and 2 based on the Technical Guidelines of Land Evaluation for Agricultural Commodities (FAO, 1976; FAO, 2007; Ritung et al., 2011), resulting in an actual suitability map for cacao. In order to obtain potential land suitability, the improvement in exceeding the actual limiting factors had been made based on the capability of local farmers in cultivating the cacao plant. All the suitability maps were presented based on their subclass, denoting their major limiting factors.

Table 1.   Explanation of suitability classes based on ICALRRD criteria

Order	Class	Description
S	S1	Very suitable: The land has no significant limiting factors affecting cacao productivity with regard to sustainable use.
	S2	Moderately suitable: The land has limiting factors with an impact on cacao productivity; therefore, additional input is required. The farmers usually overcome this barrier without external help.
	S3	Marginally Suitable: The land has a tremendous limiting factor, with an immense impact on cacao productivity, and therefore requires more additional input compared to S2. This challenge needs high capital, hence, requires assistance and collaboration from the government or the private sector.
N	N	Not suitable (N): The land is unsuitable for cacao production because the limiting factor is enormous and difficult to overcome.

Table 2. Land suitability for cacao based on ICALRRD criteria

Requirements for land use/characteristics	Land suitability class			
	S1	S2	S3	N
Temperature (tc)				
Average temperature (°oC)	25 – 28	20 – 25 28 – 32	32 – 35	< 20 > 35
Water availability (wa)				
Annual precipitation (mm)	1500 - 2500	2500 - 3000	1250 - 1500 3000 - 4000	< 1250 > 4000
Range of the dry month	1 – 2	2 – 3	3 – 4	> 4
Oxygen availability (oa)				
Drainage	well drained, moderately drained,	Somewhat poorly drained	poorly drained, moderately well-drained	very poorly drained, excessively drained
Root media (rc)				
Texture	smooth, moderately smooth	medium	moderately rough, very smooth	rough
Soil depth (cm)	>100	75 – 100	50 – 75	< 50
Nutrient retention (nr)				
CEC land (cmol/kg)	> 16	5 – 16	< 5	-
Base saturation (%)	> 35	20 – 35	< 20	-
pH H_2O	6.0 – 7.0	5.5 – 6.0 7.0 – 7.6	< 5.5 >7.6	-
Organic C (%)	> 1.2	0.8 – 1.2	< 0.8	-
Nutrients Available (na)				
Total N (%)	medium	low	very low	-
P_2O_5 (mg/100 g)	medium	low	very low	-
K_2O (mg/100 g)	high	medium	low – very low	-
Erosion hazard (eh)				
Slope (%)	< 8	8 – 15	15 – 30	> 30

RESULTS AND DISCUSSION

Actual Land Suitability of Cacao Plants in Banggai Regency

The results of the actual land suitability analysis for cacao plants in Banggai Regency in Figure 2 showed that the study area are marginally suitable for sustainably cultivating cacao plants. The land has enormous limiting factors, with a huge impact on cacao productivity. The result of this study suggested that water availability (wa), root media (rc), nutrient retention (nr), nutrients available (na), and erosion hazard (eh) were the factors currently confounding the cacao plant to produce optimal and sustainable yield. Furthermore, to get the land suitability class for each attribute, a map of the actual land unit is matched with the criteria for land suitability class for cacao plants (Syaf et al., 2019).

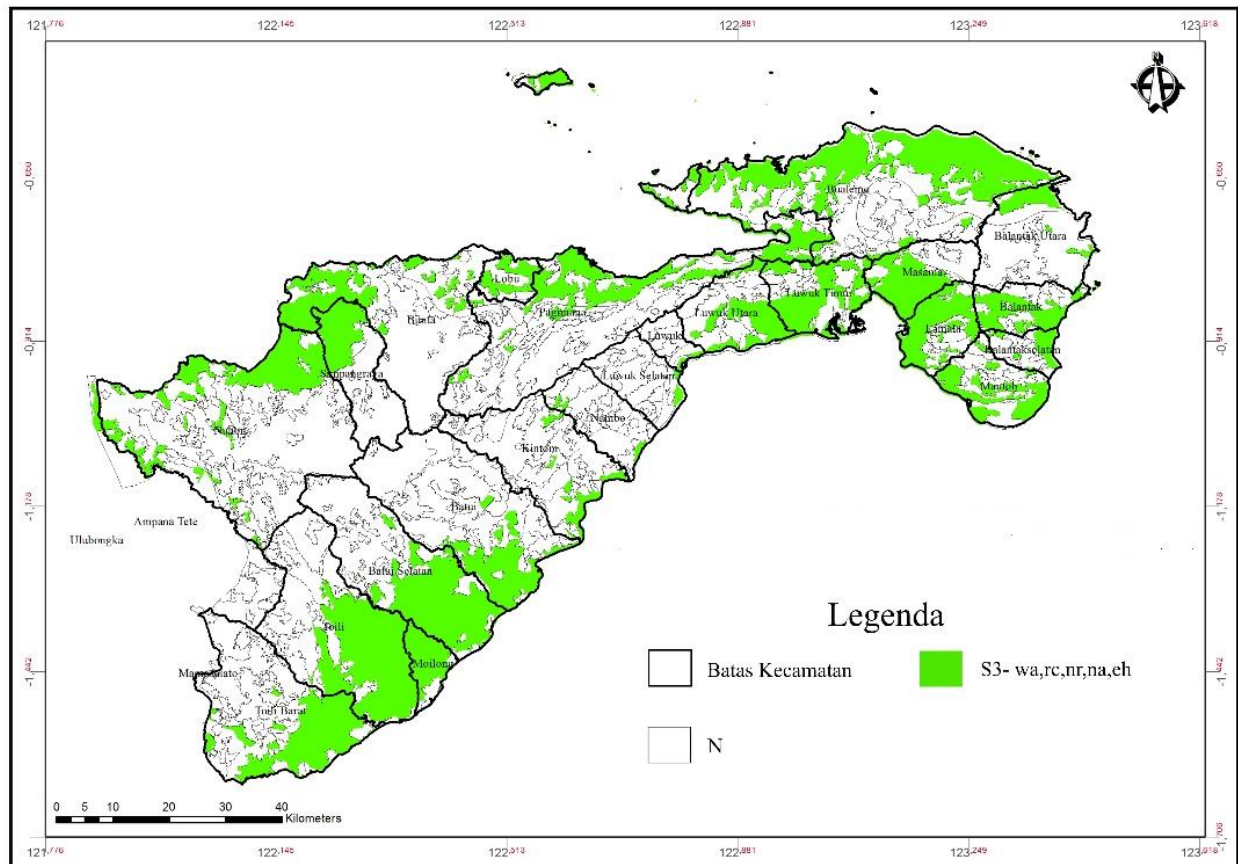**Figure 2.** Actual Land Suitability of Cacao Plants in Banggai Regency

Limiting Factors and Efforts to Improve Cacao Plantation in Banggai Regency

Factually the quality of land in the Banggai Regency obtained several limiting factors that became obstacles to the development of cacao plants. Therefore, there is a need for land improvement efforts to increase the actual land suitability class into potential land (Katili, 2020). The limiting factors for the development of cacao plants in Banggai Regency are presented in Table 3 below.

Table 3. Limiting Factors of Land Suitability for Cacao Plants in Banggai Regency

Actual Land Suitability Class	Limiting Factors
N, S3	availability of water (wa); root zone media (rc); nutrient retention (nr); available nutrients (na); erosion hazard (eh)

Description: S3 = marginally suitable; N = not suitable

The limiting factors for cacao plants on actual land in Banggai Regency include:
Availability of water (wa)

Water availability is one of the limiting factors in cacao development, hence it will affect cacao production in Banggai Regency. Indrianti (2020) stated that the availability of water, namely minimal rainfall, is a barrier that must be considered for plant development in an area because this limiting factor is quite heavy. Rainfall that is less or exceeds the plant's needs will reduce the land suitability class because the amount of water consumed by plants affects vegetative and generative growth. The low average annual rainfall results in unfulfilled plant water needs, affecting plants' vegetative and generative growth (Purba et al., 2019). However,

this limiting factor can be overcome by making irrigation canals with a moderate to the high-level pattern (Riswanto et al., 2020).

Root zone media (rc)

In this case, soil texture, root media is limiting factor for cacao plants. This is because the soils in the study area partially contain a sandy loam texture. At this limiting factor, no improvement was made because the texture could not be improved (Ritung et al., 2011).

Nutrient retention (nr)

Nutrient retention is one of the limiting factors in the development of cacao plants in the Banggai Regency; this limiting factor is due to the lack of C-Organic nutrients, cation exchange capacity and base saturation (Hazriyal et al., 2015). Nutrient retention is an essential component in determining the growth of cacao plants, as for efforts to improve on this limiting factor, namely by intensively adding lime and organic matter (Saikim et al., 2021).

Nutrient available (na)

Nutrient available are one of the limiting factors in the development of cacao plants in the Banggai Regency; this is because the nutrients, N-total, P_2O_5, K_2O, are classified as very low to moderate so that the nutrient content cannot meet the needs of the cacao plant. One of the efforts that can be done is by providing fertilizer and organic matter in a structured manner (Ndekano et al., 2021). Furthermore, fertilizer is carried out periodically to meet the nutritional needs of plants (Nangge et al., 2020).

Erosion hazard (eh)

Banggai Regency is an area with hilly landforms; the steep slope is one of the limiting factors that need to be overcome to increase the suitability of cacao plantations. Steep slopes can be said to be more easily disturbed or damaged. Erosion can also be the main factor that limits the development of cacao plants. Sariani et al., (2021) stated that the danger of erosion is the process of erosion or landslides so that soil particles are washed away by water or wind and caused by humans themselves. This erosion process can cause a decrease in soil fertility, soil carrying capacity, and the quality of the surrounding environment (Pimentel & Kounang, 1998). Therefore, to overcome this problem, land management techniques are needed to avoid the danger of erosion, namely carrying out soil conservation, such as making gulud terraces, counter farming, and land reforestation (Katili, 2020).

Land Suitability of Potential Cacao Plants in Banggai Regency

Improvement efforts are carried out based on limiting factors to reach a potential land. The suitability of potential land for cacao plantations in Banggai Regency is based on improvement efforts with moderate to high management levels, so that land management can only be carried out by medium farmers, private and government parties with medium capital, and moderate to high agriculture (Saputra et al., 2021).

The results of matching the data on soil characteristics and criteria for cacao plants (Table 2) obtained the potential land suitability of the Banggai Regency, namely the appropriate marginal class (S3). With efforts to improve medium-level land with agricultural patterns and moderate costs of limiting factors to land for cacao plant development. Therefore, Banggai Regency land is classified as very suitable (1964,2 ha), quite suitable (2616.6 ha), and marginally suitable (391,256.1 ha). The total land area for cacao development in Banggai Regency is 419,236.9 ha (Figure 3). This is because of temperature (tc), availability of water (wa); rooting medium (rc); erosion hazard (eh), where this limiting factor cannot meet the criteria for the suitability of cacao plants even though repairs have been made to a high level (Wahyuningrum & Putra, 2018).
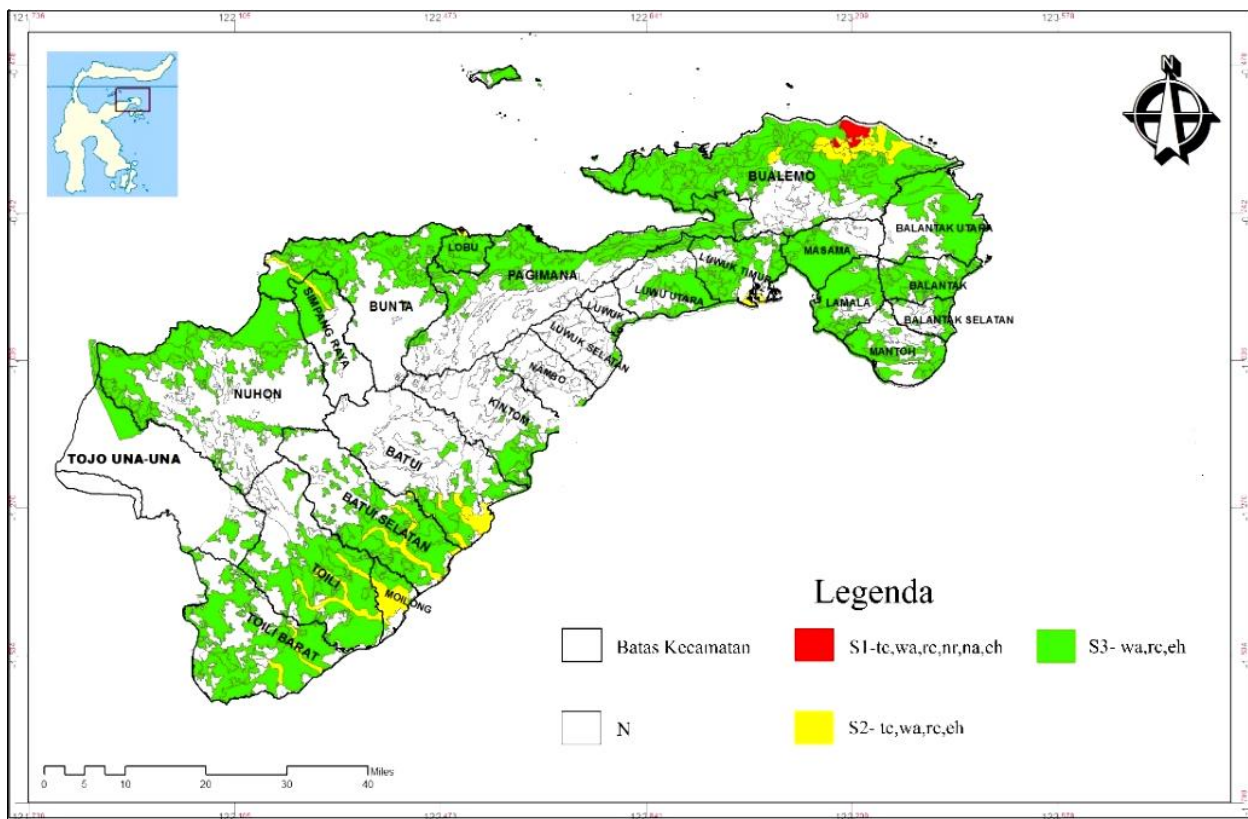
Figure 3. Land Suitability of Potential Cacao Plants in Banggai Regency

Table 4. Directions for Cacao Commodity Development in Banggai Regency

Sub-district	Land suitability class	Recommendation	Land area (ha)
Bualemo Batui, Batui Selatan Selatan, Toili Moilong, Toili Barat, Simpang Raya, Bunta, and Luwuk Timur.	S1, S2, S3	Addition of lime, fertilizer and organic matter, manufacture of mound terraces, bench terraces and credit terraces, as well as erosion-repelling plants	419.236,9

Description: S1 = very suitable; S2 = suitable; S3 = marginally suitable

Mubekti (2012) stated that heavy land limiting factors such as root media and temperature could not be repaired. Limiting factors for water availability and the danger of erosion require very high costs to carry out repairs. So that the land allocation for the cacao commodity is carried out for all areas of the Banggai Regency in potential areas. The potential area for developing these commodities is seen based on the existing potential land map (Figure 3). The directed site is outside the river border protected area, protected forest and nature reserve forest and companies (Sariani et al., 2021). Then the directed land (Table 4) has been adjusted to the RTRW map of the Banggai Regency.

CONCLUSIONS

Actual land suitability for cacao plantations in Banggai Regency is N (not suitable) and S3 (marginally suitable). This is because of the temperature limiting factor (tc); availability of water (wa); root zone media (rc); nutrient retention (nr); nutrient available (na); erosion hazard (uh). With efforts to improve land at the middle level with an agricultural pattern and moderate

costs from the limiting factor for land for cacao plant development, the land in Banggai Regency is classified as very suitable (1964,2 ha), suitable (26016.6 ha), and marginally suitable (391,256.1 ha). The total land area for cacao development in Banggai Regency is 419,236.9 ha.

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REFERENCES

Aini LN, Mappiasse MF, & Mulyono. 2020. Land suitability evaluation for cocoa (*Theobroma cacao* L.) in Gantarang sub district, Bulukumba, Sulawesi Selatan. *IOP Conference Series: Earth and Environmental Science*, 458:012001. https://doi.org/10.1088/1755-1315/458/1/012001

Amos TT. 2007. An analysis of productivity and technical efficiency of smallholder cocoa farmers in Nigeria. *Journal of Social Sciences*, 15(2):127–133. https://doi.org/10.1080/09718923.2007.11892573

Anglaaere LCN, Cobbina J, Sinclair FL, & McDonald MA. 2011. The effect of land use systems on tree diversity: farmer preference and species composition of cocoa-based agroecosystems in Ghana. *Agroforestry Systems,* 81:3, 81(3):249–265. https://doi.org/10.1007/S10457-010-9366-Z

Baja S, Chapman DM & Dragovich D. 2006. Spatial based compromise programming for multiple criteria decision making in land use planning. *Environmental Modeling & Assessment*, 12(3):171–184. https://doi.org/10.1007/S10666-006-9059-1

FAO [Food and Agriculture Organization of the United Nations]. 1976. *A Framework for Land Evaluation*. Soil Resources Management and Conservation Service Land and Water Development Division. FAO Soil Bulletin No. 32. FAO-UNO, Rome. https://www.fao.org/3/x5310e/x5310e00.htm

FAO [Food and Agriculture Organization of the United Nations]. 2007. *Land Evaluation. Towards A Revised Framework*. Land and Water Discussion Paper No. 6. FAO, Rome. https://edepot.wur.nl/488269

Hazriyal Y, Anhar A, & Karim A. 2015. Evaluasi karakteristik lahan dan produksi kakao di Kecamatan Peudawa dan Peunaron Kabupaten Aceh Timur. *Jurnal Manajemen Sumberdaya Lahan*, 4(1):579–590. http://202.4.186.66/MSDL/article/view/7162

Indrianti MA. 2020. The Suitability of actual and potential land of robusta coffee plants in Bone Bolango Regency. *Jurnal Sains Informasi Geografi*, 3(1):45–52. https://doi.org/10.31314/JSIG.V3I1.558

Jayanti DS, Goenadi S & Hadi P. 2013. Evaluasi kesesuaian lahan dan optimasi penggunaan lahan untuk pengembangan tanaman kakao (*Theobroma cacao* L.) (Studi kasus di Kecamatan Batee dan Kecamatan Padang Tiji Kabupaten Pidie Propinsi Aceh). *AgriTECH*, 33(2):218. https://doi.org/10.22146/AGRITECH.9808

Jumiyati S, Nurdin R, Rahman I, Alam AS & Akkas N. 2021. Economic and ecological adaptation to changes in agricultural land use to increase sustainable economic resilience. *IOP Conference Series: Earth and Environmental Science*, 800(1):1–9. https://doi.org/10.1088/1755-1315/800/1/012049

Katili HA. 2020. Food crop land use planning in Banggai Regency. *Jurnal Pertanian Tropik*, 7(1,April):12–24. https://doi.org/10.32734/JPT.V7I1

Kiranta F & Meydianawathi LG. 2014. Analisis tingkat daya saing ekspor biji kakao Indonesia Tahun 2007-2012. E-*Jurnal Ekonomi Pembangunan*, 3(11):502–512.

https://ojs.unud.ac.id/index.php/eep/article/view/9421

Liyanda M, Karim A & Abubakar Y. 2012. Analisis Kriteria kesesuaian lahan terhadap produksi kakao pada tiga klaster pengembangan di Kabupaten Pidie. *Jurnal Agrista*, 16(2):62–79. http://www.jurnal.unsyiah.ac.id/agrista/article/view/289

Malik A, Siska W, Sosiawan H, Tafakresnanto C, & Adi SH. 2021. Land suitability for agricultural development in Jayapura Regency, Papua. *IOP Conf. Series: Earth and Environmental Science 648:012004*. https://doi.org/10.1088/1755-1315/648/1/012004

Mubekti. 2012. Evaluasi karakterisasi dan kesesuaian lahan untuk komoditas unggulan perkebunan: Studi kasus Kabupaten Kampar. *Jurnal Teknologi Lingkungan*, 13(1):37–46. https://doi.org/10.29122/JTL.V13I1.1403

Nael N, Papilaya FS. 2019. Spatial analysis of the land suitability for cocoa plantations in East Dusun District. *Journal of Applied Geospatial Information*. 3(2):228-234. https://doi.org/10.30871/jagi.v3i2.1345

Nangge M, Yatim H & Sataral M. 2020. Growth and yield of paddy IPB 3S varieties with the application of NPK fertilizer and straw compost. *Jurnal Pertanian Tropik*, 7(1): 47–55. https://doi.org/10.32734/jpt.v7i1,April.3756

Ndekano I, Sataral M, Katili HA & Zulfajrin M. 2021. Status of Soil fertility on rice fields in Mekarjaya Village, West Toili District. *CELEBES Agricultural*, 1(2): 27–34. https://doi.org/10.52045/JCA.V1I2.27

Pamanyo K, Puspapratiwi D, Yatim H, Katili HA, Sataral M & Bidullah T. 2021. Analysis of land carrying capacity and production factors of cocoa (*Theobroma cacao* L.) in Banggai Regency. *Jurnal Ilmiah Pertanian*, 18(1): 29–36. https://doi.org/10.31849/JIP.V18I1.7377

Pereira JMC & Duckstein L. 1993. A multiple criteria decision-making approach to GIS-based land suitability evaluation. *International Journal of Geographical Information Systems*, 7(5): 407–424. https://doi.org/10.1080/02693799308901971

Pimentel D & Kounang N. 1998. Ecology of soil erosion in ecosystems. *Ecosystems*, 1(5): 416–426. https://doi.org/10.1007/S100219900035

Purba D, Widjajanto DW & Purbajanti ED. 2019. Pengaruh berbagai dosis nitrogen dan waktu pemberian pupuk organik cair terhadap pertumbuhan dan produksi tanaman terung hijau (Solanum melongena L.). *Journal of Agro Complex*, 3(3): 159–165. https://doi.org/10.14710/joac.3.3.159-165

Rahmawaty, Frastika S, Rauf A, Batubara R & Harahap FS. 2020. Land suitability assessment for Lansium domesticum cultivation on agroforestry land using matching method and geographic information system. *Biodiversitas Journal of Biological Diversity*, 21(8): 3683–3690. https://doi.org/10.13057/BIODIV/D210835

Riswanto M, Sataral M, Yatim H & Katili HA. 2020. Kelas kesesuaian lahan untuk pengembangan tanaman vanili di Kecamatan Balantak Kabupaten Banggai. *Jurnal Pertanian Cemara*, 17(2): 66–74. https://doi.org/10.24929/FP.V17I2.1148

Ritung S, Nugroho K, Mulyani A & Suryani E. 2011. *Petunjuk Teknis Evaluasi Lahan untuk Komoditas Pertanian (revisi)*. Balai Besar Penelitian dan Pengembangan Sumberdaya Lahan Pertanian.

Saikim S, Yatim H & Katili HA. 2021. Identification and assessment of soil physical and chemical properties for vanili plants in North Tinangkung District, Banggai Islands Regency. *CELEBES Agricultural*, 1(2): 35–48. https://doi.org/10.52045/JCA.V1I2.24

Saputra MF, Adyatma S & Arisanty D. 2021. Evaluasi kesesuaian lahan untuk tanaman durian menggunakan metode matching. *Jambura Geoscience Review*, 3(1): 18–31. https://doi.org/10.34312/JGEOSREV.V3I1.5652

Sariani Yatim H & Katili HA. 2021. Evaluasi kesesuaian lahan untuk pengembangan kelapa babasal (Cocos nucifera) di Kecamatan Batui Kabupaten Banggai. *Agrifor : Jurnal Ilmu*

Pertanian dan Kehutanan, 20(1): 153–160. https://doi.org/10.31293/agrifor.v20i1.5171

Setyowati DL. 2007. Kajian evaluasi kesesuaian lahan permukiman dengan teknik sistem informasi geografis (SIG). *Jurnal Geografi : Media Informasi Pengembangan Dan Profesi Kegeografian*, 4(1): 44–54. https://doi.org/10.15294/JG.V4I1.111

Sharifi MA & Van Keulen H. 1994. A decision support system for land use planning at farm enterprise level. *Agricultural Systems*, 45(3): 239–257. https://doi.org/10.1016/0308-521X(94)90140-B

Suryawan IB, Adi IGPR & Dibia IN. 2020. Evaluasi kesesuaian lahan untuk beberapa tanaman pangan dan perkebunan di Kecamatan Burau Kabupaten Luwu Timur Sulawesi Selatan. *Jurnal Agroekoteknologi Tropika*, 9(1): 62–75.

Syaf H, Kilowasid LMH & Karim J. 2019. Perencanaan lahan pesisir untuk tanaman kakao rakyat dalam upaya meningkatkan pendapatan nelayan di Labuan Kabupaten Buton Utara. Seminar Nasional Kelautan XIV " Implementasi Hasil Riset Sumber Daya Laut Dan Pesisir Dalam Peningkatan Daya Saing Indonesia", 41–49. http://karyailmiah.uho.ac.id/karya-ilmiah.php?read=9778

Wahyuningrum N & Putra PB. 2018. Land evaluation to assess performance of Rawakawuk Sub Watershed. *Jurnal Penelitian Pengelolaan Daerah Aliran Sungai*, 2(1): 1–16. https://doi.org/10.20886/JPPDAS.2018.2.1.1-16

Wahyunto, Ritung S, Wahdini W, & Agus F. 2008. Assessment of agricultural crops suitability for post-tsunami calamity. A case study of coastal area of Aceh Barat district. International Workshop on Post Tsunami Soil Management, 1-2 July 2008 in Bogor, Indonesia

Welang CP, Mononimbar W & Poli H. 2016. Kesesuaian lahan permukiman pada kawasan rawan bencana gunung berapi di Kota Tomohon. *SPASIAL : Perencanaan Wilayah*, 3(3): 136–145.