Spatial Analysis of the Land Suitability for Cocoa Plantations in East Dusun District

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Abstract

The expansion of plantations of cocoa is the main component in the plantation revitalization program which is applied by the Government of Indonesia in order to optimize the potential of cocoa. This policy has not been implemented well in East Dusun District, East Barito Regency, Central Kalimantan Province that just open cocoa plantations covering an area of 3 ha in the year 2016. The spatial analysis of land suitability by utilizing Geographic Information System capability that allows the expansion of plantations of cacao in this district. Spatial analysis to get the suitability of land for cocoa plantations uses overlay based on climate conditions and regulations of the Governor of Central Kalimantan. The proportion of land suitability class that is highly suitable, suitable, marginally suitable, and not suitable with each area size of 56,434.63 ha, 2,302.81 ha, not found, and 19,510.42 ha.

Keywords: Cocoa, Overlay, Land Suitability

1. Introduction

Indonesia is an international exporter of cocoa commodities. This country is even known as the world's third largest exporter of cocoa beans after Ivory Coast and Ghana. However, the big achievement was stopped due to various obstacles that caused the depreciation in cocoa productivity in Indonesia. The problems that occur are more charged to farmers, considering that the management of cocoa in Indonesia is dominated by smallholder plantations. Factors that are the main causes of the depreciation in cocoa productivity, such as: 1) pest attacks; 2) superior cocoa varieties are not considered; 3) low-quality cocoa; 4) not yet optimal supporting facilities for cocoa cultivation (Utami, Suharyono, & Yulianto, 2018).

In order to optimize the potential of cocoa, the expansion of cocoa plantation land is one of the main components in the revitalization of plantations by the Government of Indonesia. The development of cocoa commodities has been implemented in the District of East Dusun, East Barito Regency, Central Kalimantan Province. The opening of the cocoa plantation area is 3 ha or equal to 0.0034% of the total area of the East Dusun District (Statistic of Barito Timur Regency, 2017). The data shows that there have been efforts made on cocoa commodities, but the use of land for these plantations is still very low. This is the basis for the analysis to determine the level of regional suitability before expanding the cocoa plantation area in this District.

This research was conducted by spatial analysis of the suitability of cocoa plantation land in the East Dusun District based on climate factors and the Regulation of the Governor of Central Kalimantan by utilizing GIS. Spatial analysis is the process of manipulating basic maps by selecting, combining or reformatting existing geospatial data into new data suitable for answering spatial questions (Lo & Yeung, 2007). GIS capability or Geographic Information System in processing data and information into a system that references geography so that it can used as a policy in decision making in a plan (Safuan, Kandari, & Natsir, 2013).

The purpose of this study was to determine the level of suitability of cocoa plantation land in the District of East Dusun, East Barito Regency, Central Kalimantan Province. Based on the explanation above, the analysis based on SIG is very important in the effort to obtain spatial information to provide the level of land suitability for cocoa plantations in this region.

2. Literature Reviews

Relevant research as a reference in this study is about the analysis of overlaying of cocoa commodity regions based on agro-climate suitability based on Geographic Information Systems in Enrekang

Regency. The research aims to get an ideal environment for cocoa growth in Indonesia based on climate factors (Ilham, Nuddin, & Malik, 2017).

The research conducted was "Spatial Analysis of Land Suitability of Cocoa Plantation in East Dusun District" with overlay technique. Land Suitability is a measure of the suitability of a land. The structure of land suitability classification according to the FAO framework can be distinguished according to the following levels: (1) Order, namely overall land suitability and differentiated into appropriate and inappropriate land orders; (2) Class, which is the suitability of being in an order, where according to the land order there are several classes that are very suitable, appropriate, and according to marginal (S3). Whereas inappropriate orders are not differentiated into classes; (3) Sub-class, namely land suitability in the class based on the quality and characteristics of the land which is the heaviest limiting factor (Baktiawan, 2008).

The overlay process has facilities that can be used in conducting spatial analysis, namely: (1) Union, is a combination of polygons from the overlay theme to produce a theme containing all attributes; (2) Intersect, is a process of cutting several themes to produce output with attributes that have attribute data from both intersecting themes; (3) Dissolve, is the process of combining polygons that have identical or equal attribute data (Yosafat & Papilaya, 2017).

The spatial analysis also has another function besides overlay, which is buffering. Buffer analysis is used to identify areas around geographic features. The area is in the form of point, line or area objects (certain polygons) so as to form an area, polygon, or a new zone that covers spatial objects (buffered objects) with a certain distance (Handayani U. N., Soelistijadi, & Sunardi, 2005).

In this study an overlay analysis of the suitability of cocoa plantation land was carried out based on climate compliance guidelines and regional regulations in the District of East Dusun. Climate factors for analysis of cocoa land suitability include temperature, rainfall and elevation (Ilham *et al.*, 2017). The class sub-classes used in determining the suitability of cocoa land in the form of climate parameters are shown in Table 1.

Table 1. Cocoa Land Suitability Sub-class by Climate

Parameter	Sub-Class			
	Very Suitable (S1)	Suitable (S2)	Marginal Suitable (S3)	Not Suitable (N)
Temperature (°C)	18 – 32	-	-	< 18 or > 32
Rainfall (mm/year)	1.500 – 2.500	2.500 – 3.000	1.100 – 1.250	< 1.000 / > 3.000
Height (masl)	< 600	600 – 700	700 – 800	> 800

Source: Ilham *et al*, 2017

Temperature and rainfall data processing can be done using the Inverse Distance Weighted (IDW) method. IDW is a simple deterministic method by considering the point around it (NCGIA, 2007). The assumption of this method is that the interpolation value will be more different in the sample data that is far from the near one (Pasaribu & Haryani, 2012).

Digital Elevation Model (DEM) is a digital model that represents the surface of the earth's topography in three-dimensional form (Indarto, Wahyuningsih, Usman, & Rohman, 2008). DEM used to determine field attributes such as altitude at point, slope and any aspect (Balasubramanian, 2017).

Regional regulations used in managing cocoa plantations refer to the Central Kalimantan Governor's Regulation regarding the radius of distance between water sources and plantation development activities. These regulations are as shown in Table 2.

Table 2. Limitation of Distance to Plantations with Water Sources

No	Water Source	Distance
1	Reservoirs and lakes	500 meters
2	Spring and river swamp area	200 meters
3	River	100 meters
4	Tributary	50 meters
5	Gorge	2 times depth
6	Beach	130 times the highest and lowest pairs

Source: Regulation of the Governor of Central Kalimantan, 2011

GIS techniques have emerged as powerful tools for watershed management programs (Wicaksono, Pertiwi, P, & Widayani, 2019). Watershed boundary delineation is useful to determine the shape of peak discharge hydrograph, flood analysis, and water resource management planning.

Analysis with watershed boundary delineation has an order determination stage in a river flow. Order of the river is the position of branching of the river flow in sequence to the river parent in the watershed (Purwono, Hartanto, Prihanto, & Kardono, 2018).

Processing DEM related to watershed boundary delineation is automatically composed of algorithms

with the principle of topographic data extraction to obtain hydrological parameters of a watershed (Lin, Chou, Lin, Huang, & Tsai, 2006).
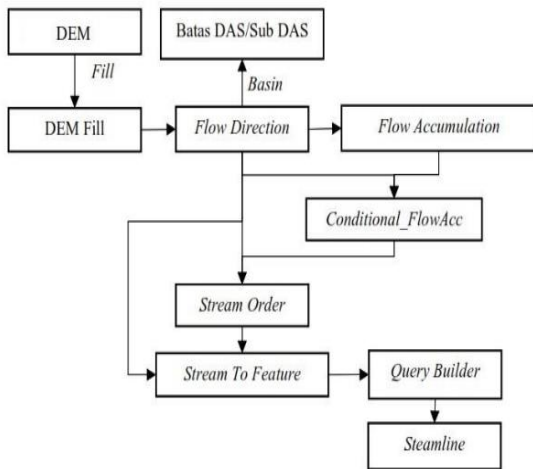

Fig 1. The Automatic Watershed Algorithm on GIS (Purwono *et al.,* 2018).

Figure 1 shows the flow of the watershed delineation process automatically from DEM data. Determination of river order can be done using the Strahler method. Based on the Strahler method, the first order is a tributary and the location of the tip of the order is considered a spring. Whereas for the next order is the river segment (Triono, 2010). Processing the map of the ravine area is done by extracting a ravine from the shadow of two solar sources. This technique utilizes azimuth and altitude in the DEM data shown in Figure 2.
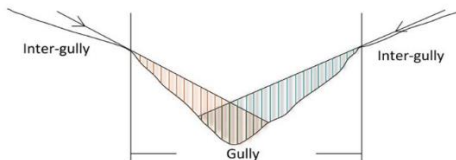

Fig 2. Determination of Gorges Based on Sun Shadows (Yang, Li, Na, & Liu, 2017)

The steps for determining the gorge based on sun shadows are: (1) running the shill-shading tool in ArcGIS according to the altitude values and some azimuths. The shadows model is checked and the shadow area will be defined with a value of 0; (2) the results are then reclassified with the value 1 for the shadow area and 0 for the non-shadow area; (3) add this boolean map using a raster calculator with an area of more than 0 considered an area affected by a ravine and 0 is a gully or inter-gully (Yang *et al.,* 2017).

3. Research Method

The method used in this study is a quantitative method. The data used are secondary data sourced from relevant agencies in providing data and results from previous studies. This research was conducted in the District of East Dusun, East Barito Regency, which is located at the coordinate point 1,99° SL – 2,40° SL dan 114,94° EL – 115,30° EL.
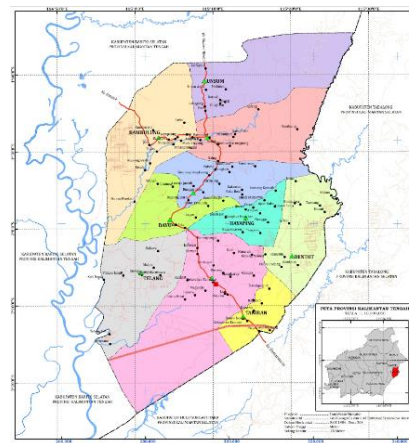

Fig 3. The Administrative Map of East Barito Regency (Pokja Sanitasi dan AMPL Barito Timur, 2015)

The stages of the study are divided into 6 parts, namely: (1) problem identification; (2) preparation and collection of data; (3) data processing; (4) conducting overlay or overlay analysis; (5) make reports from research results; (6) conclude the results.
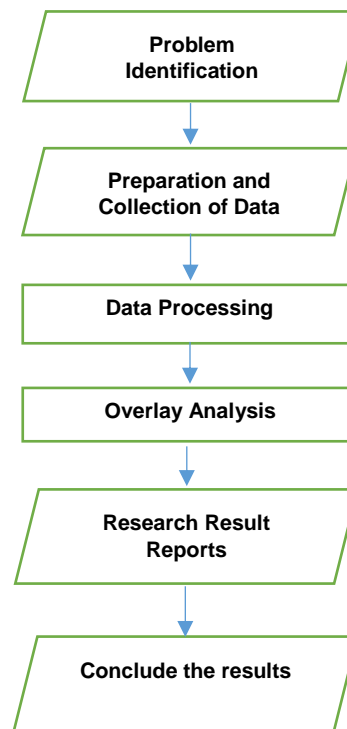

Fig 4. Research Flowchart

The stages of research shown in Figure 2 are explained in detail as follows. Stage 1: identification of problems, namely identifying problems related to the development of cocoa plantations in the District of East Dusun.

Stage 2: preparation and collection of data, namely preparing and collecting data needed in conducting research. Data used, namely: (1) Administrative map of East Dusun District; (2) temperature and average rainfall data of East Dusun District from the en.climate-data.org website (Climate-

data.org, 2019); (3) DEM imagery from DEMNAS from the website tides.big.go.id (The Indonesian Geospatial Information Agency, 2018); (4) landing data on distance of development activities with water sources from the Central Kalimantan Governor Regulation (Regulation of the Governor of Central Kalimantan, 2011); (5) land system map (Mantel, Wösten, & Verhagen, 2007); (6) reservoir and lake maps from the website portal.ina-sdi.or.id (The Indonesian Geospatial Information Agency, 2019).

Stage 3: data obtained is then processed so that it can be used in conducting spatial analysis. Administrative map of the East Dusun District as a research case area coverage.

Maps for climate suitability are used, namely: temperature, rainfall, and elevation. Temperature and rainfall data are entered according to the village and the Sub-District coordinate points of East Dusun District which then automatically forms a temperature and rainfall map using the IDW method. While the elevation map is processed by extracting DEM.

Processing maps for suitability of water sources, in the form of: (1) watershed boundary delineation to determine maps of rivers, creeks and springs; (2) maps of rivers and swamp areas by intersecting watershed boundary delineation results in swamp areas with land system maps; (3) a ravine map is processed by extracting a map of DEM based on 2 directions of the sun's shadow; (4) maps of reservoirs and lakes are processed based on the boundaries of the District of East Dusun; (5) coastal maps are processed based on visual analysis and geographical conditions of East Dusun District; (6) determination of maps for the distance of water sources with buffer functions based on the Central Kalimantan Governor Regulation and combined with the map of the Eastern Dusun RTRW using the intersect function.

Stage 4: Spatial analysis is done by the overlay method. The parameters used are in accordance with the data that has been processed and analyzed the level of suitability using the FAO method. The land suitability class and sub-class are divided into 4 (four) types, namely: S1 class (very suitable), S2 class (suitable), S3 class (marginal suitable), and N (not suitable). Sub-class processing is done by dissolve function based on each suitability and the map is overlaid to obtain a class of conformity with the intersect function.

Stages 5 and 6: the research process carried out from the beginning to the end is documented and concluded into the research report.

4. Result and Disscussion

Rainfall maps are obtained from the average temperature and rainfall data that occur in each village / sub-district in the sub-district of East Dusun. Rainfall and temperature data in the study area are based on climatic data modeling collected from 1989 to 2012 as presented in Table 3.

Table 3. Rainfall and Temperature Data of East Dusun District

No	Village / Sub-District	Temperature (°C)	Rainfall (Mm/year)
1	Tamiang Layang	26.6	2,449
2	Sarapat	26.5	2,460
3	Pulau Patai	26.5	2,427
4	Matabu	26.5	2,434
5	Magantis	26.6	2,424
6	Karang Langit	26.4	2,510
7	Jaweten	26.4	2,519
8	Jaar	26.5	2,438
9	Haringen	26.5	2,481
10	Harara	26.5	2,447
11	Dorong	26.5	2,474

Source: Climate-Data.org

Maps are obtained using the Inverse Distance Weighted (IDW) method. The results of processing temperature and rainfall maps are shown in Figures 5 and 6.
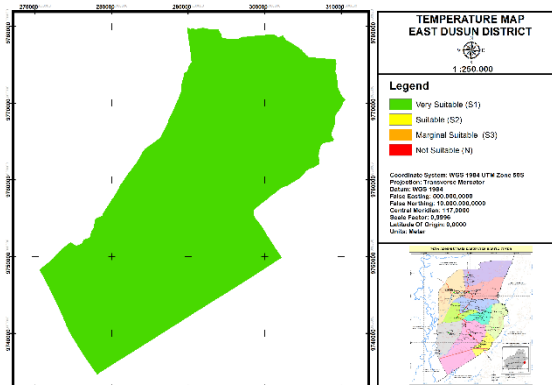

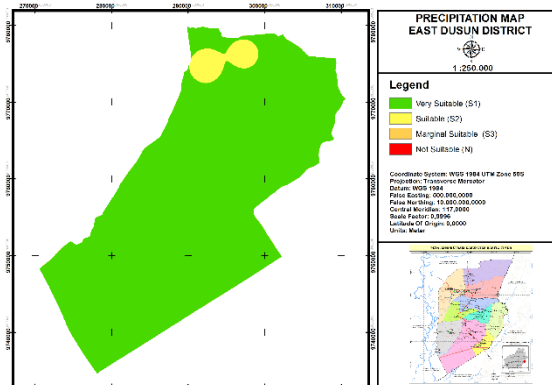Fig 5. Results of Processing the Temperature Map of the East Dusun District

Fig 6. Results of Processing the Rainfall Map of the East Dusun District

The temperature map interpolation results in Figure 5, the lowest temperature is at 26.4 ° C and the highest is 26.63 ° C. While the results of the interpolation of rainfall maps in Figure 6, the lowest rainfall is 2,410.03 mm / year and the highest is 2,519 mm / year.

Elevation maps are obtained by extracting DEM data based on the case study area of the cocoa plantation suitability land, which is in the East Dusun District area. The resulting map of extraction of the DEM Imagery to obtain an elevation map is shown in Figure 7.
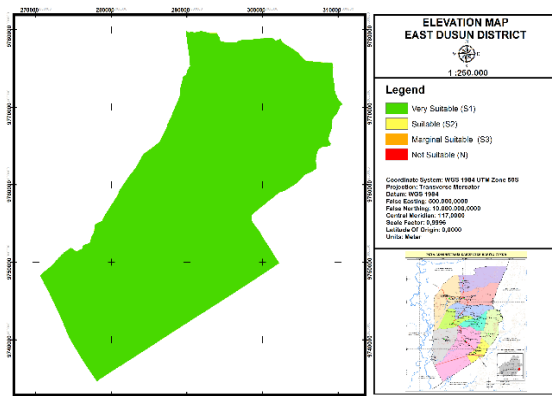
Fig 7. Results of Elevation Map Processing of DEM Data Extraction Results

The processing of DEM data in Figure 6 shows that the Kecamatan Dusun Timur has a height of less than 100 meters above sea level. The area that is located below 600 meters above sea level is a very suitable area for planting cocoa (Ilham *et al.,* 2017).

Suitability of water source distance based on Central Kalimantan Governor Regulation regarding plantation distance limits (Regulation of the Governor of Central Kalimantan, 2011). Areas where plantations are outside the boundary of the specified water source are areas that meet the Central Kalimantan Governor's Regulation. Whereas the plantation area which is less than the distance of the water source is an area that does not meet the Central Kalimantan Governor's Regulation. Based on this, it can be concluded that the suitability of the water source distance sub-class is divided into 2 sub-classes, namely S1 and N.

Map of the distance of water sources is obtained by conducting buffering from the results of data processing of rivers, creeks, swamps, ravines, lakes, reservoirs, and beaches. The buffer results from each map are then combined with union facilities to produce a map of the water source distance shown in Fig 8.
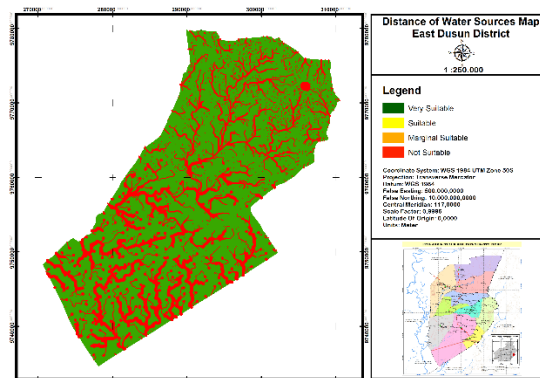

Fig 8. Results of Map Processing Distance of Water Sources

The results of processing a map of the distance of water sources within the distance of the water source with the plantation obtained an area of 19,510.42 ha. Whereas for areas outside the distance of water resources with plantations, an area of 58,737.44 ha is obtained.

The land suitability class is based on the assessment of the hardest limiting factors for each sub-class. S1 land suitability class according to climate suitability with average rainfall between 1,500-2,500 mm / year, the elevation is below 600 masl above sea level, and the average temperature is in the range of 15-32 ° C with the optimum temperature at 30-32 ° C (Ilham *et al.*, 2017).

Land suitability in plantation regulations, areas outside the radius of distance from water sources are the right areas for plantation development (Regulation of the Governor of Central Kalimantan, 2011). The results of processing land suitability classes using the overlay technique are shown in Table 4.

Table 4. Results of Cocoa Plantation Suitability Class Overlays

Land Suitability Class	Large (ha)	Temperature (°C)		Elevation (masl)		Rainfall (mm/year)		Water Source Distance	
		Value	Class	Value	Class	Value	Class	Value	Class
Suitable (S2)	2.302,81	15-32	S1	< 600	S1	2.500-3.000	S2	Suitable	S1
Not Suitable (N)	508,02	15-32	S1	< 600	S1	2.500-3.000	S2	Not Suitable	N
Very Suitable (S1)	56.434,63	15-32	S1	< 600	S1	1.500-2.500	S1	Suitable	S1
Not Suitable (N)	19.002,40	15-32	S1	< 600	S1	1.500-2.500	S1	Not Suitable	N

S1 land suitability classes for cocoa plantations were found with an area of 56,434.63 ha. The area of S1 land suitability dominates in the study area with a broad percentage of 72.12% of the total area analyzed.

The land suitability class N is in the heaviest limiting factor in the form of a parameter of water source distance. Areas that are within the boundary area of water resources are areas that are not allowed for plantation development (Regulation of the Governor of Central Kalimantan, 2011). The division of land area for suitability class N is divided into 2 due

to the presence of the second ballast factor in the form of S2 rainfall sub-class of 508.02 ha and in addition an area of 19,002.40 ha. However, the suitability class remains in the N range with a total area of 19,510.42 ha or 24.93% of the total area analyzed.

The next land suitability class is the S2 suitability class with the heaviest limiting factor located in the rainfall parameter. Land suitability classes with limiting rainfall factors in the range 2,500 - 3,000 mm / year are in the suitability of S2 (Ilham *et al.*, 2017). The area for this suitability is 2,302.81 ha or 2.94% of the total area analyzed.

The land suitability class not found in the study area is the S3 land suitability class. S3 suitability level is not classified due to sub-classes in each parameter not found the heaviest limiting factor with S3 sub-class.

The total area was analyzed using the overlay technique in the East Dusun sub-district with an area of 78,247.86 ha. The results of overlaying the suitability of cocoa plantation land in the District of East Dusun are presented in the form of maps shown in Figure 9.
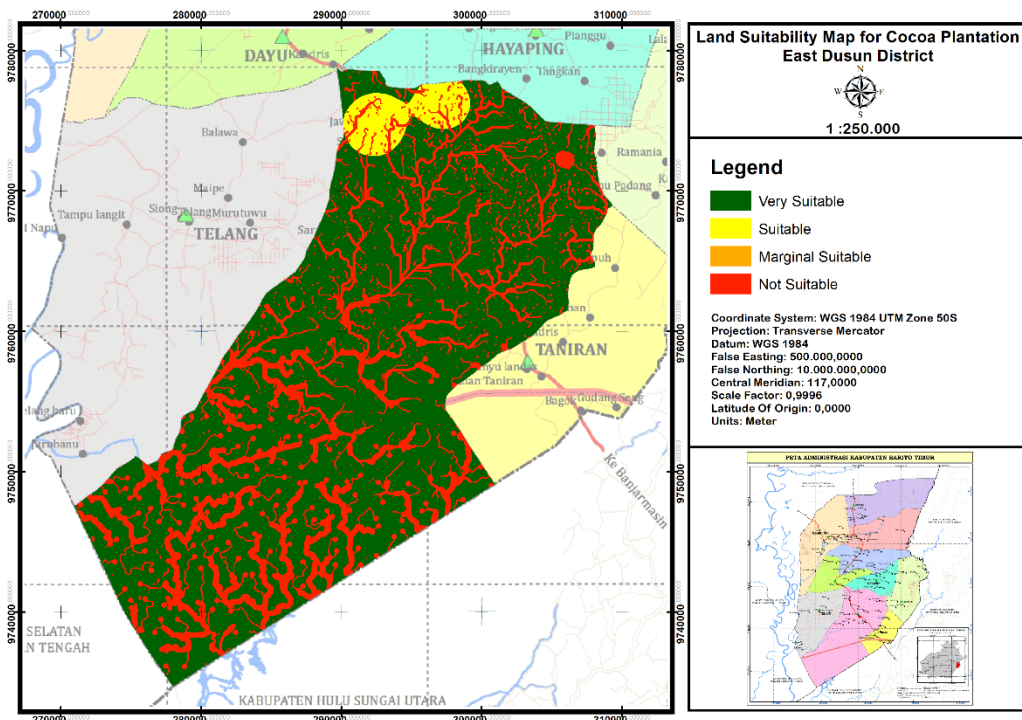

Fig 9. Land Suitability Map for Cocoa Plantation in East Dusun District

6. Conclution

Based on the spatial analysis of the suitability of cocoa plantation land that refers to the climate and the conditions contained in the Central Kalimantan Governor's Regulation, it shows that the East Dusun District is dominated by land suitable for cocoa plantations. Appropriate proportion of land suitability class (S1), appropriate (S2), appropriate marginal (S3), and not appropriate (N) with the total area of each is 56,434.63 ha (72.12%), 2,302.81 ha (2.94%), not found, and 19,510.42 ha (24.28%) of the total area of land analyzed.

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