Land suitability evaluation 3D method for mapping the feasibility of the Gambir plantation (*Uncaria Gambir. Roxb*) in West Sumatra, Indonesia

Cite as: AIP Conference Proceedings **2583**, 060014 (2023); https://doi.org/10.1063/5.0116402
Published Online: 13 January 2023

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Land Suitability Evaluation 3D Method for Mapping the Feasibility of the Gambir Plantation (*Uncaria gambir. Roxb*) in West Sumatra, Indonesia

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Abstract. Efforts to characterize the soil in the Mahat Watershed (MW), Lima Puluh Kota Regency, West Sumatra, Indonesia, have been disclosed in this study for the evaluation of land suitability for sustainable community Gambir plantations because the Mahat watershed supplies 80% of the world's Gambir needs. The method FAO 1976 was used combined with spatial multi-criteria analysis and three-dimensional (3D) mapping. It was found that from 67 soil samples taken in the MW can be grouped into three soil orders namely Ultisols (UT), Inceptisols (IC), and Entisols (EN). This soil develops from a single parent material geology. The Physicochemical properties of the soil were analyzed using standardized methods using AAS and Spectrophotometers and 3D Mapping using the Surfer tool software. Evaluation of soil suitability based on soil sample no.1, 11-14, 18-21, 27-29, 32-34, 36-40, 43-45, 47-50, 57, 60 and no.63-65" moderate suitable "(S2) and soil sample no. 1-7, 9-10, 15-17, 22, 24-26, 52-56, 59, 62 and no, 66-67 in the class" "marginally suitable" (S3). The soil sample no. 23, 30-31, 35, 41-42, 46, 51, 58, 61 in the class "not suitable" (N) for the Gambir plantation in the MW. Based on the analysis of the area of the 3D Map in the MW, it was found that around 1785 ha (10%) of the total MW area in class (S2). An area of 7140 ha (40%) is classified as "marginally suitable" (S3). The area classified as "not suitable" (N) was found to be 8924 ha (50%). However, there was no or (0 ha and 0%) found area in the class "suitable" (S1) due to climatic factors, high soil erosion and degraded soil fertility. Through the application of soil and water conservation practices technology such as flat terraces, credit terraces, mound terraces, bench terraces, garden terraces, mulch and balanced fertilization, Gambir soil suitability class increased to class S2 (55%), to class S3 decrease to be (30%) and Reboisation forest (15%). The FAO method combined with multi-criteria analysis and 3D mapping is very helpful in determining with precision the location of the Gambir plantation in classes S1, S2, S3, N in the MW and very helpful in recommending the application of soil and water conservation practices with specific location.

INTRODUCTION

Knowledge of soil, its properties, and the spatial distribution of soil properties is indispensable for agricultural development in the territory of Indonesia because it opens up opportunities for more rational land resource management [1,2]. Information on site characteristics, landforms, and soil quality has been recognized as an important requirement in the planning process for the evaluation of land suitability for the Gambir tree (*Uncaria Gambir. Roob*). Land evaluation using scientific procedures is very important in assessing the potential and constraints of soil properties for this agriculture purpose [3,2]. Various land evaluation approaches have been developed and each has specific methodological procedures [4, 2]. The main objective of the evaluation of the suitability of land for Gambir plantations is to assess the potential of land for land use for Gambir plantations by comparing the systematic requirements for Gambir gardens with the resources owned by the land [5,2].

The 5th International Conference on Agriculture and Life Science 2021 (ICALS 2021)
AIP Conf. Proc. 2583, 060014-1–060014-14; https://doi.org/10.1063/5.0116402
Published by AIP Publishing. 978-0-7354-4216-0/$30.00

Computer software programs (such as: Surfer tools) are then used to assess and map land units and present the results as a land suitability map for Gambir plantations. In the last decade multi-criteria evaluation has been widely used for decision making using the Surfer tool [2] which can be useful in solving conflict for individuals or groups interested in spatial context, with advances in information and communication technology, computer modeling in decision making has been developed for land evaluation [6, 2], land suitability for specific crops. The soil data base developed systematically based on the Surfer tool is very important in assessing and analyzing the suitability of plants to be planted on the soil so that the available resources are used optimally [7,8,9]. Topographic characteristics, climatic conditions, and soil quality of an area are the most important parameters for the determination of land suitability evaluation for Gambir. Gambir land evaluation using map analysis techniques can be done with the Surfer tool [10,2], because it has succeeded in developing a theoretical framework based on the Surfer tool for soil erosion characteristics, recommending land use and assessing the suitability of land for rice fields in the Sumani watershed [7].

The Agricultural practices vary widely under different agroecological conditions. Indonesia is currently the supplier of 80% of the world's gambir needs and the oldest gambier production site in Indonesia has been started in 1833 is Nagari Mahat in Limapuluh Kota Regency (29). The gmbir plant in Mahat has long supported the livelihood of local farmers and improved the farmers' economy to date, but now the issue of the plant has caused environmental degradation because it is planted on sloping land and this needs to be scientifically proven. For this reason, the suitability of the gambir plantation land which has been around for a long time in the Mahat River Basin is currently very important to be assessed so as not to cause harm to farmers and the environment. [11] stated that in this context, evaluation of the physical environment and its impact on crop production is important, it helps to determine the potential for effective land use and ultimately to optimize agricultural yields for the benefit of local farmers.

Gambir tree is a genus of *Rubiaceae* plants, useful for tanneries and dyes and medicines, contains catechins, is also a natural ingredient that is an antioxidant.[12] The catechin isolate is an active compound derived from the uncaria plant which has the main function as an antioxidant. The catechin isolate was obtained from the uncaria plant material, namely gambier. Gambir will then be extracted and the active ingredient taken, namely catechin isolate (*Uncaria gambir. Roxb*) is one of the commodities in West Sumatra that is used as a material for plywood. It is also used as a traditional medicine for diarrhea, toothache, and fever due to its catechin content which can act as a natural antioxidant [13].

The gambir tree is a leading commodity of West Sumatra Province from the plantation sub-sector and contributes to the export of gambier in Indonesia by 80%. According to gambier plantation area in West Sumatra is 21412 hectares with a production of 14220 Tons/ year, 6% of which is exported gambier and 94% or 168087.67 tons remaining is gambier extraction waste [6]. In addition, the number of gambier processing units in West Sumatra is 3,571 units by 6,908 workers. Therefore, the use of gambier substitution in livestock will improve the community's economy [14]. The gambir tree has been used by the public as a wound healing drug, anti-nematode, autonomic nerve stimulator, and antioxidant. The gambir contains catechins which are antioxidants, flavonoid phytochemicals include catechins 50%, pyrocatecols 20% -30%, gambirin 1% -3%, red catechus 3% -5%, quercetin 2% -4%, wax 1% -2 % and 2%-5% alkaloids. The catechin content in the leaves is 40%-50% (7).

Based on the results of qualitative analysis showed that gambier contains quinones, terpenoids, alkaloids, tannins, flavonoids and saponins (8) and the antioxidant activity of gambir extract is 172.62 ppm. While the results of direct analysis carried out by (9) gambier extraction waste contains 56.43% dry matter, 10.66% crude protein, 4.90% cride fat, 29.35% crude fiber, 35.73% BETN and 5% tannin. [14]. Although, gambir tree is an export commodity from West Sumatra Province, this commodity faces various obstacles in its production process. Some of these obstacles include: 1) gambier is generally planted in non-cultivated areas so that it has the potential to damage the environment; 2) the location of planting gambier which is far from the reach of guidance coupled with the low ability of farmers, both in terms of knowledge and capital, causes cultivation technology to be relatively lagging behind and 3) Gambier commodity prices fluctuate where prices often fall in the market causing garden maintenance to be carried out traditionally [13, 14].

Mahat watershed has been used for the production of gambir since 1830 until now. The land is steeply sloped and flat with and is now showing signs of watershed degradation. Marginal land overgrown with reeds and shrubs has been found in the Mahat watershed.The factors associated with fluctuations in Gambir yield in different soils are not yet known. To find the most sustainable soil and the factors that influence the fluctuation and stagnation of current Gambir production even though all technologies have been adopted in Indonesia Gambir yields remain low and stagnant. This study attempts to correlate Gambir yields with agricultural environmental factors such as soil physiographic conditions, chemical properties, soil geology and climate in the Mahat Watershed, Indonesia. It is very important to educate the Regional Governments in West Sumatra, Indonesia to realize that there has been a stagnation and decline in the quality and quantity of Gambir production in Indonesia, where this production on average does not want to increase again with fertilizer innovation, it is necessary to find a solution.

Evaluation of the suitability of Gambir land is still very little done on a watershed scale in Indonesia to find limiting factors due to the stagnant and declining production of Gambir in Indonesia in terms of quality and quantity. Geochemical-physico-climate method combined with FAO method and 3-dimensional mapping with Surfer tool is a new break through. In this study an effort was made to evaluate the current agricultural land resources in the Mahat watershed, West Sumatra Indonesia, in evaluating the suitability of agricultural land for gambir tree and assessing its potential to be planted with the new gambir so that it is easy and efficient, the multi-criteria overlay analysis technique used with Surfer tool combined with geochemical-physico-climate method. This effort involves land form analysis, characterization of soil physico-chemical properties, creation of spatial databases and overlay techniques and multi-criteria analysis with Surfer tool using modified land suitability criteria evaluation for gambir.

MATERIAL AND METHODS

Study area

Mahat watershed, covering an area of 17849.66 ha, is located in Lima Puluh Kota Regency, West Sumatra, Indonesia. (latitude 00º 02'42'' - 0º09'98'' S, longitude 100º 40'2'' - 100º 5'5'' E), has an altitude range from 100 to 2200 m, above sea level (Figure. 1). The Mahat watershed outlet is the Mahat river whose water is used for the Koto Panjang hydropower plant for electricity needs in Riau Province. The average annual rainfall ranges from 1859 mm to 3096 mm with an average annual rainfall of 2936 mm with an average number of rainy days 187 days/year. The average annual temperature is 24^0C to 32 ^{0}C, from the highest location to the lowest location. Average humidity varies from 91% to 95%. Average wind speed varies from 2 to 8 km h^{-1}. The located in a tropical zone with a very humid climate. The Mahat watershed has land use patterns such as Gambir Gardens, primary forest, tree plantations (mixed gardens, coconut plantations, rubber plantations), rice fields (rice), shrubs (shrubs, grasses, and alang-alang (land overgrown with Imperatacylindrica).

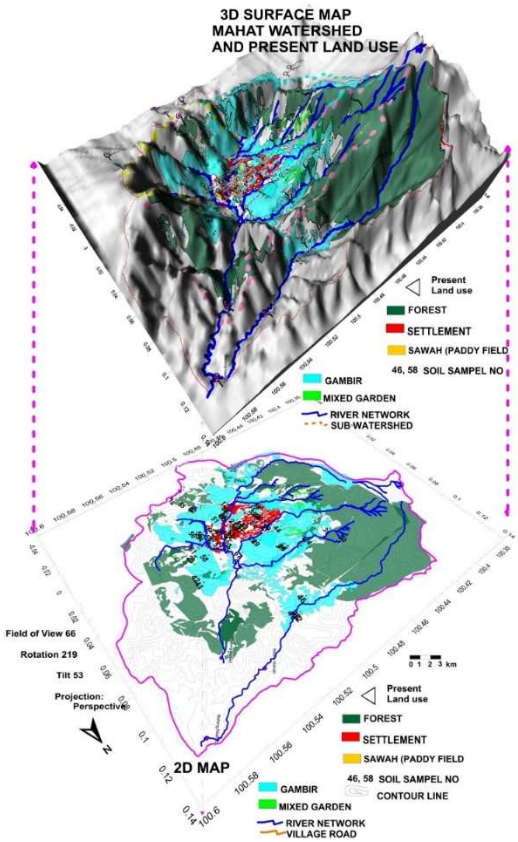

FIGURE 1. Study locations and distribution of sampling points and 3D Surface Map and Present Land Use in Mahat Watershed, West Sumatra -Indonesia

Field survey and analysis method

To investigate the real data in Table 1, a soil survey was conducted at 67 sites in the Mahat watershed and soil samples were taken based on uniformity and differences in geomorphic positions, land use types and soil types. Soil samples were taken with an auger drill at a depth of 0-20 cm and up to a depth of 110 cm. Soil samples were air-dried and after drying they were pulverized with porcelain mortar and then sieved with a 2 mm mesh sieve for physico-chemical analysis requirements. Soil texture was determined by the feeling method in the field and corrected by the pipette method in the laboratory [15].

Bulk density (BD) was calculated by taking a soil sample with a ring sample volume of 100 cm^3, after which the soil sample was heated at a temperature of 105°C for about 72 hours, the weight of the soil per core sample volume (100 cm^3) was measured. The total pore space (TPS) was calculated by the same method. Determining the current physical condition of paddy fields, drainage, flooding, rock on the ground surface, coarse fragments, soil depth, peat soil depth, peat soil maturity and sulfide layer depth, field observations and interviews with local farmers were carried out at the time of sampling. We calculated soil erosion in Gambir, Sawah, Mixed Gardens and Settlements in the Mahat watershed using the USLE Model [16] as reported by [7,8,9] and the percentage of slope of Gambir gardens in the field was measured by abney level or clinometer at the time of sampling. The map is calculated using the Surfer tool application [17] based on the coordinates and height of the 32674 grid points.

Climate (temperature and humidity) was measured by the climatology station in Lima Puluh Kota Regency. Soil chemistry is measured directly from soil samples. While the parameters analyzed are Organic Carbon (C-org). C-org was measured using the wet combustion method with the Balck and Walkley method. Soil pH and soil EC (electrical conductivity) were measured using the glass electrode method with a soil:water ratio of 1:2.5.

Exchangeable acidity (Al-dd) was determined by first extraction with 1mol L^{-1}KCl and titration with NaOH. The exchangeable base cations (Ca-dd, Mg-dd, K-dd and Na-dd) were extracted from the soil using 1 mol L-1 neutral ammonium acetate (NH_4OAc pH 7) measured by AAS Atomic Absorption Spectrophotometer-AAS (Shimadzu AS680). Cation exchange capacity (CEC) is the sum of the number of cations (Ca, Mg.K.Na) that can be exchanged and the acidity (Al and H) that can be exchanged. Base saturation (BS) is calculated from the total base cations divided by CEC and multiplied by 100% . Alkalinity (ESP) was calculated by the Exchangeable Na concentration divided by the CEC and multiplied by 100% [19].

Procedure for evaluating the suitability of the soil for the Gambir Garden community

This study adopts the land suitability evaluation method developed by the Food and Agriculture Organization (FAO)[18] enriched with geochemical physico-climate methods. Finding soil and climate limiting factors for crops is the most important, this method compares Gambir land requirements and land resource characteristics. The data shown in Table 1and Table 2. Figure 2 shown the process of analyzing the data base.

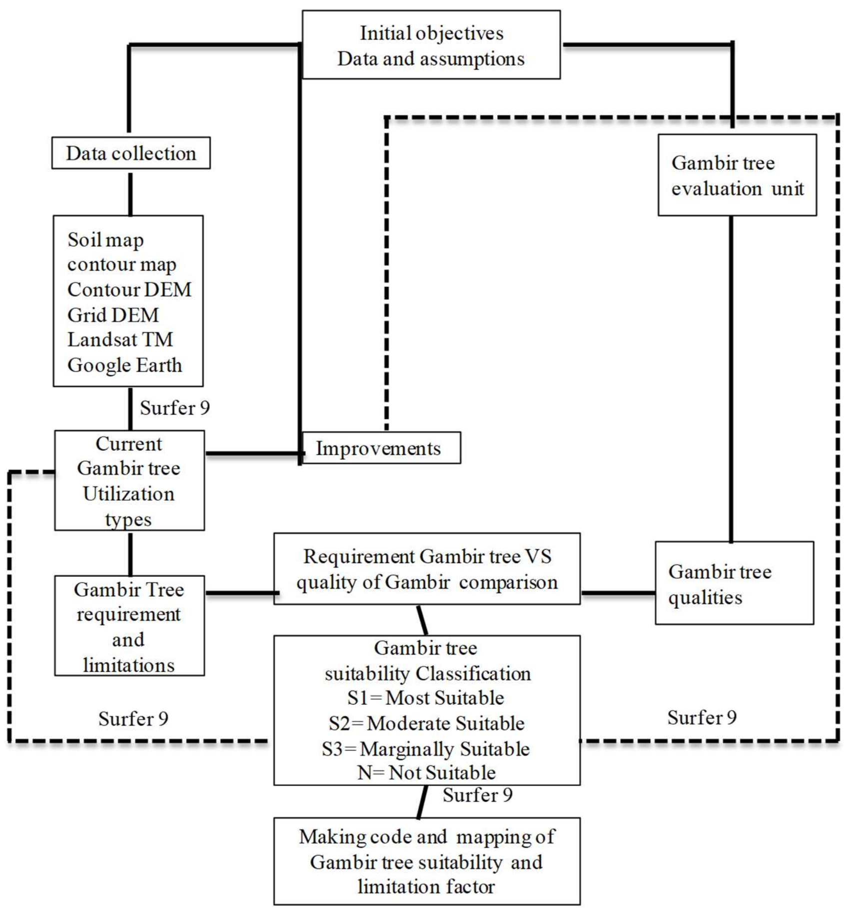

FIGURE 2. Modification of FAO land evaluation procedure [18] Gambir Garden community and 3D mapping using Surfer Tool in Mahat watershed, West Sumatra, Indonesia

The process of assessing land suitability for gambir is through a procedure of matching the requirements for growing gambir with certain soil unit characteristics. For gambir, land units are made from the overlay process of the specified layer theme or the quality of the land that is the basis for suitability. Land classified as suitable (S1) is the best land for gambir cultivation; Moderately suitable (S2) is clear for gambir suitable for use but has limitations, and Less Suitable (S3) for gambir which is near (but above) the limit for suitability. Unsuitable land (N) is clearly impractical to address the current problem or not as an acceptable form or should be forested instead. The gambir suitability map has been generated from the spatial distribution of the factors in the study area. Soil quality matches

Gambir's requirements and is classified into different suitability classes, and suitability maps for gambir become available where none existed before.

A modified version of the criteria for suitability of climate and soil characteristics for gambir is based on a parameter match between gambir requirements or a particular land use and the soil parameters followed (Table 1). Matching the soil parameters with the requirements for a particular gambir growth and definition of the gambir suitability class is carried out first. Gambir's suitability analysis process is designed in Surfer's tools to integrate disparate theme information. In the multi-criteria overlay analysis model in the Surfer tool [18], twenty one (21) effective soil parameters are the basis for consideration. The suitability class for the fields is in accordance with the procedural model in the Surfer tool.

TABLE 1. The Requirement suitability for climate and soil properties criteria for gambir tree

Soil-Site Characteristic	Gambir tree suitability criteria			
	S1	**S2**	**S3**	**N**
Climatic characteristics (c)				
1.Mean temperature (^{0}C) (tc)	26-30	30-24 or 24-26	20-24	> 40 or <20
2.Humidity (%) (h)	70-85	<70 >85		
3.altitude (mdpl) (alt)	50 -1.100	<50 >1.100		
Water availability (wa)				
4.annual rainfall (mm) (ar)	2.500-3.000	2000-2500 3000-3500	1500-2000 3500-4000	<1500 >4000
Site characteristic Erosion Hazard(eh)				
5.Slope (%) (S)	< 8	8-15	15-30	>30
6.Soil Erosion (ton/ha/y) (A)	<15	15-60;60-180	180-480	>480
Oxygen availability (oa)				
7.Drainage (D)	W	W	RS,P	VP,E
8.Flood risk (Fh) (F)	F0	-	F1	>F1
Land preparation (lp)				
9.Stoniness in soil surface (%) (SS)	< 5	5-15	15-40	> 40
10.Rock in surface soil (%)(rs)	< 5	5-15	15-25	> 25
Media for Root (rc)				
11.Texture (t) (PD)	Halus (cl,sicl,sc,sic)	-	Agak kasar (sl,ls,fs)	Kasar (s)
12.Efective Soil Depth (cm)(SD)	>100	75-100	50-75	<50
Peat soil (Gambut)				
13.Peat soil depth(cm) (PS)	<60	60-140	140-200	>200
14.Peat soil maturity	Sapric+	sapric, hemic+	hemic, fibric+	fibric
Sulfidic Hazard (xs)				
15.Depth of sulfidic layer founded (cm) (DS)	>175	125 -175	75-125	<75
Nutrient retention (nr)				
16.Soil fertility CEC (cmol(+)/kg)	>16	< 16	-	-
17.Base saturation(%) (BS)	>50	35-50	<35	-
18.pH H2O(p) (pH)	4,8 – 5,5	<4,8 ,>5,5		
19.Total Carbon (c) (%)(TC)	>0,4	< 0,4	-	-
Toxisitas (xc)				
20.ECe(e)(Salinity) (dS/m)	<5	5-8	8-10	>10
Sodicity (xn)				
21.ESP (Alkalinity)(a)(%) (A)	<10	10-15	15-20	>20

P=Poor; W=Well; RS=Rather slow; E=excess. cl=clay; sicl=silty clay loam; sc=sandy clay; sic=silty clay; l=loam; s=sandy; csi=clay silty; sl=silty loam; ls=loam sandy; fs=fine sand.; F=flood; I = imperfect; MW=Good enough; P=bad; W=good; VP=Very Bad; RE=Slightly exaggerated; E = excess.

Estimation of soil erosion and 3D Mapping procedures

Soil erosion was estimated using the Universal Soil Loss Equation (USLE) Model equation [16]. Six erosion factors are required to measure annual soil loss at the watershed scale:

$$E = R\ x\ K\ x\ L\ x\ S\ x\ C\ x\ P \quad (1)$$

Where: A is soil erosion in Mg/ha/y; R is the erosivity factor of rainfall (dimensionless); K is the soil erodibility factor (without dimensions); L is the slope length factor (without dimensions); S is the slope factor (dimensionless); C is the plant factor (dimensionless); and P is the factor accounting for the effects of soil conservation practices (dimensionless).

The first step in making a 3-dimensional soil map for erosion and distribution of gambir suitability evaluation is then after laboratory analysis and then the Mahat watershed is divided into a grid measuring 125 mx 125 m. Base data is then allocated and defined in each grid coordinating and populating the baseline. Data were obtained by entering soil parameter data, reading maps, assessing Landsat and Google Earth images for types of land use and altitude, and for mapping the use of the kriging method on the Surfer tool [17]. Quantitative distribution or distribution of soil physicochemical properties and distribution of suitability of Gambir were mapped with the help of Surfer ® 9, GPS digitier and TCX Converter.

Map creation and data processing

A topographic map with a scale of 1:50,000, containing the Mahat Indonesia watershed , was entered in Surfer® 9 with manual digitization. The elevation map in vector form is converted into a grid format with a spatial resolution of 125 m x 125 m. Based on the kringin in Surfer® 9, an interpolation routine is performed to obtain altitude data from raster line data. The kriging method and its applicability in detail described by [20] Digital elevation model (DEM) have been established as the foundation for other topographic-related analyses. Soil properties, land use types and other things related to attributes are also input into Surfer® 9 by digitizing manually and data entry by keyboard. Polygons with all their attributes are linked by a uniform code. Polygons are a common method used to describe irregular objects. The vector map is also converted to raster format, which has the same reference system and the same resolution as the DEM. The data sources are converted in the form of a grid format. Each grid is marked at a fixed location by providing the grid orientation and size of the grid and a list of the attributes it resides in. To predict the rate of soil erosion in the spatial domain, each map unit was set to 125 m by 125 m, which matched the required resolution size with available data and the author's computer facilities. Each grid is defined as a plain with a single slope for the purpose of applying USLE and 21 parameters for climate geochemical-physico - climate for land suitability on each grid.

RESULTS AND DISCUSSION

Landform characterization

The identified Mahat watershed landscape is in the form of bird feathers. The Mahat watershed consists of three sub-watersheds consisting of the Nena, Koto Tinggi and AurDuri sub-watersheds (Figure 1). Based on field morphology and laboratory characterization, the GAmbir garden in the Mahat watershed was cultivated in two soil orders including six groups, namely humitropept and hapludults [20]. The distribution of soil groups depends on the geological type and parent material and morphological position (Figure 1).

Soil morphology and soil physical properties

The field survey revealed that the Gambir soil in the Mahat watershed is dark brown (7.5 YR), because the soil order inceptisol (humitropept) [21,22] is characterized by black to dark brown color spread from moderate elevation to plains (Figure 1). The climate criteria and the location of the soil are suitable for smallholder gambier plantations (Tables 1, 2). The physical properties of the soil indicate that the soil in the Mahat watershed has a depth ranging from 90-110 cm and covers the entire watershed. Table 2 shows that coarse fragments and rock fragments are few in number (<5%) Based on field observations, the presence of coarse fragments is directly related to the topography of the Mahat watershed where the lowland areas along the river are filled with large stones.

The average annual temperature ranges from 23-32 ºC, which varies along the elevation gradient. Average annual humidity varies from 90-95% (Table 2). This climate shows good conditions for Gambir production. Peat soil, depth and depth of sulfide layer were not found in the whole Mahat watershed. The flat area with a slope of <3% in the middle of the Mahat watershed used for rice fields by local farmers. In general, flat land <3% has been used as rice fields for a long time in the lowlands of the Mahat watershed because the prehistoric heritage found, namely menhir stone graves in the stone age BC. The particle size distribution shows that most of the soils have high clay content in the high elevation areas in the hills surrounding the Mahat watershed (Table 2). In general, an increasing trend of clay is observed in hilly areas and also found in valley areas far from rivers as soil deposition due to severe erosion that occurs in upland areas in relation to land use change and intensive agricultural activities in the highlands, dominated by by the people's gambier plantation.

TABLE 2. Characteristics of Average Geochemical-physico-climate land in the Mahat watershed

Soil-Site Characteristic	Gambir tree suitability criteria			
	Minimum	Maximum	mean+stdev	Suitabiliy Class
Climatic characteristics(c)				
1.Mean temperature (^{0}C) (tc)	32	23	25.9+4.2	S2,S3
2.Humidity (%) (h)	76	95	87,27+8,98	S1,S2
3.altitude (mdpl) (alt)	100	1200	-	S1
Water availability (wa)				
4.annual rainfall (mm) (ar)	1859	3096	2491.5+336.9	S2,S3
Site characteristicErosion Hazard(eh)				
5.Slope (%) (S)	3	75	23.7+19.7	S1,S3,N
6.Soil Erosion (ton/ha/y) (A)	0.99	717.6	95.6+0.07	S1,S3,N
Oxygen availability (oa)	Well	Poor	-	S1,N
7.Drainage (D)				
8.Flood risk (Fh) (F)	Not Flooding	Flooding	-	S1,N
Land preparation (lp)	5	0	0.86+1.9	S1
9.Stoniness in soil surface (%) (SS)				
10.Rock in surface soil (%)(rs)	5	0	0.86+1.9	S1
Media for Root (rc)	cl,sicl,cl	cl	-	S1
11.Texture (t) (PD)				
12.Efective Soil Depth (cm)(SD)	95	100	108.2+4.7	S1
Peat soil (Gambut)	0	0	0	S1
13.Peat soil depth(cm) (PS)				
14.Peat soil maturity	-	-	-	S1
Sulfidic Hazard (xs)				
15.Depth of sulfidic layer founded (cm) (DS)	0	0	-	S1
Nutrient retention (nr)				
16.Soil fertility CEC (cmol(+)/kg)	28.6	29.9	29.3+0.24	S1
17.Base saturation(%) (BS)	78.8	81.9	80.7+0.59	S1
18.pH H_2O(p) (pH)	5.49	5.69	5.61+0.04	S1,S2
19.C-organic (c) (%)(C-org)	1.2	2	1.48+0.28	S1
Toxisitas (xc)				S1
20.ECe(e)(Salinity) (dS/m)	0.07	1.21	0.54+0.21	
Sodicity (xn)	2.1	2.6	2.26+0.1	S1

Soil-Site Characteristic	Gambir tree suitability criteria			
	Minimum	Maximum	mean+stdev	Suitabiliy Class
21.ESP (Alkalinity)(a)(%) (A)				
Bulk Density (BD) (g/cm3)	0.6	1	0.80+0.11	-
Total Pore Space (TPS)(%)	64.2	75.9	70.17+3.8	

P=Poor; W=Well; RS=Rather slow; E=excess. cl=clay; sicl=silty clay loam; sc=sandy clay; sic=silty clay; l=loam; s=sandy; csi=clay silty; sl=silty loam; ls=loam sandy; fs=fine sand.; F=flood; I = imperfect; MW=Good enough; P=bad; W=good; VP=Very Bad; RE=Slightly exaggerated; E = excess.

The value of the bulk density (BD) of the soil varied from 0.6 to 1 Mg/m^3 (Table 2). This variation of soil BD varies with soil type and may be due to the high clay and loam content, organic matter content present in the soil. As pointed out by [21],the soil surface is less compact due to high organic matter and many plant roots. The percentage of pore space (TPS) values in the study area varied from 64% to 76% and was related to specific gravity and BD, clay content and organic matter (Table 2). [21] stated that for an ideal medium-textured, fine-grained soil are good conditions for plant growth, about 50% of the soil volume will consist of pore space, and the pore space will be half full of air and half full of water. Total porosity varies for soils because each soil BD also varies. The BD values range from a loss of 25% in compacted soils to more than 60% in surface soils with high organic content. BD and soil management can affect the soil pore space (TPS).

Soil chemical properties in the Sumani watershed, Indonesia

Soil chemical characteristics from laboratory analysis found that the overall pH value of the soil in the studied Sumani watershed ranged from 5.49 to 5.69 indicating that the soil was very acidic to slightly acidic. The electrical conductivity analysis of the soil showed that the soil from the study area had very low dissolved salt concentrations (0.67-1.4 dS/m) with electrical conductivity ranging from low (0.18 and 2 dS/m), moderate (2 and 4 dS/m), high (4 and 4.2 dS/m) (Table 2). Low EC means the soil has no salinity hazard. This shows that the soil in the Mahat watershed is salt free so the soil is responsive and responds well to fertilization practices and management. However, medium and high EC values indicate that the soil has a salinity hazard and therefore the soil is not responsive to the given fertilization and management practices [23]. The content of organic carbon (C-org) in the soil of the study area ranged from 1.2 to 2%, because the soil type was Humitropept.Thecation exchange capacity (eCEC) of soils varies from 29.9 to 28.6 cmol(+)/kg and is related to clay, loam and slightly high organic matter content (Table 2). This high CEC value is associated with a fairly high content of clay, organic matter and clay (Table 2). Soils show little variation in their percentage of soil alkalinity (ESP) (2.1-2.6%). The low alkalinity indicates that the soil has no sodium hazard (Table 2). Soils show moderate variation in the percentage of base saturation (78-82%). High base saturation > 50% and low alkalinity (<20%) indicate that the soil is suitable for cultivation of Gambir Rakyat plantations in the Mahat Watershed of West Sumatra, Indonesia.

Evaluation of the suitability of the Gambir Garden community in the Mahat watershed, Indonesia

To evaluate the suitability of gambir land , the results obtained from climate data and soil physicochemical properties in the Mahat watershed are summarized in Table 2, Table 3 and Figure 3. Classes and parameters required for multi-criteria overlay in Surfer Tool for input parameters in evaluating the suitability of Gambir soil where the data are shown in Table 2 and Figure 2. Based on the analysis of the area of the 3D Map in the MW, it was found that around 1785 ha (10%) of the total MW area in Class (S2). An area of 7140 ha (40%) is classified as “marginally suitable” (S3). The area classified as “not suitable” (N) was found to be 8924 ha (50%). However, there was no or (0 ha and 0%) found area in the class “suitable” (S1) due to climatic factors, high soil erosion and degraded soil fertility (Table 3, Table 4).

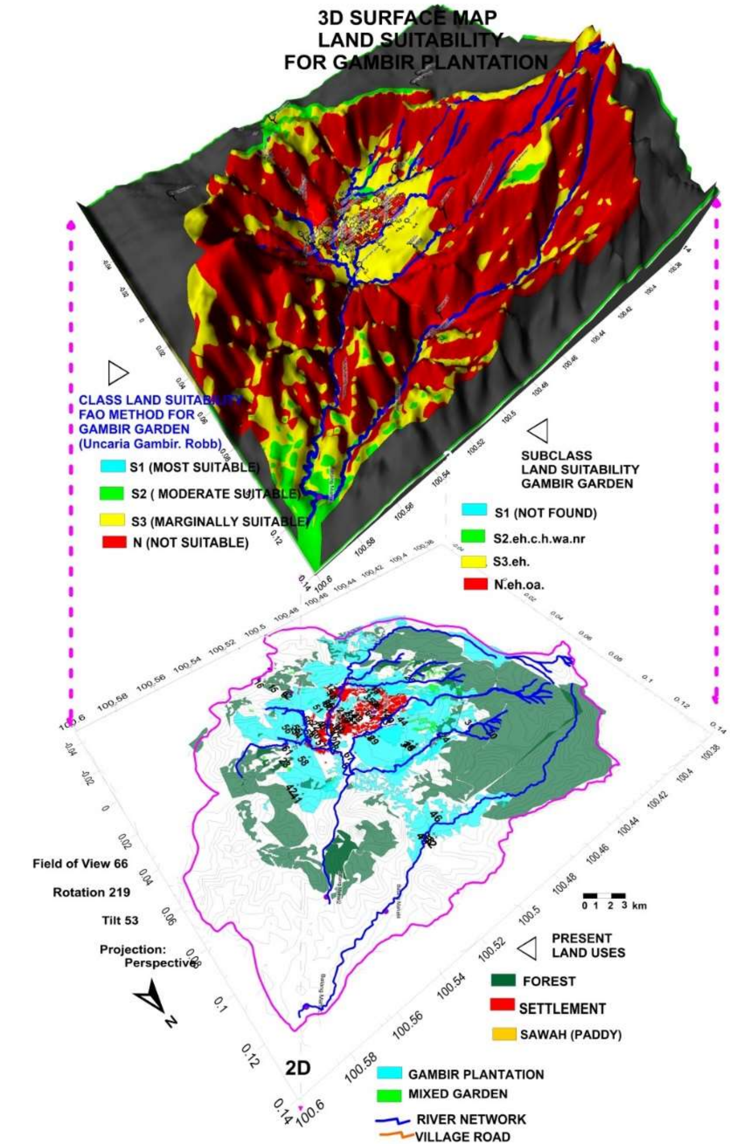

FIGURE 3. 3D Surface Map Actual Land suitability for Gambir Plantation in Mahat Watershed, West Sumatra, Indonesia

Explanation 3D Surface map actual land suitability:" Class S1, most suitable(sky blue S1): Soil has no significant inhibition or has only a small inhibiting factor. Intensive use provides significant benefits in productivity. requires input of fertilizers and technology at an acceptable level.provides business advantages; S2 class, moderate suitable(leaf green color S2): Land has severe limitations for continuous or sustainable use. existing constraint factors will reduce productivity or profits and require improvements in inputs and technology but there are still gains. advantages and productivity under Class S1; S3 class, marginally suitable(yellow S3): Land has very severe limitations for application/use continuously/sustainably usually the inhibiting factor will reduce productivity or profits. There is a need to improve technology, so it provides a slight advantage. Class N not suitable
(red N) as an agricultural business, various technological inputs for agriculture cannot be justified. It would be better if it was forested."[7,8,9,23]. Inhibiting factors that cannot be changed by humans are climate such as rain, temperature, humidity. While the inhibiting factors can be changed by humans such as soil fertility.

Sub class S1 most suitable(sky blue S1):no gambir class S1 (most suitable) garden land was found due to the inhibiting factors of temperature, rainfall and humidity.Sub class S2.eh.c.h.wa.nr. moderately suitable (leaf green color S2): gambir class S2 gardens were found, but had inhibiting or limiting factors, namely steep slopes, high soil erosion, temperature, humidity, water availability and soil nutrient retention. S3 subclass.eh. marginally suitable(yellow S3): is found on gambir gardens class S3, but has inhibiting or limiting factors, namely steep slopes, high soil erosion.SubclassN.eh.oa Not suitable(red N): There was found gambir class N garden land, because it has a limiting factor or steep slope, high soil erosion. The availability of soil oxygen due to poor drainage and flooding (Table 3).

Table 4. Shows the details of the name of the village with the actual suitability class for gambir land in the Mahat watershed , Indonesia which is generally dominated by the S3 class.

TABLE 3. Sample code, villages and actual land suitability class in Mahat watershed, West Sumatra, Indonesia

No. Sam-ple	Sample Location	Land Suita-bility Class	No.Sa mple	Sample Location	Land Suita-bility Class	No. Sam -ple	Sample Location	Land Suita-bility Class
1	Heg1	S3	23	Sopan	N	45	Jr.Nenan	S2
2	Heg2	S3	24	Heh3	S3	46	Nenan G	N
3	Heg3	S3	25	Posuk	S3	47	Jr. Ronah	S2
4	Heg4	S3	26	Jr.AmpangGadang	S3	48	Ronah G	S2
5	Heg5	S3	27	Menhir2	S2	49	Ronah S	S2
6	KT.Nenan	S3	28	Palansingan1	S2	50	Kp.AmpangGd 2	S2
7	S.Bt. Maek	S3	29	Palansingan2	S2	51	A.Godang 2 G	N
8	S. Palangsingan	S2	30	A.T. SarasahPanawan	N	52	A.Godang 1 S	S3
9	Jr. Koto Gadang	S3	31	S. Panawan G	N	53	Jr.AmpangGd 1	S3
10	Jr. A.Gadang1	S3	32	AT Sarasah7 tingkek	S2	54	KP.AurDuri	S3
11	Sarasahbarasok	S2	33	ATS 7 Tingkek G	S2	55	A.Duri KC	S3
12	KP. Koto Tinggi	S2	34	SarasahBarasok	S2	56	A.Duri G	S3
13	Ronah	S2	35	S. Barasok G	N	57	KP.Sopan Tanah	S2
14	Menhir	S2	36	S.Barasok S	S2	58	Sopan G	N
15	Jr.KotoGadang	S3	37	Menhir 4	S2	59	BungoTanjuang	S3
16	Jr.KotoGadang2	S3	38	Menhir G	S2	60	B.Tanjung S	S2
17	Jr.KotoGadang3	S3	39	Menhir S	S2	61	B.Tanjung G	N
18	SarasahBarasok	S2	40	Sungai BatangMaek	S2	62	Jr. KotoGadang	S3
19	Kp.KotoTinggi	S2	41	BukikPosuak	N	63	Menhirpmk	S2
20	RonahG	S2	42	Posuk G	N	64	K.Tinggi 3 pmk	S2
21	Menhir	S2	43	KP. Koto Tinggi3	S2	65	Ronahpmk	S2
22	S.Bt.Maek	S3	44	K.Tinggi G	S2	66	A.Duripmk	S3
						67	Palangsinganpmk	S3

Potential land suitability of Gambir garden community with the application of soil and water conservation practices

Analysis of morphology, geology and physicochemical soil properties shows that Gambir Rakyat plantations are strongly related not only to climate but also to soil type, geology and their position in the landscape. Potential Suitability soil for Gambir garden is the most suitable soil (S1). However, Gambir garden community in the Mahat watershed is generally the actual land suitability is marginally suitable (S3) to not suitable (N) due to high soil erosion and no soil and water conservation practices (Figure 2) .

The land suitability analysis of the Gambir community based on the Surfer Tool shows that in this study, the area is mostly marginally suitable (S3) to not suitable (N) for Gambir garden cultivation. Therefore, smart innovations in soil and water conservation practices are introduced.Therefore the suitability of the Gambir garden in the Mahat watershed can be increased by adopting technologies such as soil and water conservation using flat terraces, credit terraces, mound terraces, bench terraces and garden terraces as well as applying mulch to the Gambir garden community to control soil erosion and increase potential land suitability from S3 to S2 and from N to S3 (Table 4).

TABLE 4. The Actual Land suitability for gambir and Recommended practicesof soil and water conservation for Mahat Watershed in West Sumatra, Indonesia

No	Actual Suitability land for Gambir Garden commu-nity	Area (ha) (%)	Criteria Slope (%)	Recommended Practices Soil and water Conservation	Potential Suitability land for Gambir after practices soil and water conserva-tion	Area (ha) (%)
1	S1	0 ha (0%)	Slope <3%	Flat Terrace+mulch	S2	893 (5%)
2	S1	0 ha (0%)	Slope 3%-10%	Credit Terrace+mulch	S2	3570 (20%)
3	S2	1785 (10%)	Slope 10%-15%	Terrace Guludan+mulch	S2	2677 (15%)
4	S3	7140 (40%)	Slope 15%-30%	Terrace Bench+mulch	S2	2677 (15%)
5	N	4462 (25%)	Slope 30-50%	Garden Terrace+mulch	S3	5355 (30%)
6	N	4462 (25%)	Slope >50%	Protected Forest or Reforestation	N	2677 (15%)
	Total area	17849,7 (100%)			Total area	17849,7 (100%)

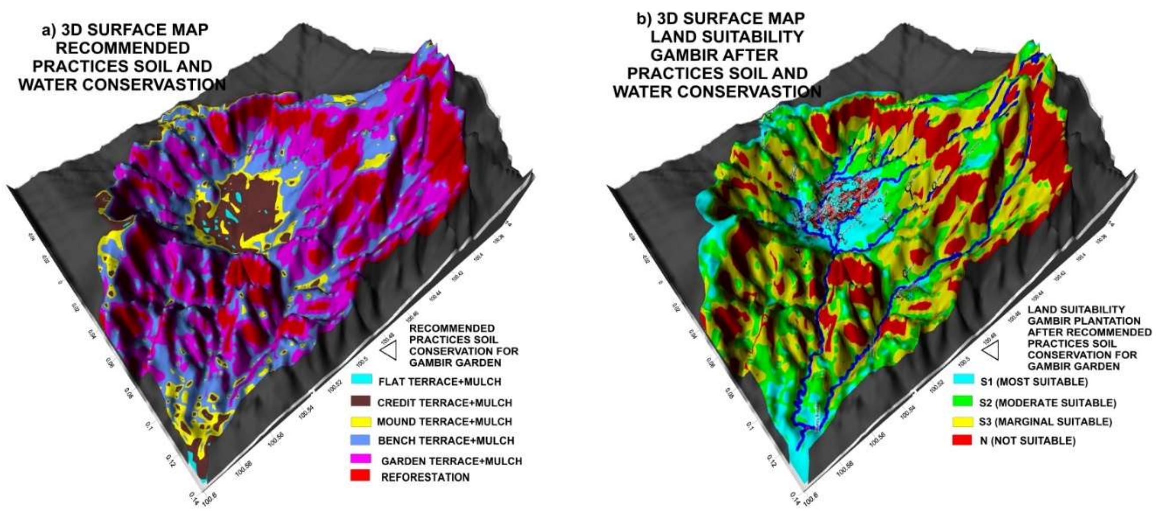

FIGURE 4. The 3D Surface Map of Gambir land suitability in Mahat watershed, West Sumatra, Indonesia. a).3D Surface Map recommended practices of soil and water conservation. b): 3D Surface Map potential land suitability Gambir after practices soil and water conservation.

This study reveals that through the application of soil conservation technology and balanced fertilization, on Gambir soil, the potential suitability of Gambir land can be improved for the better. Through the application of soil and water conservation practices technology and balanced fertilization, Gambir soil suitability class increased to Class S2 (55%), to class S3 decrease to be (30%) and Reboisation forest (15%)(Figure 2 and Figure 4)

This study shows that the creation of a data base for Gambir soil parameters using the Surfer tool and the Geochemical-physico-climate method as well as a multi-criteria overlay is a successful blueprint for evaluating land suitability for the Gambir plantation community. The potential and limiting factors of soil are very important to be studied in order to optimally manage natural resources and find alternative land uses, especially in unsuitable gambier land in watersheds. Three-dimensional (3D) maps of Gambir's land suitability can be enriched with administrative boundaries and can be used to show specific locations or sub-locations, where Gambir is suitable. The 3D map product can be used by scientists and extension workers to select Gambir Gardens which will be given the right treatment to increase Gambir productivity.

CONCLUSIONS

Evaluation of soil suitability for Gambir Plantation based on field surveys and analysis of soil samples in the laboratory, it was found that the actual condition of gambier gardens is currently dominated by in the class N and S3 in Mahat Watershed because planting gambier on land with slopes > 30% results in increased erosion exceeding erosion allowed by the Indonesian government. Based on the analysis of the area of the 3D Map in the MW, it was found that around 1785 ha (10%) of the total MW area in Class (S2).An area of 7140 ha (40%) is classified as "marginally suitable" (S3).The area classified as "not suitable" (N) was found to be 8924 ha (50%). However, there was no or (0 ha and 0%) found area in the class "suitable" (S1) due to climatic factors, high soil erosion and degraded soil fertility Through the application of soil and water conservation practices technology and balanced fertilization, Gambir soil suitability class increased to Class S2 (55%), to class S3 decreased to be (30%) and Reboisation forest (15%).The FAO method combined with multi-criteria analysis and 3D mapping is very helpful in determining with precision t he location of the Gambir garden in classes S1, S2, S3, N in the MW and very helpful in recommending the application of soil conservation and balanced fertilization with precise location for Gambir agriculture in Indonesia as a developing country.

ACKNOWLEDGMENTS

The author would like to appreciate the Mendikbud Ristek and P3M Politani, Indonesia for their invaluable contributions during the analysis, suggestions. We also thank the Government of Indonesia for its support in funding this research.

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