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Distribution of Ideal Soil Composition Combined With 3 Dimensional Contour of Mahat Watershed for Sustainable Gambir Farming

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***Abstract*—The quality and efficiency of the 3-dimensional contour map of the Mahat watershed are very useful in helping to analyze the distribution of the ideal soil composition (Vw, Vg, Vs). Furthermore, the distribution of soil characteristics is compared with the topography to help integrate and sustainable Gambir farming in the Mahat watershed, which plays an important role in supplying 80% of the world's demand for catechins. It has been proven that the Surfer tool is able to create 3D maps of the contours of the Mahat watershed and 3D maps of the ideal soil composition after being compared with the realities in the field where there has been a significant increase in efficiency in data analysis, saving time, effort and cost in mapping for researchers and practitioners. It was found that the soil composition close to ideal for the % water volume (Vw) was found in Gambir farming (at altitude 250 - 1150 m ASL) and forest (at altitude 400 - 1600 m asl). The % gas or air volume (Vg) in Gambir farming, mixed garden, and forest are also close to the ideal soil composition. For % solid volume (Vs) it is found close to ideal in the mixed garden (at altitudes 250 - 1600 m ASL) and forests. The Sawah in the valley on the flat topography has the highest value Vw and the lowest value Vg. No ideal soil composition was found for Vw, Vg, and Vs owned by one land use in the Mahat watershed.**

***Keywords*—soil composition, gambir farming, nutrient, sustainable, 3D map**

I. Introduction

The Mahat watershed is located in the tropics, Indonesia, which has an annual rainfall of 3000 mm where the area is hilly which has the potential to erode the fertile layers of the soil. It is a Gambir agricultural production center (Uncaria Gambir. Robx) as a catechin producer to meet 80% of the world's needs [1]. Soil is a valuable natural resource which affects the ecosystems on planet earth in various ways as it is a component of life on earth.In the soil there are many important natural processes that occur for gas exchange, carbon storage, nutrient cycling, plant growth, and waste decomposition and waste disposal.In this world, soil is formed from parent material, namely rock or organic material. Mineral soils are formed from weathered rock consisting of a mixture of rock, nutrients, living organisms, organic matter, water and air [2].

In agricultural production on tropical soils, in principle, it is very important to pay attention to nutrient management in order to maximize the production of crops cultivated by farmers. Therefore, it is mandatory to understand some of the basic principles of tropical soil. Matters that need to be discussed are soil composition, soil minerals, soil organic matter, ground water, soil air, soil profile. While the factors that influence soil characteristics are the process of soil formation, soil texture, soil structure and soil mineralogy. Now, this paper focuses on discussing soil composition as soil physical properties [2,3].

Discussing the soil nutrient management, there is an important role of Soil Composition (Vs, Vw, Vg).The role of Vs (soil minerals and organic matter volume) to store and hold soil nutrients.The role of Vw (soil volume water) to dissolve and provide soil nutrients for absorption by plants. The role of Vg (soil, air or gas in the soil volume) is no less important because it provides air for microorganism in the soil to carry out its biological processes in order to be able to release soil nutrients from molecular form to ion form which can be absorbed by plants through root hairs [2,3].

The basic components of the ideal soil composition are the water phase, the gas phase and the solid phase (minerals and organic matter).The percentage ideal soil composition consists of the solid phase, namely 45% minerals, 5% organic matter, the liquid phase, which is 20-30% is water, the gas phase is 20-30% is air in volume percent units. This percentage is a generalization and it is very difficult to find this condition in the field. Due to the fact that soil is very complex and dynamic. The ideal soil composition can fluctuate every day. As for the influencing factors, namely the supply of rainwater or surface water, cultivation practices, topography and/or soil types [4].

Soil solid phase (Vs) which consists of minerals and organic matter contained in the soil where generally the percentage is stable and stable. However, if the organic matter is not managed properly, it may run out of the soil. The liquid phase and soil gas, namely water and air, are the most dynamic properties of soil. The amount of the relative percentage of water (Vw) and air (Vg) in the soil often changes because the soil dries out or becomes muddy [2,4].The size, shape, and clumping of soil particles determine the percentage volume of the soil composition, especially the volume of air and water in the soil. For example, soil that has a larger volume of pore space tends to contain more air and is more permeable to pass water, which can affect the types of crops a farmer can grow. In general, soil quality has different properties which determine the land suitability for a particular crop [5,6].

Mapping the distribution of soil composition from many sample points collected will make it easier to understand to help researchers and policy makers [1]. In research that aims to quantitatively evaluate the spatial characteristics of a watershed, then Contour maps are the most important tool for scientists or practitioners who must exist.It is useful for researchers and practitioners to more easily understand the characteristics of the spatial variation of the watershed object under study [7]. Fields of science which include hydrology, meteorology, geography [8], geology, environment, soil science are the most widely used contour maps [1,3]. The process of making maps requires a lot of time, costs and high labor. Therefore, researchers make savings and efficiency by using mapping software, namely the Surfer Tool [1,3]. Researchers and practitioners have been using the Surfer Tool a lot in the past decade becausedisplays a three-dimensional (3D) visual contour map. Also, it's easy and fast to use.

To obtain a more accurate determination analysis, data processing and interpretation in watershed management, the Surfer Tool application is used. The quality and efficiency of the 3-dimensional contour map of the Mahat watershed is very useful in helping to analyze the distribution of the ideal soil composition (Vw, Vg, Vs).This research is useful to provide basic data to assist integrated Gambir plantation management. Help define specific areas for which appropriate conservation measures are provided.At present, it is seen that in the downstream area there have been frequent flooding because the upstream area in the Mahat watershed on the slope has changed its function to become gambier and there has been a conflict of interest in one land and research is trying to find a solution.

Therefore, a faster technology is needed to describe maps that have integrated and well-connected functions, so the Surfer Tool is used because it has scientific, engineering advances, is more visual and fast data processing [8]. Because the composition of the soil, which consists of a percentage of solid, water and air are important aspects of nutrient management and watershed sustainability. In addition, there is no detailed soil composition reported for the Mahat watershed. The hypothesis is that the distribution of soil composition in Das Mahat is influenced by land use and topography in Das Mahat. Based on this background, the Mahat watershed case study aims to make the distribution and characteristics of the soil composition Associated with land use and 3D visual contours to assist integrated Gambir farmingmanagement.

II. Material and Methods

A. Study Site

The area owned by the Mahat watershed is 20068.38 ha. Its administrative area is in the District of Limapuluh Kota, West Sumatra.(Latitude00º 02'42 "- 0º09'98" S, longitude 100º 40'2 "- 100º 55 'E), has an altitude range of 100 m to 1700 m above sea level (m ASL) (Figure 1). 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. There are 3 Subdas, namely (g1) Nenan, (g2) Koto high, (g3) Aur Duri (Figure 1). Ultisols and Inceptisols were found in the Mahat watershed.

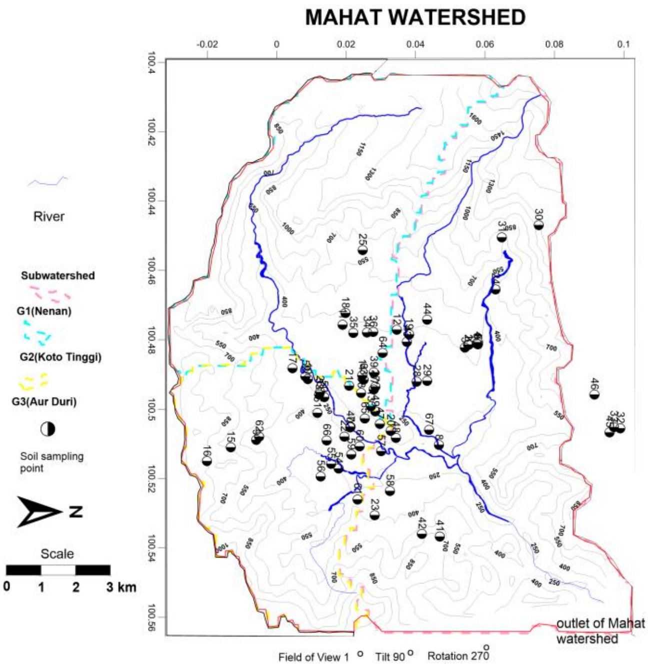

Fig. 1. Distribution of 66 soil sample points and contour map of the Mahat watershed.

The land use pattern in the Mahat watershed has namely Gambir farm, primary forest, Mixed garden refers to the land where annual crops, mostly trees such as coconut, cloves, coffee, rubber, cinnamon, cocoa are planted in combination with annual crops. Sawah, and settlement areas (Fig 2). The term sawah refers to the rice growing on leveled land and bounded by bonds with water inlets and outlets for irrigation and drainage [1,3,9]. The Gambier garden has been cultivated for generations and is attached to the local community in the Mahat watershed.

B. Fields Survey and Analytical Methods

The 68 locations of soil samples were taken based on various land uses and topographic positions in the watershed (Figure 1). Soil samples were taken with ring samples to analyze the ideal soil composition and brought to the laboratory. The % solid volume (Vs), The % water volume

(Vw) and the % gas or air volume (Vg) was analyzed by gravimetric method and ring samples [1,3]. The formula for Total volume of Soil composition is $(Vt)\ is\ Vt = Vs + Vw + Vg$.

Fig. 2. The Gambir farming, catechin, river condition and other land use type in Mahat watershed.

This is the formula explain how the percentage of soil composition computed:

$$Vt = Vs + Vw + Vg \quad (1)$$

Where:

Vt = Volume Total (Volume Ring Sample= 100 cm3)

Vs = Volume solid (cm3)

Vw = Volume water (cm3)

Vg = Volume gas or air (cm3)

Continued:

$$Vw = \frac{Bw}{Bj}.water \quad (2)$$

Where: Vw = volume of water (cm^3); Bw = weigh of water; Bj water = Density of water = 1 g/ cm^3)

Continued:

$$\%Vw = \frac{Vw}{Vt} * 100\% \quad (3)$$

Where: %Vw = % water volume; Vt = volume ring 100 cm^3)

Continued:

$$Vs = \frac{Bs}{Bj\ soil} \quad (4)$$

Where: Vs = solid volume (cm^3); Bs = weigh of dry soil (g); Bj soil = density of soil (2.65 g/ cm^3)

Continued:

$$\%Vs = \frac{Vs}{Vt} * 100\% \quad (5)$$

Where: %Vs = % solid volume; Vt = volume ring = 100 cm^3)

Continued:

$$Vg = Vt - (Vw + Vs) \quad (6)$$

Where: Vg = gas or air volume (cm^3); Vt = volume ring =100 cm^3); Vs = solid volume (cm^3)

Continued:

$$\%Vg = \frac{Vg}{Vt} * 100\% \quad (7)$$

Where: %Vg = % gas or air volume; Vt = volume ring =100 cm^3)

C. Data Processing for 3D Contour Mapping and Soil Composition Distribution

Contour map created from digitizing google earth. The digitization results are processed with a TCX converter and Surfer toll (Figure 3). The overall data processing involved was carried out using the Surfer® 9 [10] based on the parameters obtained from the soil survey and soil samples, digital elevation models. Block kriging is used to obtain coordinate points, elevation and soil data due to the construction of a smoother map with a smaller estimated variance [1,3].

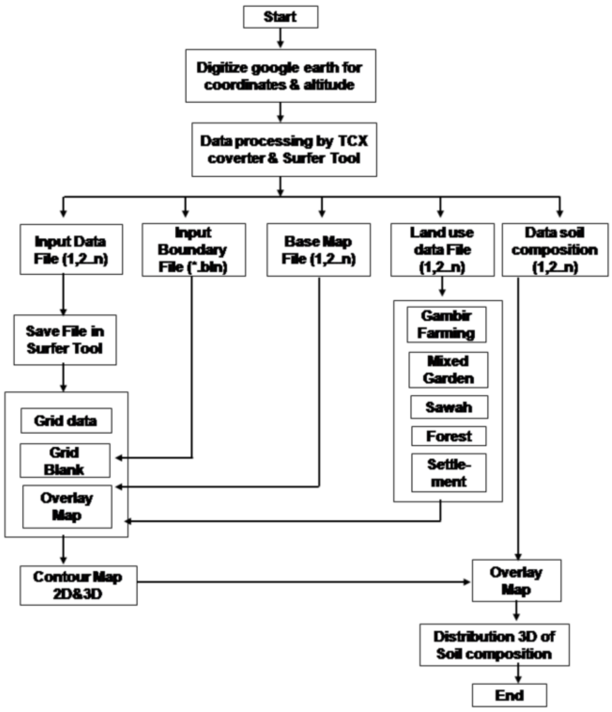

Fig. 3. Logical frame work of processing visual 3D contour map and distribution soil composition in Mahat watershed.

Surfer® 9, manufactured by Golden Software, Inc. (Golden, Colorado), is a three-dimensional surface mapping software that is relatively inexpensive and easy to use by scientists and engineers. Basic proficiency with Surfer® 9 can be achieved with a few hours of self-study. In this study, we used universal kriging. As shown in Fig. 1 and Fig 3. Accordingly, polygons with boundaries that limit the sampling area are used, and estimates are only generated for the area within them. We use cross validation to estimate krigingdensity through various approaches.

D. Validation

Cross validation involves values from observations from sample points and comparing the predicted values on the measured map [11]. This procedure is fast, inexpensive to compare predicted and measured values on maps [11]. The number of samples taken for validation was 66 samples from the interpolation results. Three indices are computed wherein the basic data is taken from the measured values and interpolated at each point.Since there are n sample points included in the validation data set, the mean error (ME), mean absolute error (MAE) and mean square root error (RMSE) are determined from the measured values z (xi) and the predicted values. z * (xi) [11]. The formula is:

$$ME = \frac{1}{n} \sum_{i=1}^{n} \{z^*(Xi) - z(Xi)\} \quad (6)$$

$$MAE = \frac{1}{n} \sum_{i=1}^{n} \{\vdots\, z^*(Xi) - z(Xi)\, \vdots\} \quad (7)$$

$$RMSE = \sqrt{\frac{1}{n} \sum_{i=1}^{n} \{z^*(Xi) - z(Xi)\}^2} \quad (8)$$

Interpreting the value of the results of the 3 validation methods as follows: ME is a measure of the bias value of the interpolation which must be close to zero, so the meaning of the interpolation method is good and unbiased, and MAE and RMSE are measures of interpolation accuracy whose values must be as small as possible to show the meaning that the interpolation is used is accurate and valid. ME, MAE and RMSE values were also calculated for each sample validation set, after which the average of the ME, MAE and RMSEs was made for 66 validation data, which is useful for finding the accuracy of the soil characteristic distribution map and the performance of the best interpolator method.

III. Results and Discussion

A. General Soil Composition According to Land Use Type in the Mahat Watershed

Table 1 shows general soil composition characteristics according to different land uses in the Mahat watershed. It was found that the soil composition close to ideal for the % water volume (Vw) was found in Gambir farming (at altitude 250 - 1150 mASL). Based on data from Table 1 and (Fig. 4, Fig. 5, Fig. 6 and Fig. 8), farmers in the Mahat watershed have local wisdom planted Gambir plants on the hillside because scientifically local farmers understand slope topography naturally controls water availability (Qw) and gas (Qg) Land of Gambir Garden so that the roots of the Gambir plant do not rot because they are flooded by water. Table 1 reveals that in the gambier field, both grew at Qw (20-33%) and Qg (29-48%). Sawah are planted in valleys or in the middle of the Mahat watershed because sawah require a lot of water (Qw = 45-54%) and little soil gases (Qg = 12-20%). Naturally, all the water collects in the middle of the Mahat watershed because of its topography (Fig 4). Henceforth, it is necessary to pay attention to the provision of conservation practices on Gambir land because it is planted in sloping areas where traces of furrow erosion have been found.

TABLE I. General Characteristic of Soil Composition in Respective Land Use in Mahat Watershed

Land Use Type	Soil Composition			
	% Water volume (Vw) (%)	*% Solid volume (Vs) (%)*	*%Air volume (Vg)(%)*	*Total volume (%)*
Gambir Farming 1	**33**	38	**29**	100
Gambir Farming 2	**20**	32	48	100
Mixed garden 1	38	**40**	**22**	100
Mixed garden 2	36	33	**31**	100
Forest 1	**28**	**39**	**33**	100
Forest 2	**34**	30	**36**	100
Sawah 1	54	34	**12**	100
Sawah 2	45	34	**20**	100
Average (n=66)	35	37	29	100
Soil composition ideal level[a]	20-30	45-50	20-30	100

[a] Brady and Weil (2019). 1= maximum value; 2=minimum value.

This indicates that erosion has exceeded tolerable erosion [3] and forest (at altitude 400 - 1600 m ASL). The % gas or air volume (Vg) in Gambir farming, mixed garden and forest are also close to the ideal soil composition. For% solidvolume (Vs) it is found close to ideal in mixed garden (at altitudes 250 - 1600 m ASL) and forests. No ideal soil composition was found for Vw, Vg and Vs owned by one land use in the Mahat watershed (Fig 4, Fig 5, Fig 6 and Fig 8).

B. Visual Map of the 3D Mahat Watershed from the Contour Map

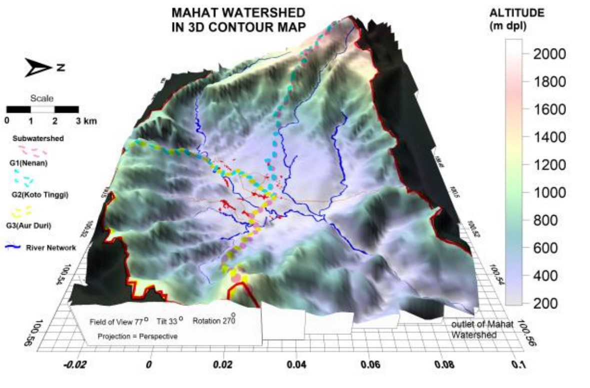

Fig. 4. Mahat watershed's 3D visual map was created from contour maps.

Figure 3 reveals that Mahat Watershed's 3D visuals made from Google earth, TCX converter and Surfer tool turned out to be in the shape of a cauldron. Where surrounded by steep hills and in the middle of the plains. Based on the evidence from the comparison of Figure 2 and Figure 4, with 3D visuals, it is easier to understand the morphology of the Mahat watershed.

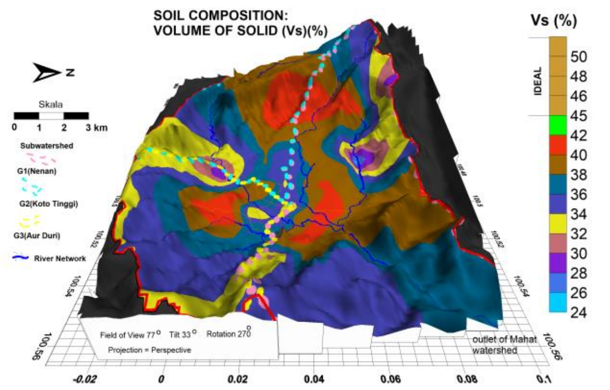

Fig. 5. Distribution of soil composition of the % solid volume (Vs) combined with topography of Mahat watershed.

To make a 3-dimensional map of the Mahat watershed, 15015 coordinates and elevation points are required. It took 35 hours to input and extract data from Google Erath to the TCX converter and to the Surfer Tool to create a Base Map.In fact, making a base map takes a long time. Meanwhile, the work to make a 3D distribution of soil water content (Qv) took 100 seconds. To validate measured and estimated data on a map it takes 30 minutes.Distribution of Soil Composition combined with topography of Mahat Watershed.

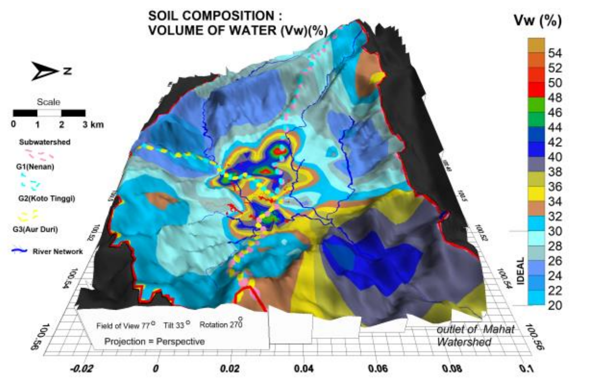

Fig. 6. Distribution of soil composition ofthe % water volume (Vw) combined with topography of Mahat watershed.

Figure 5, reveals there is found Vs close to ideal (45-50% by volume) [11] with a brownish color. The location is not in the middle or valley, but on the west and east sides of the Mahat watershed and on the north and south sides of the Mahat watershed. Generally overgrown by forests, Gambir farming, mixed gardens (comparison of Figure 5 and Figure 8). Figure 6, reveals where Vw which is close to ideal conditions (20-30% by volume) [11] is scattered almost around the Mahat watershed, which is covered by Gambir farming, mixed garden and forest, except in the middle, which is covered with rice fields and the eastern side of the watershed is overgrown with forest (Figure 8).

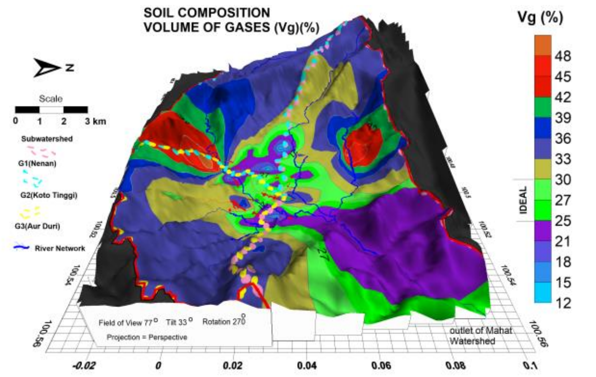

Fig. 7. Distribution of soil composition of% gas or air volume (Vg) combined with a 3-dimensional map of the Mahat watershed.

Figure 7 shows that Vg is close to ideal conditions (20-30% by volume) [10] found mostly in the middle of the watershed and slightly scattered on the west, east, south and north of the Mahat watershed.The controlling factors for in ideal soil composition are topography, soil, water supply [2,8]. Generally overgrown by forests, Gambier farming and mixed gardens (Figure 8).

Figure 8, combined with Figures 5,6,7 found that the quantitative ideal soil composition is generally influenced by land use and topography in the Mahat watershed. The minimum tillage is carried out by farmers in the land use of Gambir farming and mixed garden and natural conditions in the forest which influences the finding of ideal compositions for (Vw) and the (Vg), found in sloped topography at altitudes. Sawah (found at an altitude of 200 - 450 m ASL) have the (Vw) which is 1.5 times more than the ideal soil composition. Settlements inhabited by residents while maintaining local wisdom (found at an altitude of 200 - 350 m ASL) indirectly play a role in minimizing tillage in cultivation which keeps the ideal soil composition unchanged.

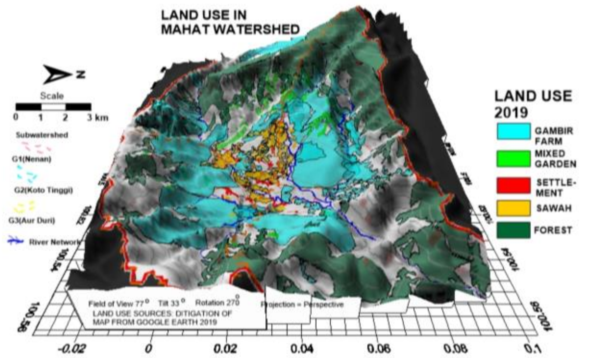

Fig. 8. Distribution of land use type (Gambir farming, mixed garden, sawah, forest and settlement) combined with topography of Mahat watershed.

The facts obtained from this research are that the 3D map of the distribution of soil composition combined with the topographic map of the Mahat Manpu watershed was made by the Surfer Tool.Topographic 3D visual maps are made from contour maps from digitizing Google earth maps and TCX converter as free software. The results of this study have been able to significantly save energy, time and money. The 6 maps from this study can be made in 1 hour. At the beginning of the job was difficult. However, continue to practice will be more using the Surfer tool.

C. Validation Result

We calculated the mean values of ME, MAE and RMSEs from 71 validation data sets as shown in Table 2. The ME of Vw, Vs and Vg ranged from 0.413 to 1. 022. These values are all close to 0 for all cases, which indicates that they are all valid in the interpolation of the values of Vw, Vs and Vg of the soil.

TABLE II. THE MEANS OF ME, MAE AND RMES AND R2 AND MODEL LINEAR OF 71 VALIDATION SETS BASED MEASURED AND ESTIMATED VALUE FOR %VW, %VU AND %%VS

n=71	Soil Composition		
	% Water volume (Vw) (%)	*% Solid volume (Vs) (%)*	*%Air volume (Vg)(%)*
ME	1.022	0.413	0.422
MAE	2.999	1.818	2.563
RMES	4.302	2.388	3.759
R2	0.837	0.744	0.859
Model Linear	y= 0.6268x + 11.953	y = 0.5319x + 16.712	y = 0.6878x + 9.3657

y= estimated value; x=measured value.

The Interpolation method in the Surfer tool using Kriging's Gridding has a MAE value (1.818-2.999). Likewise, the RMSE values ranged from (2,388-4,302).The MAE and RMSE values are relatively small compared to the Average Vw, Vs and Vg values (29-37), which means that the map produced by the Kriging method in the Surfer Tool is valid and has good performance in predicting soil Vw, Vs and Vg in the Mahat watershed. This is reinforced by the linear model with a value of R2 (0.744-0.859) which means the level of truth is close to 74% -86%.

IV. CONCLUSION

With the help of the Surfer Tool application, a 3D map of the Mahat watershed was successfully created and a 3D map of the distribution of the ideal soil composition (Vw, Vg, Vs).Based on local wisdom, farmers in the Mahat watershed plant Gambir on sloping land and sawah in flat valleys related to the management composition of the natural liquid phase (Vw) and gas phase (Vg) by topography.The modern science used in this study, namely ideal soil composition and 3 D contour maps, proved that farmers in the Mahat watershed, with their local wisdom, were correct in placing their position in planting Gambir, sawah and forests.It was found that theGambir farming (found at altitude 250 - 1150 m ASL) and mixed garden (found at altitude 250 - 1150 m ASL) and natural conditions in the forest (found at altitude 400 - 1600 m asl) which influences the finding of ideal compositions for the % water (Vw) and the % gaseous or air (Vg), found on sloped topography at altitudes. Sawah (found at an altitude of 200 - 450 m ASL) have the % water (Vw) which is 1.5 times more than the ideal soil composition. No ideal soil composition was found for Vw, Vg and Vs owned by one land use in the Mahat watershed.

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