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Land Suitability Analysis for Peanut (*Arachis hypogea*) Farming in World Heritage Conservation Area Sangiran

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ABSTRACT

Sangiran Archaeological Site was conservation area protected by national and international regulations. Sangiran Site, however, was an open site inhabited by people commonly working as farmer cultivating food crops and horticulture. During dry season, most farmers generally cultivate peanut. This study aims to determine the suitability of land in the Sangiran area for peanut cultivation. The study was conducted by analyzing soil samples taken from several locations at the Sangiran site: Blue Clay and Black Clay from the Pucangan formation in Pablengan Village, and Kabuh soil from around the Sangiran Triangulation Monument. The results from 3 sampling areas showed that the score of Black Clay area 2.13 mean "unhealthy soil" for peanut farming. The Blue Clay area showed the score about 1.87 also mean that "unhealthy soil" for peanut farming. Kabuh formation area showed the score about 2.97 mean that "marginal health" for peanut farming. Overall the score of Sangiran areas mean that the soil belongs to "very bad" quality for peanut cultivation.

1. INTRODUCTION

The Sangiran Archaeological Site is located in Sragen and Karanganyar Regencies, Central Java Province. The Sangiran site has become one of the symbols of Central Java tourism (Abdulah, 2017; Adiati, 2016) because it is included in the category of unique sites that receive special treatment. The uniqueness and special treatment of the Sangiran Site is seen from the fact that although it has been recognized as a "World Heritage," this site is not a sterile (empty) area and is also not sterilized from domestic reach (Harianja, 2018). The Sangiran Site is categorized as an "open site" in a broad sense, which not only "Open to the Public," but also inhabited and cultivated as agricultural land by residents. Many resident activities are visible at the Sangiran Site, one of which is food crop farming and horticulture (Puspita *et al*., 2016). The land in Sangiran is categorized as barren and less fertile, but many residents still cultivate their land for agriculture (Puspita *et al*., 2016; Nuryanti & Suwarno, 2008; Nurwanti *et al*., 2013; Prabaningrum *et al*., 2019). Agricultural land throughout the Sangiran area involves irrigated rice fields, teak tree gardens, rain-fed rice fields, and food crop and horticultural gardens such as beans and vegetables (Puspita *et al*., 2016). In the dry season, only rain-fed rice fields and gardens remain productive due to a lack of irrigation water. The dry season in Sangiran is longer than in surrounding areas, lasting from April to November (Wulandari, 2017; Handayani *et al*., 2020). During the dry season, many irrigated rice fields are cultivated with corn and peanut (*A. hypogea*) (Nuryanti & Suwarno, 2008; Nurwanti *et al*., 2013; Prabaningrum *et al*., 2019).

In addition to corn and rice, peanut is one of the typical foods of Sangiran (Puspita *et al*., 2016; Nuryanti & Suwarno, 2008; Nurwanti *et al*., 2013; Prabaningrum *et al*., 2019). Currently, farmers in Sangiran are planting peanuts of local varieties (Kancil and Bison). Peanut in the Sangiran area and are generally planted on hilly land, dry terraces, and rice fields during dry season (Puspita *et al*., 2016). Although it is a typical agricultural crop of Sangiran, peanut farming is also affected by the nature conditions of Sangiran which are barren and less fertile (Wulandari, 2017; Gintu *et al*., 2020). Farmers commonly add chemical fertilizers, but the use of fertilizers should be controlled to limit pollution in the site (Gintu *et al*., 2020; Cano *et al*, 2022; Davidson & Wilson, 2006; Di Turo *et al*, 2016; Van Grieken *et al*, 1998). In addition to rainfall, generally farmers pump water from irrigation canals to water the peanut land (Puspita *et al*., 2016; Prabaningrum *et al*., 2019). The problem of meeting water needs will be worse if the drought is prolonged and irrigation water also dries up (Handayani *et al*., 2020; Gintu *et al*, 2019).

Sangiran is a unique site because of its soil geological formations. The geological formations are found on land owned by residents, both in settlements and agricultural lands. The oldest geological formations are: (1) Kalibeng, the oldest formation with characteristic seabed ecosystem deposits; (2) Pucangan, a formation characterizing ancient swamp deposits; (3) Grenzbang, a formation that is a boundary between land and sea; (4) Kabuh, the first open dry land formation; and (5) Notopuro, the youngest formation, which is a dry land formation formed after the Kabuh. Agricultural activities in the Sangiran area need restriction because large-scale farm mechanization activities can damage the stratigraphy of the formation. Some of the agricultural areas of local residents are also crowded with research because they are the locations that contribute the most to the treasury of display objects in museums so that they are highly protected from potential pollution from the agricultural sector such as fertilizers and pesticides (Gintu *et al*, 2020; 2022). The locations of residents' farms that are also research locations including the Blue Clay and Black Clay areas (Gintu *et al*., 2022). These two locations are traces of environmental change from seabed type to open dry land so that many ancient animal fossils (Sémah, 2017; Sémah *et al*, 2016; 2009). Another area that is no less important is the Kabuh formation area. This formation is the area most touched by domestic activities because most of the land of Sangiran residents (including housing and agriculture) is in the Kabuh formation (Wulandari, 2012). Therefore, it is necessary to analyze the suitability of agricultural land especially for peanut cultivation during dry season. It is expected that results of this research can be used to design productive farming system but not violate conservation regulations (Prabaningrum *et al*., 2019; Gintu *et al*., 2020).

2. METHODS

This research was conducted in February 2019 – March 2020. Soil sampling was carried out in several places at the Sangiran site, namely Blue Clay and Black Clay from the Pucangan formation of Pablengan village, Sangiran and Kabuh soil from around the Sangiran Triangulation Monument. Soil physicochemical characterization and charcoal synthesis were carried out at the CARC Laboratory and FPB Soil Lab, Satya Wacana Christian University, Salatiga.

2.1. Tools and Materials

The tools included ovens, UV-Vis spectrophotometer, HAACH photometer, Flame photometer, pH meter, multimeter, 100mL burette, beaker cup and petri dishes. The materials used in this study were aquades, aquabides, HCl. KH_2PO_4, mureksides, EDTA, NRE, and ascorbic acid. All materials were standardized pro – analysis (PA) MERCK production.

2.2. Research Data

The data used in this study were primary and secondary data. The primary data was in the form of physicochemical characterization data on the soil of the land that is studied, namely from the soil of the former seabed formation (Kalibeng) in the form of Blue Clay, the formation of the former ancient swamp (Pucangan) in the form of Black Clay, and the open land formation, namely the Kabuh formation (Gintu *et al*., 2022). Meanwhile, the secondary data involved climatological data for the Sangiran area obtained from the central statistics agency (BPS) of Sragen Regency. The climatological data was a summary of data for 7 years, namely 2009 – 2015 (Wulandari, 2017).

2.3. Research Design

This study analyzed agricultural land suitability reviewed from the physicochemical conditions of the soil and the microclimate of the study area. The research design followed the rules of complete random design, which is the presentation of data using the average of the overall measurement results. Soil physicochemical characterization data (primary) was presented in the form of an average taken 3 times of repetition of each parameter. Climatological (secondary) data was presented in the form of average results of reported observations at BPS for 7 consecutive years. The results of the microclimate and physicochemical analysis of the soil were presented following the table of the Bunting System (Sulaeman *et al*., 2005). The monitoring parameters were shown as in Table 1.

Table 1. Physicochemical characterization parameters and their references

Parameters			**Reference**
Moisture content			Presiden RI (2000)
Potential		Ph	Presiden RI (2000)
		Eh	
		DHL (µS $^{cm-1}$)	
Ash		Ash	Presiden RI (2000)
		Organic	
		Carbon	
		Pill	
		The	
Toxicity (Al^{3+})			Presiden RI (2000)
Salinity (Na)			Presiden RI (2000)
Porosity			Presiden RI (2000)
Hardness		CaO / $CaCO_3$	Presiden RI (2000)
		MgO / $MgCO_3$	
		Total	
CEC			Presiden RI (2000)
KB			Presiden RI (2000)
Microbe		Plate	AOAC, 1990; 2005
		O.D. McFarland	
Non-Metallic Minerals	Ca	CaO	Presiden RI (2000)
		$CaCO_3$	
		Ca^{2+}	
	K	K_2O	Presiden RI (2000)
		K^+	
	N	$NO_{.3}$	Presiden RI (2000)
		NO_2	
		NH_3	
		Urea	BSN (2010)
		N Total	BSN (2010)
	P	PO_4	BSN (2005a; 2005b)
		P_2O_5	
		P Total	
	S	SO_4	BSN (2005c)
		SO_2	
		S^{2-}	
	Cl	Cl^-	Presiden RI (2000)
		Cl_2^-	
	F		Presiden RI (2000)
	C	$KMnO_{Titration\ 4}$	Presiden RI (2000)
		$FeSO_4$ Titration	
Metal		Fe	Presiden RI (2000)
		Cu	Presiden RI (2000)
		Cr^{6+}	Presiden RI (2000)
		Zn	Presiden RI (2000)
		Mn	Presiden RI (2000)
		Ni	Presiden RI (2000)
Climatic			Sulaeman *et al*. (2005)

2.2.3. Climatological Analysis (Sangiran Microclimate)

The climatological data was obtained from the annual report of the BPS of Sragen Regency which consisting the amount of rainfall, rainy days, and daily temperature for 7 consecutive years. The analysis of the microclimate of the Sangiran area used several approaches (Lal *et al*, 1994; Lowery *et al*, 1996; Kartasapoerta, 2019), namely: rainfall by Lang, number of rainy days by Oldman, number of dry months by De Martone, and microclimate type based on Scmidth-Ferguson.

2.2.4. Soil Sampling

Soil sampling was carried out using the usual soil sampling method (without rings), namely by using a shovel on a spot area of 12 cm x 20 cm (Sulaeman *et al*., 2005; Lal *et al*, 1994; Lowery *et al*, 1996; Kartasapoerta, 2019). The physicochemical characterization of soil was carried out following Sulaeman *et al*. (2005).

3. RESULTS AND DISCUSSION

The conservation regulation divides the 56 km^2 Sangiran site area into 3 categorical zones, namely the core zone, the development zone and the outer zone (Nuryanti & Suwarno, 2008; Nurwanti *et al*., 2013). The core zone is a "sterile" area, which is an area that is only intended for housing, research and educational tourism (Nuryanti & Suwarno, 2008; Nurwanti *et al*., 2013). Development zone is areas that can be managed by the community but still comply with applicable conservation rules (Nuryanti & Suwarno, 2008; Nurwanti *et al*., 2013). In the core and development zones, there are many local agricultural locations, especially food, teakwood, and horticultural crops. While, the outer zone is categorized as a "safe zone" and is not very bound by conservation rules except for environmental health (Nuryanti & Suwarno, 2008; Nurwanti *et al*., 2013). Strict regulations (national and international) that supervise Sangiran, as well as natural conditions that are not ideal for food crop farming and horticulture make it very difficult for farmers (Prabaningrum *et al*., 2019; Gintu *et al*., 2020; Gold, 2022). In this study, an analysis of the suitability of Sangiran agricultural land to peanuts was carried out. The results of the study are shown in Table 2.

From the mineral content, Blue Clay and Black Clay are rich in minerals but the soil is less fertile. This is thought to be caused by several natural possibilities, namely: (1) because these minerals are not ionized properly (Gintu *et al*, 2020; Gintu *et al*, 2022). To ionize soil minerals, sufficient water availability is required, whereas in Sangiran it is classified as a barren area and the soil evaporates water very quickly (Gintu, 2022). The large amount of soil evaporation in Black Clay and Blue Clay is caused by the entire expanse of soil being mixed with Mollusca and Foraminifera fossils which enlarge the soil pores (Gintu *et al*., 2022; Budiantoro *et al*., 2012; Rahmayani & Donan, 2017). The large porosity and hot daytime conditions in Sangiran cause low soil water content which is needed to ionize minerals so they can be absorbed by plants. Another prediction for the cause of infertile soil is (2) toxicity stress that occurs naturally. Black Clay Soil is rich in rocks containing iron (Fe) whose characteristics are blackish red. These rocks are often found around the Puren River which flows through the Black Clay area. These stones are thought to dissolve in river water (or rainwater) and then w*et al*l the land in the Black Clay and Blue Clay areas. Especially in the Blue Clay, because its position is lower than the Black Clay, it is very possible that the rock solution was carried from the Black Clay by rainwater and the Puren River to the Blue Clay. The excess iron content in the soil causes instability in the chemical conditions of the soil, causing plants to suffer so that they grow infertile. The estimated cause of black clay and blue clay soil infertility is (3) because the soil minerals and rocks are naturally difficult to decompose. If we consider the mineral richness, along the Puren stream many rocks are found containing Ca, K, PO4 and SiO (Fathoni, 2016; Fathoni, 2018; Rahmat, 2016). All of these minerals are minerals needed for agriculture (Gintu *et al*, 2020; Gintu *et al*, 2022). However, because the rocks and soil minerals have been compressed many times by natural forces, so that on the nano to micro scale, these minerals have reached their true crystal form (perfectly crystallized and stable) (Fathoni, 2016; Fathoni, 2018; Rahmat, 2016). In this condition, these minerals will be very difficult to decompose even if there is sufficient water available for irrigation. The mineral crystals in this soil have been stable for centuries because of the fluorine (F) content which is naturally contained in Sangiran soil (Arif & Siregar, 2016). In this section, fluorine acts as a natural conservator (preservative) for rocks and sediments that are compressed in the soil layer so that they do not become brittle and decompose easily (Arif & Siregar, 2016). This natural mechanism causes Sangiran soil to have very minimal mineral content (Gintu *et al*, 2020; Gintu *et al*, 2022). Especially for the Blue Clay area, the infertility of the soil increases by 1 more, namely the content of Nickel (Ni) and

Table 2. Analysis of the suitability of agricultural land for peanut under different geological formations (Black Clay, Blue Clay, and Kabuh)

Quality attribute		**Black Clay**	**Category**	**Suitability**		**Blue Clay**	**Category**	**Suitability**		**Kabuh**	**Category**	**Suitability**	
Climatic	Annual air temperature (°C)	28.5 (max 34)	Semi Arid	S2	3	28.5 (Max 34)	Semi Arid	S3	1	28.5 (Max 34)	Semi Arid	S3	1
	Dry month	5-8		S2	3	5-8		S3	1	5-8		S1, S2	5; 3
	Annual rainfall (mm)	190-390		S2	3	190-390		N2	0	190-390		S3, N1	1; 0
	Climate Type	Arid Savannah (Aw-Bw)		S3	1	Arid Savannah (Aw-Bw)		S3, N1	0	Arid Savannah (Aw-Bw)		S3	1
	Climate Categories	$D_{4,E\ 1-E\ 4}$				$D_{4,E\ 1-E\ 4}$				$D_{4,E\ 1-E\ 4}$			
Soil Moisture	Moisture Content (%)	1.04	Slightly Dry	S3	1	0.46	Slightly Dry	S3	1	0.60	Slightly Dry	S2	3
	Moisture (%)	13.8				5.10				5.00			
	Drainage	Difficult to Flood		S2-S3	3; 1	Difficult to Flood		N2	0	Difficult to Flood		S1	5
	Porosity	6.60	Low			24.60	Moderate	S2	3	19.00	Moderate	S2	3
Retention of Offense	pH Aq	7.94	Slightly Alkaline	S3	1	8.50	Slightly Alkaline	N1	0	7.84	Slightly Alkaline	S2	3
	C-Organic (%)	31.8	Very High	S1	5	18.53	Very High	S1	5	7.53	Very High	S3	1
	N-Total (%)	2.50	Very high	S3	1	2.95	Very High	S3	1	2.46	Very High	-	-
	K2O (%)	5.16	Moderate	S3	1	4.05	Low	S1	5	0.88	Very High	S1	5
	P2O5 (%)	17.29	Moderate	S2	3	32.04	Moderate	S2	3	28.79	Moderate	S3	1
	Salinity (%)	6.08	Low	-	-	10.24	Marginal	-	-	5.06	Marginal	S2	3
	Toxicity (Al) (%)	3.75	Very Low	S1	5	5.20	Very Low	S1	5	0.75	Very Low	-	-
	CEC (%)	71.14	Very high	N1	0	76.39	Very High	S3	1	18.72	Moderate	S1	5
	Base saturation (%)	0.05	Very Low	-	-	0.07	Very Low	-	-	0.25	Very Low	S2	3
Root zone	In the roots	5; 10-15cm	Shallow	N2	0	5; 10-15cm	Shallow	S3	1	5; 10-15cm	Shallow	-	-
Geo-graphic	Elevation											S3	1
	Slope												
	Rock Overlay												
Soil Quality (Lal *et al*, 1994; Lowery *et al*, 1996)		Score = 2.13 0 < Score < 6 Criteria: Very Bad 0 < Score < 3 Health: Less Healthy				Score = 1.87 0 < Score < 6 Criteria: Very Bad 1.5 ≤ Score < 3 Health: Unhealthy				Score = 2.79 0 < Score < 6 Criteria: Very Bad 1.5 < Score ≤ 3 Health: Slightly Healthy (Marginal)			

Copper (Cu) which causes the blue color. On the other hand, Ni and Cu can cause stress to plants. In addition to Black Clay and Blue Clay, another area processed by residents is the Kabuh Formation area. The characteristic of this formation is its reddish and dry soil (Wulandari, 2012; Nugraha, 2018; Wulandari, 2017). Most of the agricultural land of the Sangiran population is in the Kabuh formation (Prabaningrum *et al*., 2019; Wulandari, 2012; Nugraha, 2018; Wulandari, 2017). Because it is also processed by the community for agriculture, it is necessary to analyze the suitability of the land to describe the condition of agriculture (Nuryanti & Suwarno, 2008; Nurwanti *et al*., 2013; Prabaningrum *et al*., 2019; Wulandari, 2012; Nugraha, 2018; Wulandari, 2017). The results of the land suitability analysis are shown in Table 2.

The results of the analysis in Table 4 show that the condition of the Kabuh soil is the same as the two previous soils, namely "very bad" condition (Lal *et al*, 1994; Lowery *et al*, 1996). Even though the conditions are very bad, they are somewhat ideal (somewhat healthy) for farming. The reason for the poor condition of Kabuh's soil is because the mineral content is very high but cannot be absorbed because it is not ionized. The physical condition of the land also causes poor soil conditions. Kabuh soil, like Sangiran soil in general, does not have an organic layer (Fathoni, 2016; Fathoni, 2018; Rahmat, 2016; Nugraha, 2018; Wulandari, 2017). Meanwhile, the surface of the soil itself is mixed with sand which causes the soil pores to become large (Fathoni, 2016; Fathoni, 2018; Rahmat, 2016; Nugraha, 2018; Wulandari, 2017). Kabuh soil is also difficult to be flooded with water, and at a depth of 10-12cm, soft textured cross sand mixed with diatoms is found (Fathoni, 2016; Fathoni, 2018; Rahmat, 2016; Nugraha, 2018; Wulandari, 2017), making the soil prone to erosion by rainwater (leading to landslides) (Nuryanti & Suwarno, 2008; Prabaningrum *et al*, 2019; Sukronedi & Haryono, 2016) Kabuh land that is commonly used as peanut land is located on hills or hillsides (Puspita *et al*, 2016; Prabaningrum *et al*, 2019). These areas are prone to landslides in the rain due to the fragile soil of Kabuh (Wulandari, 2012; Sukronedi & Haryono, 2016; Rahmayani, 2019). Because it is fragile and difficult to hold water (both puddles and moisture), Kabuh's soil looks very dry and barren like tropical savanna soil (Wulandari, 2012; Sukronedi & Haryono, 2016; Rahmayani, 2019; Sukoco, 2010). The problem faced in Kabuh is also the same as the two previous soils, namely chemical stability. Many mineral rocks are found which are needed for agriculture, but the soil is not fertile (Gintu *et al*, 2020; Gintu, 2022). This is thought to be caused by the same phenomenon, namely that the mineral rock has reached crystal stability because it has been compressed for millions of years, making it difficult to decompose. Even if there are small portions of decomposed rock mixed with the soil, due to the lack of water content, these minerals are difficult to ionize and therefore difficult for plants to absorb. Even though the mineral content in Kabuh and Clay soil is relatively high, due to the lack of water, these minerals are not absorbed. However, if irrigation is increased, Sangiran's soil generally cannot hold water so it is at risk of landslides (Rahmayani, 2019; Sukoco, 2010). This low ability to hold water is due to the large porosity and sand layers. Additionally, high temperatures during the day will speed up the evaporation of water from the soil. This dry soil condition is a problem that farmers complain about because it causes the land to be less fertile and yields are small (Gintu *et al*, 2020). The physical condition of the soil on the research land is shown in Figure 1-3.

Figure 1. (a) Black Clay soil mixed with mollusca shell fossils.

Figure 2. Blue Clay and its sand (Documentation of the River HOH Team 1, 2018)

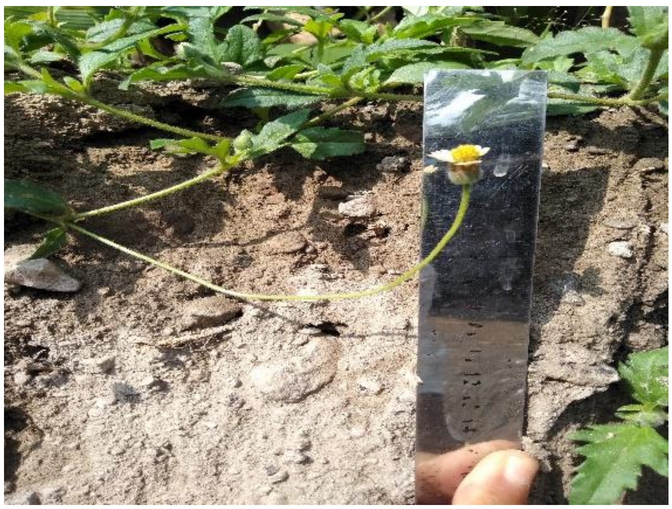

Figure 3. Kabuh formation with thin top soil without organic layer, and fine sand under top soil.

In managing land as agricultural land, the Sangiran community is constrained by several conservation regulations both nationally and internationally (Nuryanti & Suwarno, 2008; Nurwanti *et al*., 2013; Gintu *et al*., 2020; Sukronedi & Haryono, 2016). These regulations limit land expansion, mechanization, and fertilization (Gintu, 2022; Gintu 2022). These three agricultural mechanisms are considered to have a high chance of damaging the archaeological wealth within the site's soil layer (Gintu *et al*., 2020; Cano *et al*, 2022; Davidson & Wilson, 2006; di Turo *et al*, 2016; Van Grieken *et al*, 1998). Meanwhile, for the irrigation system, it is not limited because naturally the Sangiran site is a category of barren land to be used as agricultural land such as irrigated rice fields (Handayani *et al*., 2020; Gintu *et al*., 2018; 2019) but slightly safer for gardens (Puspita *et al*., 2016).

In addition to the constraints of soil infertility and fragility, it is also important to study Florin (F) which is naturally contained in all soils in the Sangiran area (Arif & Siregar, 2016). The F content in soil, especially land that is used as agricultural land, will endanger the health of people who consume their agricultural products (Mansir *et al*, 2018; Agbota *et al*, 2013). Exposure to F that accumulates over a long period of time will cause health problems (Agbota *et al*, 2013; Eugenio *et al*, 2018). Florin on the land of Sangiran is estimated to come from the former ancient marine environment which has now become a stretch of dry land that is used as a residence and agricultural land for the community (Gintu, 2022; Arif & Siregar, 2016). The F content of Sangiran soil is shown in Table 3.

Table 3. Florin content in Sangiran land

Soil	Florin Content	
	g/g	(%)
Blue Clay	0.0099	0.99
Black Clay	0.0045	0.45
Kabuh	0.0003	0.03

The presence of F content detected in Sangiran soil is very important to be considered in the study of agricultural land development (Puspita *et al*., 2016; Mansir *et al*, 2018; Agbota *et al*, 2013; Eugenio *et al*, 2018; Fermo *et al*, 2022). However, the obstacle is that generally the agricultural land suitability analysis system only considers the toxicity of Al^{3+} (Sulaeman *et al*., 2005), while the toxicity of F is still rarely considered, especially if the case is natural F content such as in Sangiran (Agbota *et al*, 2013; Eugenio *et al*, 2018; Fermo *et al*, 2022). The traceability of F content in Sangiran soil will greatly affect soil quality assessment both in the Bunting assessment system and in the field (Puspita *et al*., 2016; Agbota *et al*, 2013; Eugenio *et al*, 2018; Fermo *et al*, 2022). Generally, in addition to coastal areas, areas with high F content in their environment will be limited to agricultural land (Agbota *et al*, 2013; Eugenio *et al*, 2018; Fermo *et al*, 2022). If the area will continue to be inhabited, the community must be educated and given treatment to minimize exposure to F to the body, as well as minimize F contamination to their agricultural crops.

4. CONCLUSION

Sampling showed a weighting of 2.13 from Black Clay. This result is less than the standard weight of 3 for soil health which means "unhealthy" for peanut farming. The Blue Clay area showed a weighting result of 1.87. This result is less than the standard weight of 3 for soil health which also means "unhealthy" for peanut farming. The Kabuh area showed a weighting point of 2.97. These results are close to the standard weight of 3 for soil health which means "somewhat healthy" for peanut farming Overall the soil weighting results show results less than the standard weight of 6 which means that the soil quality is classified as "very poor".

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