

Analysis of soil physical quality index (case study: groundnut/ *Arachis hypogea* L.)

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Abstract. Physical properties of soil are good for plant growth is closely related to the management of the soil, so it will need to integrate of physical properties to get an overall assessment with making soil physical quality index (SPQI). This study aims to an evaluation of physical properties and determines the physical quality index using several unit treatments to produce various physical qualities on Groundnut/ *Arachis hypogea* L. The location of the research was carried out in a farmer's garden in Cimaung Village, Cikeusal District, Serang Regency, Banten Province (Coordinates 6o12'14'' S dan 106o11'52''E). To analyze the SPQI using several physical properties of the soil such as texture, bulk density, porosity, permeability, and aggregate stability. Each indicator has a scoring parameter to assess the soil physical quality index with a score range of 0-5. An assessment SPQI in a land unit is able to describe the various physical qualities of the soil which are represented by several physical properties of the soil. The unit treatment which class categorization of soil physical quality index indicated slightly good (U2), medium (U1, U3-U6), and slightly poor (U7) as a control.

1 Introduction

The function of soil will could work optimally if attention to the potential factor of the soil and physical condition of the soil. However, so far, the community has many factors that have an impact on the ability of the soil to work so that it affects plant growth. Good soil workability is when the soil can be cultivated easily to provide a growth medium for a plant that is supported by the physical qualities of the soil [1]. Physical quality of soil has an important contribution to plant growth, thats 1) as a physical medium for the presence or place of the presence of nutrients, water and gases needed for plants, 2) as a controller for providing available water for plants and 3) as a process controller supply of gases needed for plants [2]. Soil with good physical quality has the ability to provide adequate and appropriate supply of water, air and nutrients for plants so that it is closely related to the management and use of growing plants [3, 4]. While poor soil physical quality will show

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symptoms such as poor water, runoff from surface filtration, soil hardening, poor aeration, poor rooting ability and poor workability. Sometimes, the soil shows some or all of these physical problems occurring simultaneously and all of these symptoms have the same cause, poor soil structure [1]. Whereas soil structure is relevant to describe the quality of a soil, especially its relation to soil and water functions [5]. Poor soil structure indicates that there has been a decline in the physical quality of the soil.

The decline in soil physical quality is an important limiting factor for plant growth in the long term [6, 7]. Because the degradation of soil physical properties not only directly affects plant growth but also affects the infiltration capacity of the soil [8] as part of the physical properties of the soil. Furthermore, soil physical quality was monitored in long-term field studies designed to determine the economics and environment of agriculture [9]. To see various of physical quality of the soil in a large range can used soil ameliorant. Soil ameliorant can be used to accelerate the recovery of soil quality especially physical properties [10]. that can support the role and function of some soil physical properties. Therefore, it is necessary to determine physical quality of the soil. Physical quality of the soil can be done by changing the physical properties of the soil to changes in function through an assessment of land use which can be done through physical evaluation of the soil. By knowing the physical quality of the soil of an agricultural land, it can provide an overview sustainability of soil resources and also the general trend of changes in soil conditions during use [11], especially on land where plant is grown.

The crop that has long been cultivated and developed by the community in Cikeusal District, Serang Regency, Banten Province is groundnut (*Arachis hypogea* L.). Groundnut are the main commodity in the cultivation of local communities. In addition, cultivation that is carried out without consideration of factors management results in degradation of the physical quality of the soil, this will have an impact on soil management and crop productivity. Good physical soil quality will produce good plant productivity as well. So that the physical quality of the soil can be used as a key element of soil management for the sake of a land in production [5]. To assess the physical quality of the soil, it is necessary to select various indicators of soil physical properties. The indicators were selected based on their relevance to soil functionality and sensitivity to changes caused by land management [12]. Some researchers state that there is no single measure to assess the physical quality of soil [1], so that necessary to integrate the indicators of soil physical properties to obtain an overall assessment.

To integrate the physical properties of the soil, in this study, leveraging was carried out by artificially making the physical properties of the soil, in several treatment. This study aims to evaluation of physical properties and determine physical quality index using several unit treatments to produce various physical qualities on Groundnut/ *Arachis hypogea* L.

2. Methodology

2.1 Study area and characteristics of research sites

Research was carried out in May 2020–March 2021. The research location was in a farmer's garden in Cimaung Village, Cikeusal District, Serang Regency, Banten Province (Coordinates 6°12'14" South Latitude and 106°11'52" BT). Soil sample analysis was carried out at the Soil Physics Laboratory and the Laboratory of Soil Chemistry and Strength, Department of Soil Science and Land Resources, Faculty of Agriculture, IPB University and Bogor Soil Research Institute. The tools and materials used are adjusted to the needs of the analysis carried out. The materials used for this research are groundnut seeds, soil ameliorant and fertilizer components, soil samples and aquadest.

The research site is a rainfed land (suboptimal dry land) with an average rainfall of 104 mm/month or 957 mm/year and annual rainfall occurs during the rainy season from November to April, the average temperature is 27°C, minimum humidity 77% and maximum 96% [13]. This study assumes that the research location is not influenced by climate so that climate is not a limiting factor. The characteristics of the subgrade soil at the research site are as follows:

Table 1. The characteristics basic of the soil at the research

Soil Characteristics	Analysis
Soil Depth (cm)	>60
Particle size distribution (%)	
- Sand	48,77
- Silt	25,99
- Clay	25,00
Texture	Sandy loam
Soil pH (1:5)	
- H ₂ O	4.72
- KCL	4.42
Soil Organic Carbon (SOC) (%)	0,33

2.2 Unit treatment

Unit treatment carried out with various soil ameliorant and fertilizer recommendations on each plot which contained seven unit treatments, each unit had 3 replications so that there were 21 experimental plots and experimental plot size 5 mx 6 m (30 m²). The treatments used in this study were:

- U1 : Lime 1 + NPK + Dolomit + HUMIKA
- U2 : Lime 2 + NPK + Dolomit + HUMIKA
- U3 : Lime 1 + NPK + Dolomit + Petrogenik
- U4 : Lime 2 + NPK + Dolomit + Petrogenik
- U5 : Lime1 + Dolomit
- U6 : Lime 2 + Dolomit
- U7 : Control

The recommendation treatment were :

- Lime 1 = 1.5 kg/plot
- Lime 2 = 4,5 kg/plot
- NPK = 1.5 kg/plot
- Dolomit = 1.5 kg/plot
- HUMIKA = 3 kg/plot
- Petrogenik = 3 kg/plot

Soil sampling was carried out after the application of fertilizer treatment in one growing season on peanuts to obtain data in assessing the physical quality index of the soil. Intact soil samples were taken using a ring sample and taken from each plot intended for determination of bulk density, porosity, available water capacity and permeability. While aggregate soil to analyze the percent aggregates. Disturbed soil sampling was carried out in a composite from tillage layers at a depth of 0-20 cm for texture.

2.3 Soil analysis

Soil analysis was carried out to determine the physical characteristics of the soil as the parameters chosen to assess the physical quality of the soil. Physical properties that are used as the main parameters in the physical soil quality index are texture, bulk density,

available water, permeability and percent agregation. These parameters are the most frequently used to determine physical soil quality and soil quality in general [14,15]. The following are the parameters of the physical properties of the soil to be analyzed in the Laboratory.

Table 2. Parameters of soil physical properties for analysis in the laboratory

Parameters	Method Analysis/Reference	Unit
Texture	Hydrometer/pipet	-
Bulk density	Gravimetri (ring sample)	g cm ⁻³
Porosity	Gravimetri (ring sample)	%
Available water capacity	Gravimetri (Pressure plate apparatus)	%
Permeability	Water Constant Head (Klute dan Dirksen, 1986)	cm jam ⁻¹
Agregat stability	Dry Sieving	-

2.4 Data analysis

Analysis SPQI was carried out based on three conceptual frameworks that is 1) Selection of Indicators, 2) Interpretation (Scoring indicators of soil physical properties, 3) Integration. which were used to assess the quality of soil properties in favor of or contribute to soil function to produce a soil management function [16, 17].

SPQI management can then be obtained by following several expert opinions [18]. Then give a score of 0 to 5 on each selected indicator according to its conditions and performance. Soil parameters and scoring criteria can be seen in (Table 3) to calculation of the SPQI. Then categorize the SPQI scores into 7 categories to determine the soil physical quality class (Table 4). IKFT can be calculated using the following equation:

$$SPQI = \sum \left(\frac{S}{n \cdot i} \right) \quad (1)$$

Where:

- SPQI = Soil Physic Quality Index
- S = Denotes score of soil parameters
- n = The number of parameters
- i = Maximun Index

Table 3. Parameters of soil physical properties and criteria for assessment of SPQI [19, 20, 15]-modification

Parameters	Score					
	0	1	2	3	4	5
	Strongly Very Poor	Very Poor	Poor	Medium	Good	Very Good
Texture	S	CL	CW	SL,C	ScL, Si, SiL, SiC	L, SacL, CIL, ScL
Bulk Density (g/cm ²)	>1,6	1,4-1,6	1,2-1,4	1,0-1,2	0,8-1,0	≤ 0,8
Available Water Capacity (%)		<5	5-10	10-15	15-20	>20
Porosity (%)	<20	20-30	30-40	40-50	50-60	>60
Permeability (%)	<0,5	0,5-2,0	2,0-6,3	6,3-12,7	12,7-25,4	>25,4
Agregat Stability	<40	40-50	50-66	66-80	80-200	>200

Description: S = Sand; CL = Clay Sand; SL = Sandy Loam; L = Loam; SiL = Silt Loam, ScL= Silt clay Loam; SacL = Sandy clay Loam; CIL = Clay Loam ; ScL = Sandy Clay, Si = Silt; SiC = Silt Clay; C = Clay; CW = Clay Weight (Clay > 80 %)

Table 4. Category assessment of SPQI - modification

Class	Value	Criteria
1	< 0,2	Very Poor
2	0.2 – 0.39	Poor
3	0.4 – 0.54	Slightly Poor
4	0.55 – 0.69	Medium
5	0.7 – 0.79	Slightly Good
6	0.8 – 0.89	Good
7	0.9 – 1.0	Very Good

3. Results and discussion

3.1 Physical properties of soil

Physical quality assessment of soil carried out using seven unit treatments on the same land with an effective soil depth of > 60 cm. The treatment is able to produce a variety of characteristics of the physical properties of the soil. The parameter that has greatest coefficient of variation, which is above 50%, is indicated by the size distribution of silt and clay as part of determining soil texture and permeability. Then the parameter that has a coefficient of diversity <10% is indicated bulk density and porosity. The physical properties that are used as the main parameters in the physical soil quality index are texture, bulk density, available water, permeability and aggregate stability (Table 5).

Table 5. The results analysis of the soil physical properties

Unit	PSD			T	BD (g cm ⁻³)	AWC (%)	Por (%)	Ks (cm jam ⁻¹)	AS (%)
	S	Si	C						
U1	48,32	30,48	21,2	L	1,6	7,78	39,63	62,87	47,54
U2	64,26	8,16	27,58	SacL	1,4	9,38	45,37	26,05	52,77
U3	39,7	3,54	56,76	C	1,4	9,03	46,57	22,05	47,15
U4	60,97	0,21	35,91	CS	1,4	9,13	45,68	75,85	65,55
U5	47,36	42,46	10,19	SL	1,5	10,03	42,82	19,18	50,04
U6	54,76	35,12	10,12	SL	1,5	12,50	43,59	69,69	54,83
U7	52,07	33,21	14,73	SL	1,7	7,61	37,70	23,95	44,94
Nilai Min	39,7	0,21	10,12	-	1,4	7,61	37,70	19,18	44,94
Nilai Maks	64,26	42,46	56,76	-	1,7	12,50	46,57	69,69	65,55
KK (%)	18,18	84,24	70,26		8,40	19,94	8,50	58,62	15,32

Description: PSD: Particle size distribution, S: Sand, Si: Silt, L: Loam, SacL : Sandy clay loam, C: Clay, CS: Sandy Clay, SL: Sandy Loam, T: Texture, BD: Bulk density, AWC: Available water capacity, Por: Porositas, Ks: Permeability, AS: Agregate Stability, KK: Koefisien Keragaman

Texture is a basic physical characteristic of the soil [21] which is difficult to change and takes a long time. Of the seven unit treatments carried out there was a diversity of soil texture in 4 treatments (U1, U2, U3, U4, and 3 treatments (U5, U6, U7) which had a texture the same. Furthermore, for the bulk density in this study, it was found that the contents of all unit treatments were between 1.4-1.7 g cm⁻³. This weight is still very high even though the optimal value for conducive plant growth is 0.9-1.2 g cm⁻³ [22]. The lowest bulk density (U2, U3, U4) while the highest is control treatment (U17) with a bulk density of 1.7 g cm⁻³. Bulk density indicated a very high soil density. This is in accordance with the opinion of [23] that the weight is the first step, the denser, and the higher the weight. Thus the bulk density of the soil is one of the important physical properties of the soil that characterizes the composition of the soil and can affect the nature of groundwater [21].

For available water capacity, five unit treatments were included in poor conditions, its U1-U4, U3, U4) and also control treatment (U7) had the lowest available water, which was

only 7.61% while 2 the other treatments were in moderate condition (U5-U6) which was between 10.03% – 12.50%. Available water capacity is water in the soil between the field capacity and the permanent lay point [20]. Furthermore, soil porosity generally has poor to moderate soil porosity and the lowest occurred in the control unit treatment it's 37.70%. Soil porosity is the total space occupied air in the soil which reflects the conditions of soil pores that affect or determine movement of air in the soil. Percentage of porosity is in line with the density value, soils with high total pore space. Soil mineral materials, such as dominant minerals with high particle density in the soil cause higher bulk density [23].

Permeability is one of the soil properties that is very influential on the existence of soil erosion, besides that permeability is one of the physical properties needed to assess land [24]. From the results of the analysis showed that each unit treatment was in the category of good to very good permeability which was in the range of 19.18 - 69.69 cm jam⁻¹. Quantitatively, permeability is defined as the movement of a liquid in a porous medium in a saturated state, these properties are influenced by the space and the nature of the fluid flowing in it. Size determines whether the soil has low or high permeability. Air that can flow easily in the soil has largepores and has a good relationship between pores. Small pores with uniform fit between pores will have lower permeability because air flows through the soil more slowly. Permeability is closely related to soil texture, this is in accordance with the texture of each treatment which shows that it is still in the moderate to very good category because the dominant texture is clay, sandy loam to sandy. Therefore the permeability of the soil texture is in accordance with the statement of [25] that soils dominated by sand have high permeability, on the contrary if soils with clay textures have low permeability.

Furthermore, stability of soil agregate are still in the very bad to bad category which is in the range of 44.94 - 65.55. Stability agregate in each unit treatment showed diversity because it was caused by the magnitude of the treatment but because they were still in the bad category, it was necessary to add soil organic matter, which can support the stability of soil aggregates. This is in accordance with the statement of [26] that organic matter can affect soil aggregation, because land use that produces little or no organic matter can cause degradation of soil physical properties. And it is supported by the statement of [27] that high organic matter in the soil will improve the soil structure so that the soil will have a lot of air conditioning. In addition, the stability of soil aggregates can be defined as the ability to with stand forces that will destroy it and is usually characterized by high levels of infiltration, permeability, and available water capacity [28]. Solid soil aggregates will maintain good soil properties for plant growth such as porosity and available water longer than unstable soils. Overall, with several unit treatment showed a very significant difference from some of the physical properties of the soil its texture, bulk density, porosity, Available water capacity, permeability and soil aggregate after planting once a season.

The values of the pearson correlation coefficient between the analysed soil physical quality indexes are presentated (Table 6). The correlation coefficient indicates very high dependencies in the case of most parameters with a very high negatif correlation was found between the values of BD and Porosity ($r = -0,988$) also Silt and clay ($r = -0,863$) which follow the texture of the soil in the treatment.

Table 6. Person correlation coefficients of soil physical parameters

Variable	Sand	Silt	Clay	BD	AWC	POR	Ks	AS
Sand	1							
Silt	-0,260	1						
Clay	-0,261	-0,863	1					
BD	-0,214	0,709	-0,598	1				
AWC	0,164	0,193	-0,277	-0,401	1			
POR	0,141	-0,704	0,630	-0,988	0,451	1		
Ks	0,357	-0,105	-0,108	-0,075	0,277	0,054	1	
AS	0,641	-0,467	0,103	-0,583	0,374	0,548	0,666	1

Description: BD: Bulk Density, AWC: Available Water Capacity, POR: Porosity, Ks: Pemeability, AS: Agregate Stability

3.2 Soil Physical Quality Index (SPQI)

Scoring in each treatment using six parameters of soil physical properties as a parameter in assessing soil physical quality index can be seen in (Table 7). From the results of the analysis showed a significant difference because it depends on the several various unit treatment in a land unit.

Table 7. Score values for each physical parameter of the soil

Unit	Texture	Bulk Density (g cm ⁻³)	Available Water Capacity(%)	Porosity (%)	Permeability (cm jam ⁻¹)	Agregate Stability	Total
U1	5	1	2	2	5	1	18
U2	5	2	2	3	5	2	21
U3	3	2	2	3	4	1	17
U4	4	2	2	3	5	2	20
U5	3	1	2	3	4	2	17
U6	3	1	3	3	5	2	19
U7	3	0	2	2	5	1	15

Furthermore, the class categorization of the physical quality index of the soil is slightly poor to slightly good. But because they were still in slightly poor so that it is still necessary to use organic matter that can support the role and function of some soil physical properties for plant growth with good nutrients, providing good aeration and easy penetration of plant roots into the soil [29]. Thus the physical properties of the soil will be very important because soil quality is supported by the statement [24] that physical properties and soil quality will increase productivity and soil management measures.

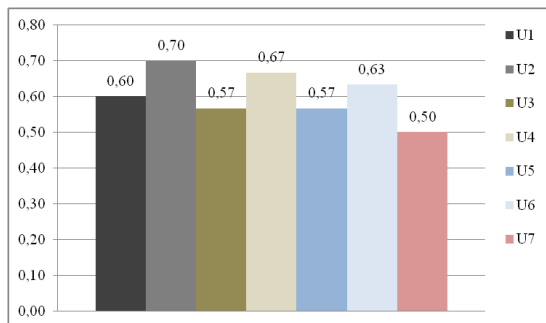


Fig 1. Soil physical quality index (SPQI) in each unit treatment

Table 8. Category assessment of SPQI of unit treatments

Unit	Criteria
U1	Medium
U2	Slightly Good
U3	Medium
U4	Medium
U5	Medium
U6	Medium
U7	Slightly Poor

4 Conclusion

The results showed that physical properties of the soil used as the main parameters to assess the soil quality index were texture, bulk density, porosity, available water capacity, permeability and percent agregation. The soil physical quality index showed that the high score for each parameters indicating a high total score for each unit treatment and indicating good soil physical quality index. The unit treatment which class categorization of soil physical quality indeks indicated slightly good (U2), medium (U1, U3-U6) and slightly poor (U7) as a control.

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