Bozok Tarım ve Doğa Bilimleri Dergisi
(Bozok Journal of Agriculture and Natural Sciences)
https://dergipark.org.tr/en/pub/bojans
e-ISSN: 2822-4604

Araştırma Makalesi /Research Article

Determination of Physical Characteristics for Dry Agricultural Land of Ciliwung Hulu Watershed

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Article Info

Geliş: 10.03.2023
Kabul: 10.04.2023
DOI: 10.59128/bojans.1263149

Keywords

Bulk Density, Indonesia, Permeability, Porosity, Texture

Abstract: This study aims to determine the physical characteristics of soil on dry land agriculture in the Ciliwung Hulu watershed, West Java Province and its relation to soil infiltration capacity. This study used a survey method through land surveys and direct observations at the research area, subsequently followed by taking soil samples for soil analysis in the laboratory. The results showed the soil texture of clay, clayey loam, loam and sandy loam, very high soil density, poor porosity, and moderate to very fast permeability. The results of soil data analysis in the laboratory showed that the physical characteristics of the soil in the Ciliwung Hulu watershed need improvements in the physical properties for rainfed agriculture.

Atıf Künyesi: Fitri, R., Perkasa, A. Y., Mangunsong, N. I. ve Satriawan, H (2023). Çiliwung Hulu Havuzu Kuru Tarim Arazisinin Fiziksel Özelliklerinin Belirlenmesi, *Bozok Tarım ve Doğa Bilimleri Dergisi,* 2(1), 12-18. **How To Cite:** Fitri, R., Perkasa, A. Y., Mangunsong, N. I. and Satriawan, H. (2023). Determination of Physical Characteristics For Dry Agricultural Land of Ciliwung Hulu Watershed, *Bozok Journal of Agriculture and Natural Sciences,* 2(1), 12-18.

Çiliwung Hulu Havuzu Kuru Tarım Arazisinin Fiziksel Özelliklerinin Belirlenmesi

Makale Tarihçesi

Received: 10.03.2023
Accepted: 10.04.2023
DOI: 10.59128/bojans.1263149

Anahtar Kelimeler

Yığın Yoğunluğu, Endonezya, Geçirgenlik, Gözeneklik, Tekstür

Öz: Bu çalışma, Endonezya'nın Batı Java Eyaleti, Çiliwung Hulu havzasındaki çorak kuru arazi tarımın yapılması için yerel toprağın fiziksel özelliklerini ve bunun toprak infiltrasyon kapasitesini belirlemeyi amaçlamıştır. Bu çalışmada, araştırma alanında arazi inceleme ve doğrudan gözlemler yoluyla bir ETÜD yöntemi geliştirilmiştir. Ardından, laboratuvarda toprak analizi için toprak örnekleri alınmıştır. Elde edilen sonuçlara göre, killi, killi tınlı, tınlı ve kumlu tınlı bünyesini, çok yüksek toprak kütle yoğunluğunu, düşük gözenekliliği ve orta - çok hızlı arasında geçirgenliği göstermiştir. Laboratuvardaki toprak veri analizinin sonuçları, Ciliwung Hulu havzasındaki toprağın fiziksel özelliklerinin yağmurla beslenen tarım için toprağın fiziksel özelliklerinde ıslah gerektiğini göstermektedir.

1. Introduction

A watershed is a land separated by a topography that is able to receive, accommodate rainwater as a watershed input that flows towards the outlet. The current condition of the watershed in Indonesia is generally damaged so that it often causes natural disasters such as erosion, landslides and floods. Watersheds are damaged due to the habits and insensitivity of the community in managing the environment (Ekawaty et al., 2018; Fitri et al., 2022; Prasetyo et al., 2020). The dry land agricultural landscape in the upstream watershed is characterized by undulating and mountainous topography. Farming that is cultivated in areas with steep slopes without adequate soil and water conservation causes erosion so that it can lead to a decrease in soil quality (Haryati et al., 2010). Soil is a layer of the earth's surface, a medium for all living things that physically can have a function as a place for growing and developing roots, supporting the growth of plants as well as providing nutrients for plants (Hanafiah, 2014; Suwarno, 2018). Analysis of the physical characteristics of the soil is important in an effort to determine the capacity of the soil and ensure good plant growth, so that plants are able to produce as expected, and prevent soil damage due to planting that is not appropriate for the soil's characteristics (Silalahi et al., 2019).

The Ciliwung Hulu watershed is located at the top of Mount Pangrango and its downstream part is in the Katulampa dam area. The Ciliwung Hulu watershed has a function as a buffer for the watershed area, so that if there is a change in the components of the watershed it could affect all parts of the watershed and damage the natural resources of the Ciliwung Hulu watershed, which will negatively affect and reduce hydrological functions like increasing critical land, erosion, landslides, and decreasing river water quality (Nuraida, 2019; Fitri, 2020). Land use change is one of the main factors affecting soil infiltration (Sun et al., 2018). Infiltration is the vertical flow of water into the soil through the soil surface. Infiltration capacity is the ability of the soil to absorb a small amount of water into the soil. The low soil infiltration capacity causes most of the rainfall that falls on an area to become puddles on the soil surface and flows into surface runoff so that only a small portion of the water flow that enters the soil becomes groundwater storage in the dry season. The physical parameters of the soil analyzed were soil texture, specific gravity, water content, permeability and porosity (Azizah et al., 2019; Elfiati and Delfian, 2010; Wahyuni et al., 2019). This study aims to determine the physical characteristics of soil on dry land agriculture in the Ciliwung Hulu watershed, West Java Province and its relation to soil infiltration capacity.

2. Material and Methods

The research was conducted in the Ciliwung Hulu watershed (DAS), with an area of 2544.6 Ha (16.85%) of the total watershed area (Fitri et al., 2018), and is located in West Java Province of Indonesia with approximate slope of ~8-15%. Rainfed farming is very dominant. The local farmers generally practice rainfed farming and grow papaya, taro, banana tomato, chili and sweet potato in the area (Figure 1). All of these crops were found in the surrounding areas within the boundary limits of the watershed as an alternate crop at the time of carrying out the experiment.

Figure 1. Agricultural landscape condition of upstream Ciliwung watershed

Source: Field Observation Results, 2021.

The soil was prepared using oxen drawn bullocks followed by fertilizing the soil with goat manure. The research location determined is an area with a slope of 8-15%. The Ciliwung Hulu watershed area is administratively included in 2 regencies in West Java Province (6° 38’-6° 46’ S and 107° 50’-107° 0’ N), namely Bogor Regency and Bogor City.

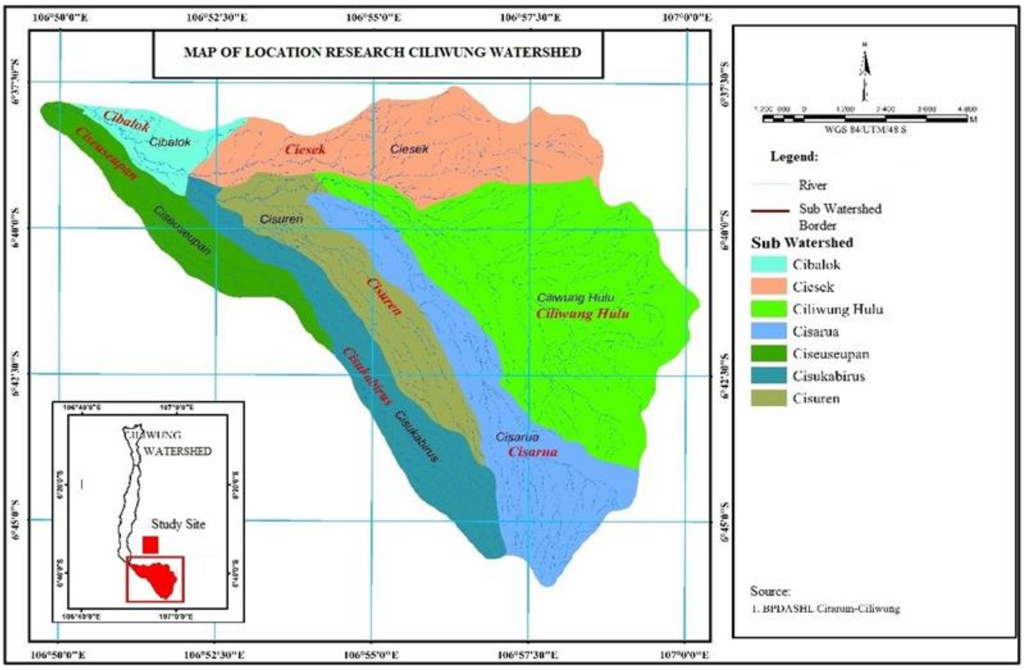

Figure 2. Research Site of Ciliwung Watershed

The field global positioning system, munsell soil color chartbook, soil drill, ring sample, land map unit, intact soil sample, incomplete soil sample, digital camera and stationery, along with soil analysis equipments in the laboratory were used in this research and land survey.

Furthermore, this study also used a descriptive survey method for soil sampling execution in the field to evaluate soil texture, by using a simple jar test to determine the percentages of sand, silt, and clay. Once the percentages were calculated, the soil textural triangle could be used to determine the soil type. The physical properties analysis of the soil use particle size distribution (PSA) was carried out in the soil laboratory of Bogor Agricultural University (IPB), Indonesia.

2.1 Measurement of Land Map Unit

Measurement of land map unit is a component of land units resulting from overlaying three (3) maps, including land use maps, soil type maps, and slope maps. The land use unit used in this study was the measurement of uniformity of land use, soil type, slope, and land use direction in the Ciliwung Hulu watershed, West Java Province.

2.2 Statistical analysis

The statistical analysis was performed by taking the means of three samples taken from each place. These samples were sent to the laboratory for physical analysis. They were analyzed using SPSS 26 for Windows. All results were shown as percentage.

3. Result and Discussion

3.1 Agricultural Landscape of Dry Land

A dryland agricultural landscape is used for seasonal crop farming in this landscape of ecological boundaries. Seasonal plants found in the research location included papaya, taro, banana tomato, chili and sweet potato. Cultivation of these plants by local community (in the research location) is carried out alternately. Cultivated land is usually given additional organic fertilizer from goat manure. The area of dry land agriculture in the Ciliwung Hulu watershed was made up of 2544.6 Ha (16.85%) of the total watershed area (Fitri et al., 2018). The research location determined is an area with a slope of 8-15%. The state of dryland agriculture in the Ciliwung Hulu watershed is shown in Figure 1.

3.2 Land Map Unit

The results of the land use map overlay, soil type map and slope map obtained 11 (eleven) land map units. There are three type of soils in the research location, namely Entisol, Ultisol and Inceptisol. The characteristics of the physical properties of the soil were analyzed in this study, which is the only dry land agriculture. The slope class at the study site is in 11 (eleven) land use units, namely <8% (flat) and 8-15% (sloping) (Fitri et al., 2018). Description of land map unit, soil type, topography and slope class in dry land agricultural landscapes are shown in Table 1.

Table 1. Description of Land Map Unit (SPL) in Land Agricultural Landscape Dry in the Upper Ciliwung Watershed

SPL	Type of soils	Topography	Slope Classes
8	Entisol	Sloping	8% - 15%
2	Entisol	Flat	< 8 %
12	Ultisol	Sloping	8% - 15%
4	Inceptisol	Flat	<8%
10	Inceptisol	Sloping	8% - 15%
7	Ultisol	Flat	<8%
7	Ultisol	Flat	< 8%
4	Inceptisol	Flat	< 8%
10	Inceptisol	Sloping	8% - 15%
10	Inceptisol	Sloping	8% - 15%
2	Entisol	Flat	< 8%

Source: (Fitri R, 2022 unpublished).

3.3 Soil Physical Characteristics

3.3.1 Soil Texture

Soil texture is one of several physical properties of soil with a relative ratio between the fractions of dust, clay, and sand in percent form. Soil texture is closely related to hardness, permeability, plasticity, fertility and soil productivity on land in the watershed. The results of the soil analysis in Table 2 show that the soil texture at the study site is dominated by clay with a percentage of clay content between 31.9-74.1% while the percentage of dust and sand is lower both at a depth of 1-15 cm and at a depth of 15-30 cm. Soil with a high clay content will form more small pores than macro pores, the high percentage of clay in the soil will inhibit the movement of water in the soil. The higher clay or softness of a soil texture, there will be more micro-pore spaces formed which are filled with water and air (Isra et al., 2019). The distribution of soil particles and soil texture in the Ciliwung upper watershed is shown in Table 2.

Table 2. Soil physical properties in each sst dryland agricultural landscape in the upper Ciliwung watershed

SPL	Depth of Taken Samples (cm)	Sand ough	Fraction (%) Fine sand	Dust	Clay	Texture Classes	Bulk density (g cm^{-3})	Porosity (%)	Permeability (cm $hour^{-1)}$
8	1-15	12.2	2.5	11.1	74.1	Clay	0.62	76.65	17.50
2	15-30	34.5	6.2	23.8	35.3	Clay	0.63	76.08	45.20
12	15-30	8.1	5.1	22.2	64.1	Clay	0.57	78.66	30.26
4	1-15	7.2	3.8	18.4	58.5	Clay	1.33	49.74	2.26
10	15-30	34.1	6.7	20.3	38.7	LC	0.55	78.66	33.76
7	1-15	32.1	7.3	6.2	54.4	Clay	0.59	77.84	63.59
7	1-15	46.1	6.3	34.4	13.1	Loamy	0.94	6348	13.37
4	15-30	39.3	7.1	21.6	31.9	LCS	0.61	75.07	42.29
10	15-30	20.5	6.6	20.1	52.6	Clay	1.22	54.06	4.33
10	1-15	16.5	4.1	14.9	64.4	Clay	0.62	76.74	30.71
2	15-30	17.3	4.2	26.5	51.9	Clay	0.98	62.98	16.68

Note : Loamy clay (LC) ; loamy clay sandy (LCS);

3.3.2 Bulk Density

The density of the dryland agricultural landscape of the Ciliwung upper watershed shows a value between 0.55-1.33 g cm^{-3}. The weight value at the point of observation of land use units was measured at every 50 cm depth. A sample depth of 1-15 cm had a bulk density of about 0.59-1.33 g cm^{-3}. A depth of 15-30 cm has a bulk density in the range of 0.55-0.98 g cm^{-3} (Table 2). The higher density of the soil can increase soil density, soil compaction could increase the specific gravity of the soil so that it will reduce the infiltration capacity of water into the soil which ultimately causes an increase in runoff and erosion (Patle et al., 2019; Silalahi et al., 2019). Different depths will result in very varied bulk density values, due to dissimilar compaction.

3.3.3 Soil Porosity

The value of soil porosity in upland agriculture in the Ciliwung upper watershed is in the range between 49.74% to 78.66% (Table 2). The porosity values in all land use units vary widely, where the lowest porosity was found in soils with clay texture with bulk density of 1.33 g cm^{-3} and low soil permeability (2.26 cm $hour^{-1}$). Based on the data, soil porosity is strongly influenced by the bulk density of the soil. Soil with a clay texture with a bulk density of > 1.2 g cm^{-3} tends to produce soil with a characteristic low pore contents. This is due to the number and mass of soil particles that fill the unit volume of soil more and become heavier, so that the pore space that should be filled with air and water, is in fact filled with solid particles of soil, especially clay.

3.3.4 Soil Permeability

The distribution of soil permeability from all land map units in upstream Ciliwung watershed agriculture at a depth of 1-50 cm has several values but all of them belong to the medium and very fast permeability class, so that the infiltration capacity of the upper

Ciliwung watershed is included in the very fast category (Table 1). Soil permeability plays an important role in infiltration capacity, where the higher the soil permeability, the faster water can enter the soil thereby reducing runoff (Human et al., 2011). The distribution of soil permeability in dryland agriculture in the upper Ciliwung watershed is in a range of moderate (2.26 cm hour^{-1}) to very fast (63.59 cm hour^{-1}).

4. Conclusion

Dryland agriculture in the Ciliwung upper watershed has several characteristics of soil physical properties including soil texture in land use units 1, 2, 3, 4, 6, 9, 10 and 11 having clay texture, soil map unit 5 LL, soil map unit 7 has a clay texture, the map unit 8 has a loamy texture. The bulk density value in eleven (11) soil map units was 0.55 g cm^{-3} to 1.33 g cm^{-3}. Soil permeability in soil map units 4 and 9 was moderate (2.26 - 4.33 cm hour^{-1}), soil map units 1, 7 and 11 have fast criteria (13.37 - 17.50 cm hour^{-1}) also land use units 2, 3, 5, 6, 8 and 10 had very fast criteria (30.26 - 63.59 cm hour^{-1}). The infiltration rate at the research site is fast. The results of soil data analysis in the laboratory showed that the physical characteristics of the soil in the Ciliwung upper watershed needed improvements in the physical properties of the soil for rainfed agriculture.

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