Soil Chemical Characteristics And Soil Fertility Status

by Silia Yuslim FALTL

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Soil Chemical Characteristics And Soil Fertility Status In Coffee Agroforestry In The Upper Ciliwung Watershed

Fitri, R.[1]; Simangunsong, N.I.[1]; Danniswari, D.[1]* and Taki, H.M.[2]

[1]*Department of Landscape Architecture, Faculty of Landscape Architecture and Environmental Technology, Universitas Trisakti, Indonesia*
[2]*Department of Urban and Regional Planning, Faculty of Lanscape Architecture and Environmental Technology, Universitas Trisakti, Indonesia*

Corresponding author: dibyanti@trisakti.ac.id

ABSTRACT

The conversion of forest land to coffee agroforestry in the Upper Ciliwung Watershed may result in accelerated leaching and impoverishment of soil quality and decreased litterfall. This study aims to analyse the status of soil chemical fertility in coffee agroforestry in the Upper Ciliwung Watershed. This research used the field survey method with a qualitative data analysis approach. The results showed that the status of soil fertility in the aspect of soil chemistry is in the medium - very high category. For the cation exchange capacity (CEC) parameter, the values were 36.02 cmol/kg (high) in Cibulao, 25.45 cmol/kg (high) in Cikoneng, 24.46 cmol/kg (medium) in Rawa Gede, and 38.85 cmol/kg (high) in Cisuren. Furthermore, the P_2O_5 parameter values were 187.8 mg/100g (very high) in Cibulao, 38.6 mg/100g (medium) in Cikoneng, 39.2 mg/100g (medium) in Rawa Gede, and 22.6 mg/100g (medium) in Cisuren. K_2O was 610.6 mg/100g (very high) in Cibulao, 87.5 mg/100g (very high) in Cikoneng, 306.9 mg/100g (very high) in Rawa Gede, and 31.1 mg/100g (medium) in Cisuren, and C-organic was 6.00% (very high) in Cibulao, 7.59% (very high) in Cikoneng, 6.39% (very high) in Rawa Gede and 17.33% (very high) in Cisuren. The findings of this study contribute to understanding the factors maintaining good soil health and fertility under coffee agroforestry in the Upper Ciliwung Watershed, while also providing a foundation for sustainable land management and ensure a productive coffee agroforestry.

Keywords: agroforestry, coffee, soil fertility, watershed

INTRODUCTION

The Ciliwung watershed is one of the priority watersheds to be restored because it supports the downstream area of Jakarta. The upstream area of the Ciliwung watershed has many coffee agroforestry practices, especially in Cibulao, Rawa Gede, Cikoneng, and Cisuren (Fitri *et al*., 2023; Fitri *et al*., 2024). Land use in the Upper Ciliwung Watershed has the potential for land degradation and decreased soil fertility. Soil as a medium for plant growth, soil is able to provide organic matter, a place for plant roots to develop, a habitat for soil flora and fauna and soil is also a place to provide nutrients and water for plants (Arsyad 2006). The need to know the status of soil fertility and the ability of soil to provide nutrients to support plant growth (Yadav *et al*., 2023). Soil fertility is the ability of soil to receive, store and distribute energy for plant growth and development. The fertility of a soil is also influenced by soil properties and slope (Jamaluddin *et al*., 2022; Rahmayanti, 2017).

Analysis of soil chemical properties can indicate the level of soil fertility in supporting plant growth (Arévalo-Gardini *et al*., 2015). It is important to assess the chemical properties and soil fertility status of land used for coffee agroforestry activities to identify constraints in the area (Martunis *et al*., 2017). The problem with coffee agroforestry is that it requires good soil management in the form of applying sufficient fertilizer to meet the nutrient needs of plants (Erlansyah *et al*., 2022; Jawang, 2021; Suleman *et al*., 2016). Diversification of land use, intensive land utilization and inadequate land use planning lead to degradation of soil properties and low soil fertility (Aji dan Arifin., 2024; Kharal *et al*., 2018). It takes a long time to improve

soil quality degraded by intensive land use (Veldkamp et al. 2020; Sena *et al*., 2021). Improper management of coffee agroforestry can lead to soil degradation and erosion (Kurniawan *et al*., 2024). Furthermore, agroforestry land in steep slope area would have more degraded soil chemical properties compared to land in gentle slope (Setyastika *et al*., 2022). Research on the assessment of soil fertility status is important in coffee agroforestry in order to know the ability of the soil to provide nutrients for the growth of coffee plants. An existing study explored the soil physical characteristics of dry agricultural lands in the Upper Ciliwung Watershed (Fitri *et al*., 2023). To the best of authors' knowledge, there is no information on the soil chemical characteristics of coffee agroforestry lands in Upper Ciliwung Watershed. Therefore, this study was conducted to analyze the status of soil chemical characteristics and soil fertility in coffee agroforestry in the Upper Ciliwung Watershed.

MATERIALS AND METHODS

This research was conducted in the Upper Ciliwung Watershed in West Java Province, the research was conducted from May to September 2023. The research was conducted using a survey method at the time of soil sampling, and the analysis of soil chemical properties was carried out in the laboratory of the Department of Soil Science, Soil and Land Resources, Faculty of Agricultural Sciences, IPB University. Soil chemical properties analyzed included cation exchange capacity, total P and K content, and organic C content. Soil samples were taken from four locations in the Upper Ciliwung Watershed, namely Cibulao, Rawa Gede, Cikoneng and Cisuren. Soil samples were collected at depths of 0 to 30 cm and 30 to 60 cm, then composited depending on depth and analyzed in the laboratory. Determination of soil fertility status based on "Technical Guidelines for Soil Fertility Assessment PPT (1995)".

RESULTS AND DISCUSSION

Soil chemical characteristics in coffee agroforestry in the Upper Ciliwung Watershed based on the results of the soil chemical properties test, the highest soil CEC value in Cisuren was 38.85 me/100g, P_2O_5 parameter value obtained 187.8 mg/100g (very high) in Cibulao, K_2O value of 610.6 mg/100g (very high) in Cibulao, 87.5 mg/100g (very high) in Cikoneng, 306.9 mg/100g (very high) in Rawa Gede. C-organic values in all coffee agroforestry locations were obtained very high at 6.00% in Cibulao, 7.59% (very high) in Cikoneng, 6.39% (very high) in Rawa Gede and 17.33% (very high) in Cisuren. The results of the analysis of soil chemical properties are presented in **Table 1**.

Table 1: Soil Chemical Properties in Coffee Agroforestry in the Upper Ciliwung Watershed

Location	CEC (cmol/kg)	P_2O_5 (mg/100g)	K_2O (mg/100g)	C-organic (%)
Cibulao	36.02	187.8	610.6	6.00
Cikoneng	25.45	39.2	87.5	7.59
Rawa Gede	24.46	38.6	306.9	6.38
Cisuren	38.85	22.5	31.1	17.33

Cation exchange capacity (CEC)

One of the soil chemical properties that is closely related to the availability of nutrients for plants is cation exchange capacity, the value of cation exchange capacity is an indicator of soil fertility. Cation exchange capacity on coffee agroforestry land in the Upper Ciliwung Watershed based on the results of laboratory analysis obtained CEC values that vary in all locations. The highest CEC value is found in coffee agroforestry in Cisuren which is 38.85 cmol/kg which is included in the high class. The lowest CEC value was found in coffee agoroforestry in Rawa Gede at 24.46 cmol/kg.

Cation exchange capacity is the ability of soil colloids to absorb and exchange cations. A study found that the CEC level of rubber agroforestry land in North Sumatera is low (Muhdi *et al*., 2023). Despite having the same land use as agroforestry land, the study area in Upper Ciliwung Watershed, West Java, has higher CEC value than in North Sumatera. The predominant soil type in Upper Ciliwung Hulu Watershed, West Java, is Inceptisol (latosol) (Fitri, 2020), and latosol soil type tend to be clayey or have high clay content (Rochrs *et al*., 2020). Meanwhile, the predominant soil type in North Sumatera is Litosol (Bappeda Sumatera Utara, 2013), and Litosol type is usually sandy (Sari, 2021).

The CEC value is strongly influenced by the type of clay, clay content, soil texture, and organic matter content contained in the soil. (Putri *et al*., 2019; Yunanto *et al*., 2022). Soil with higher clay content tend to have higher CEC (Sufardi *et al*., 2020). This shows that CEC is not influenced by the agroforestry type of land use but rather influenced by soil type and clay content.

P_2O_5

P_2O_5 parameters based on the results of laboratory analysis contained in coffee agroforestry in the class obtained very high to moderate. A significantly high P_2O_5 values was found in Cibulao at 187.8 mg/100g, while other locations show medium values ranging from 22.6 mg/100g to 39.2 mg/100g, and the lowest was in Cisuren. Phosphorus level often become the limiting factor for many crop productions because P quantity is generally small in natural ecosystems (Pradhan *et al*., 2020). The high value of P_2O_5 is likely by intensive fertilizer application and long planting of coffee agroforestry while at the Cisuren location the low P_2O_5 value is caused by the washing process.

High concentrations of P elements are generally found on land with gentle slopes, this is due to the leaching process from steep slopes that are deposited on gentle slopes (Jakšić *et al*., 2021). The type of agroforestry significantly influences the concentration of P_2O_5 in soil, and robusta coffee agroforestry tends to have the highest P_2O_5 level compared to other agroforestry systems, including arabica coffee, cinnamon, rubber, chili, and ginger (Rahmawati, 2001). This is aligned with the findings of this study because Cibulao, the location with highest P_2O_5, is the only location planted with robusta coffee, while other locations are planted with arabica coffee (Fitri *et al*., 2024).

K_2O

The results of K_2O data analysis based on laboratory tests obtained at the research location are very high and medium. The K_2O value in three coffee agroforestry locations in the Upper Ciliwung Watershed is very high including Cibulao at 610.6 mg/100g (very high), in Cikoneng at 87.5 mg/100g (very high), Rawa Gede at 306.9 mg/100g (very high), and K_2O value of 31.1 mg/100g (medium) in Cisuren.

The total K content in soil is influenced by several factors, such as soil colloid type, wet-dry conditions, soil pH and weathering rate (Suarjana *et al*., 2015). Existing studies revealed that, in agroforestry systems, higher K_2O tends to be found near tree rows or under the native/shade tree canopies (Fahad *et al*., 2022; Gota *et al*., 2024). The sampling point location during the data collection might influence the K_2O values. Other than that, the high K concentration in the study area is likely due to fertilization and agricultural land processing by coffee farmers.

C-Organic

C-organic values in coffee agroforestry in the Upper Ciliwung Watershed ranged from 6.00% -17.33%. The highest soil C-organic value was found in coffee agroforestry in Cisuren with a value of 17.33%. Agroforestry systems tend to have higher C-organic content compared to

monoculture cropping systems (Setyastika *et al*., 2022). Compared to crop monocultures, agroforestry increased C-organic by 40% (Muchane *et al*., 2020). High C-organic is thought to be influenced by the vegetation that grows on it, the greater number of trees will also increase the C-organic value (Gunawan *et al*., 2018; Bahnemiri *et al*., 2019).

According to a previous study (Fitri *et al*., 2024), the dominant shade tree in coffee agroforestry of Cisuren is *Pinus merkusii* (pine). Pine trees produce high litter, leaving a thick layer of litter under the tree stands, especially when they are old (Imanuddin *et al*., 2020). C-organic content is high because there are many dead and fallen plant debris (litterfall) in various stages of decomposition, and accumulate on the forest floor, thus affecting the high C-organic content of the coffee agroforestry land.

Soil fertility status

Soil fertility is an important factor determining crop productivity, the condition of the physical, chemical and biological properties of the soil greatly affects the availability of nutrients for plant growth. Soil chemical fertility status includes soil CEC, total K content, organic matter content, and available P. The results of soil analysis are then linked to the criteria for assessing the fertility status of soil chemical properties, indicating that the status of soil chemical fertility in coffee agroforestry in the Upper Ciliwung Watershed is classified as high. (**Table 2**).

Table 2: Results of Soil Fertility Status Analysis on Coffee Agroforestry in the Upper Ciliwung Watershed

Location	CEC (cmol/kg)	P_2O_5 (mg/100g)	K_2O (mg/100g)	C-organic (%)	Fertility status
Cibulao	36.02	187.8	610.6	6.00	High
Cikoneng	25.45	39.2	87.5	7.59	High
Rawa Gede	24.46	38.6	306.9	6.38	High
Cisuren	38.85	22.5	31.1	17.33	High

The resulting high soil fertility status of coffee agroforestry in the Upper Ciliwung Watershed indicates a good balance of soil nutrients. High soil fertility status is thought to be due to plant roots in coffee agroforestry being able to effectively absorb nutrients needed for vegetative growth and generative development of plants. Agroforestry practices can also improve soil fertility through enrichment of organic matter, tree vegetation, and soil microbial activity. (Dollinger and Jose, 2018). The level of soil fertility is high in coffee agroforestry in the Upper Ciliwung Watershed. This is likely to the combination of trees, legumes and annual crops so as to increase the amount of litter that falls from the trees. Complex agroforestry systems with a high number of tree species and individuals can improve soil physical properties (Bahuguna *et al*., 2018; Bahnemiri *et al*., 2019). Nutrient sources are enriched from a balanced biomass input and output system. The largest biomass production from plant debris left in agroforestry systems contributes to nutrient and organic carbon stocks. In general, agroforestry improves soil health and fertility (Muchane *et al*., 2020).

Agroforestry can revitalize degraded lands by improving nutrient recycling and soil fertility. Trees in these systems draw nutrients from deeper soil layers, increase N fixation, and produce litters that enrich the soil as they decompose (Sileshi *et al*., 2020). In coffee production, higher CEC and C-organic contribute to larger beans, meanwhile higher available P and K contribute to smaller beans (Yadessa *et al*., 2020). To gain a deeper understanding of how soil fertility impacts coffee production, further research about the relationship between soil health and coffee yields is encouraged.

CONCLUSION

The quality of soil chemical properties at the Cibulao, Rawa Gede, Cikoneng and Cisuren research sites is different. Despite the differences, overall soil fertility status in highly fertile. The vegetation composition, plant canopy density and the amount of litter influence the chemical properties of soil including cation exchange capacity, total K content, organic matter content, and available P. The results emphasize the importance of site-specific soil management practices in coffee agroforestry within the Upper Ciliwung Watershed. Soil fertility can be enhanced through strategies that promote vegetation diversity, canopy cover, and litter retention. A long-term study to monitor changes in soil chemical properties and fertility under different management practices is encouraged to deepen our understanding of soil dynamics in coffee agroforestry.

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PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6