Soil Chemical Status Under Natural Forest, Coffee Agroforestry and Coffee Monoculture at Air Hitam Subdistrict, West Lampung, Indonesia

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Abstract. The chemical status of soil is a crucial aspect of soil health and plays a vital role in determining plant growth and productivity. However, the change in land use from forest to coffee plantation can influence the soil's chemical condition. One strategy to improve soil condition is agroforestry. Despite the growing interest in coffee agroforestry systems as a sustainable alternative to coffee monoculture, there is limited research on their effects on soil chemical status in Indonesia. Air Hitam Subdistrict in West Lampung, Indonesia, is an important coffee-growing region where both agroforestry and coffee monoculture systems are practiced. This study aims to compare the soil chemical status of natural forest, coffee agroforestry, and coffee monoculture systems in Air Hitam Subdistrict. It particularly focuses on key macronutrients such as nitrogen, phosphorus, and potassium, as well as secondary macronutrients like calcium and magnesium, and trace elements such as sodium. The results show that soil organic carbon (SOC), N-Total, K, Ca, and Mg concentrations are higher in the natural forest than in coffee agroforestry, and higher in coffee agroforestry compared to coffee monoculture. However, the available phosphorus (P) concentration is higher in coffee monoculture due to the application of chemical fertilizers. This research reveals that coffee agroforestry can improve soil condition.

1 Introduction

Coffee is one of the leading plantation commodities in Indonesia, making it the fourth-largest coffee-producing country in the world [1]. In 2022, Lampung Province was second rank second coffee production, with a total of 113,739 tons with a land area of 155,166 hectares [2]. One of the coffee producing districts in Lampung Province is West Lampung Regency.

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Coffee cultivation in West Lampung is generally carried out as a monoculture and has been ongoing for decades. According to a study by Zhao et al. [3], long-term monoculture can reduce pH, soil organic matter content, and microorganism diversity. Li et al. [4] also explained that coffee cultivation using a monoculture system showed poor growth, low yields, and was susceptible to coffee plant diseases. In sustainable agricultural practices, improving soil quality is crucial, where the land planted can support long-term coffee cultivation and provide a stable harvest yield. However, with a monoculture system having a negative impact on soil conditions, other alternatives are needed, one of which is an agroforestry system.

Agroforestry is a land-use system that involves the intentional integration of trees, shrubs, and other woody perennials with agricultural crops and/or animals. According to research by Dollinger and Jose [5], agroforestry systems can enrich the soil with organic carbon more effectively than monoculture systems. This improvement enhances soil nutrient availability and fertility due to the presence of trees in the system, consequently increasing soil microbial dynamics and positively impacting soil health.

In West Lampung Regency, although coffee cultivation is predominantly carried out in monoculture, there are several farmers who have access to community forests and implement a coffee agroforestry cultivation system. However, there is still limited evidence regarding the impact of coffee agroforestry on soil conditions in West Lampung Regency, especially in Air Hitam Sub-District. Therefore, the aim of this research is to investigate the status of soil chemical content in natural forests, coffee agroforestry, and coffee monoculture. It is hoped that the results of this research can serve as basic data for policies related to coffee plantations in West Lampung Regency.

2 Methods

The research was conducted from October to November 2020 at Rigis Jaya Village, Air Hitam subdistrict, West Lampung, Lampung Province, Indonesia.

<table>
<thead>
<tr>
<th>Location</th>
<th>Vegetation type</th>
<th>Coordinate</th>
<th>Elevation (m a.s.l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location 1</td>
<td>Natural forest</td>
<td>S 05°03’45.8” N</td>
<td>988</td>
</tr>
<tr>
<td></td>
<td></td>
<td>E 104°27’28.3” E</td>
<td></td>
</tr>
<tr>
<td>Location 2</td>
<td>Coffee agroforestry</td>
<td>S 05°03’51.6” N</td>
<td>966</td>
</tr>
<tr>
<td></td>
<td></td>
<td>E 104°27’23.7” E</td>
<td></td>
</tr>
<tr>
<td>Location 3</td>
<td>Coffee monoculture</td>
<td>S 05°04’06.3” N</td>
<td>938</td>
</tr>
<tr>
<td></td>
<td></td>
<td>E 104°27’18.7” E</td>
<td></td>
</tr>
</tbody>
</table>

Soil samples were collected from three distinct vegetation types. (natural forest, coffee agroforestry, coffee monoculture). Soil samples were collected at depths of 0-10 and 10-20 centimeters. In one vegetation type, soil was taken from three different points to represent the location, and the soil was then mixed or composited. The soil sample was taken to the soil science laboratory at the University of Lampung for further analysis.

The chemical properties of the soil were observed: the organic soil organic carbon (SOC) content was determined by the Walkley and Black method, the soil total nitrogen (STN) content was determined using the Kjeldahl method, the soil C/N relationship was calculated, the P content was determined using the P Bray-1 method, and the K, Na, Ca, and Mg content was determined using extraction with ammonium acetate 1 N pH 7 and a reading by Atomic Absorption Spectrofotometry. (AAS). The laboratory analysis findings were then descriptively analyzed, and the parameters in various vegetation types were compared.
3 Results and Discussion

The research results indicate variations in the observed parameters. The highest soil organic content at a depth of 0-10 cm was found in natural forest soil at 3.51%, while the lowest was found in coffee monoculture at 2.19%. Although at a depth of 10-20 cm, the soil organic content in natural forests is the lowest, the accumulation is still the highest compared to coffee agroforestry and coffee monoculture. In terms of total nitrogen content, natural forests have higher total nitrogen than agroforestry and monoculture, and coffee agroforestry has a higher total nitrogen content than coffee monoculture.

Fig. 1. Soil organic carbon under different vegetation
Fig. 2. N-total carbon under different vegetation
Fig. 3. C/N ratio under different vegetation
Fig. 4. Available K under different vegetation
Fig. 5. Available Ca under different vegetation
Fig. 6. Available Mg under different vegetation
A similar pattern is found in K-available, where natural forests have the highest K-available content, and K-available in coffee agroforestry is higher than in coffee monoculture. The C/N ratio shows an inverse pattern compared to soil organic carbon, with the highest C/N obtained in monoculture. This is because the organic carbon in coffee monoculture is the lowest.

The content of available Ca, available Mg, and available Na shows a non-uniform pattern in soil samples at a depth of 0-10 or 10-20 cm. However, when accumulated (0-20 cm), the highest content is found in natural forests, followed by coffee agroforestry, and the lowest in coffee monoculture. In contrast to other parameters, the highest available P content is found in coffee monoculture, followed by natural forests, and the lowest is found in coffee agroforests. The high P content in coffee monoculture is thought to be caused by the application of synthetic fertilizer by farmers.

Soil organic matter (SOM) refers to the amount of organic matter in the soil, including plant and animal remains. Coffee agroforestry systems, where coffee plants coexist with trees and other plants, are known to have higher levels of SOM than coffee monoculture systems, which exclusively cultivate coffee plants. The reason for this distinction lies in the management of the coffee agroforestry system. The presence of trees and other plants contributes organic waste to the system, enhancing the amount of organic matter entering the soil. Research by Wardani et al. [6] shows that there is a very high soil organic matter content, namely more than 5% in agroforestry systems. The large soil organic matter content in the coffee agroforestry system is caused by land management in the form of not cleaning up litter and damaging the topsoil. Organic matter will accumulate due to the waste decomposition process, so it can play an important role in improving soil quality and will increase soil productivity in the long term.

The reason that N, K, Ca, Mg, and Na in coffee agroforestry are higher than in coffee monoculture may be attributed to a greater diversity of plant species, higher organic matter content, and reduced leaching. Increased levels of soil organic matter, as it decomposes, can release N, K, Ca, Mg, and Na. This phenomenon contributes to higher levels of these elements in the soil. Nutrient elements produced by coffee plants from the agroforestry system, such as N and K, are derived from the large amount of litter generated by coffee agroforestry system [7]. Research conducted by Nataro et al. [8] showed that the Ca content in litter from agroforestry land was quite high. This result reveal that agroforestry system gives good impact for the soil.

### 4 Conclusion

The conclusion of this research is that the chemical content (soil organic carbon, N, K, Ca, Mg, Na) in natural forest soil is higher than in coffee agroforestry and lowest in coffee monoculture.
monoculture. This finding indicates that agroforestry has better soil conditions compared to coffee monoculture. Furthermore, coffee agroforestry can be employed to enhance soil quality.

References