Initial soil properties of the restored degraded area under different vegetation cover in UB Forest, East Java, Indonesia

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Abstract. Forest ecosystem degradation due to conversion into agricultural land is increasingly widespread in tropics. This study aimed to determine the initial properties of forest soils in some restoration areas under different vegetation cover. The restoration sites were divided into three areas, namely intensive agricultural land (PI), abandoned coffee plantation (KTT), and remnant protected forest (HLS). In each restoration area, soil samples were taken at top 20 cm depth of soil from five sampling points with three replications. As a comparison, soils were also sampled from the reference sites (RS). Soil samples were then analyzed for some soil properties in the laboratory such as soil physical properties (soil aggregate, bulk density, soil moisture), soil chemical properties (organic matter, pH, electrical conductivity), and soil biological properties (soil bacteria). Results showed that soil physical and chemical properties measured in restoration areas were significantly different from RS (p<0.05). Soil physics properties among three restoration areas were not statistically different (p>0.05), but the soil chemical properties were statistically different. This soil chemical difference was presumably caused by spatial variation and vegetation cover. The diversity of soil bacteria in all studied areas was not statistically different (p>0.05) even though the environmental conditions in each area were different. Among soil properties showed interactions that affected each other based on multivariate data analysis. Forest conversion into agricultural land use had a negative impact on soil properties and tends to decrease soil quality and health.

1. Introduction
Forest degradation in the tropics due to illegal logging, forest conversion, and deforestation are increasingly widespread [1]. Forests conversion into intensive agricultural or other land-use change is a major factor that causes deforestation in developing countries, including Indonesia. Forest degradation disrupts stability, biodiversity loss, and ecosystem services in a natural environment [2, 3]. Changes in forest vegetation have an impact on wildlife, canopy cover, litter input, and soil conditions. Soil is a central part that plays a vital role in the biogeochemical cycle in forest ecosystems. Forest soils function as carbon storage, a source of nutrients for plant growth, water regulation, and habitat for microscopic organisms [4, 5, 6]. Forest degradation also negatively impact on the deterioration of soil quality and health.

Soils are the main object in the rehabilitation of degraded forests by restoration activities. Forest restoration becomes an important effort to improve the structure and function of the forest ecosystem.
through tree planting. By planting trees seedlings, the succession of degraded forests is expected to be accelerated rather than on natural process [7]. Along with the growth of the restoration plant, the tree canopy is also formed so that it can affect the below-ground properties. During the restoration period, the structure and characteristics of the soil also gradually change [8]. Changes in temperature, water infiltration, litter input, and the complexity of plant root systems are some conditions that occur in forest soils. This condition certainly not only causes alterations in one soil characteristic but also in other properties such as physics, chemistry, and biology. Thus, soil can be a crucial indicator in the process of restoring degraded land [9].

UB Forest (UBF), 544 ha, is a forest area with a specific purpose for education and research. The Indonesia Ministry of Environment and Forestry had delivered a mandate to the Universitas Brawijaya (UB) to manage the area since 2015. The UBF protected area is an example of a disturbed lower mountainous forest ecosystem due to uncontrolled and improper intensive agricultural activities. The UBF protected area should be protected against intensive agricultural activities because this area plays an important role in soil and water conservation, especially due to its location is on steep slopes or in the riparian area. In addition, this area also provides a natural habitat, food source, and corridor or shelter for wildlife, especially migratory birds. Recovery of protected area in UBF by restoration activities has continued establishing since 2017 by using local plants. However, monitoring and evaluation of restoration success were still limited to the growth of seedling. Therefore, based on this reason, the study of initial soil properties of the restored area of the UBF is very important. This initial information might improve the database for periodically monitoring of restoration success in the area.

2. Methods
2.1. Study area
This research was conducted in the UB Forest (UBF) area, an education forest, located in Karangploso District, Malang Regency, East Java, Indonesia (figure 1). The UBF area was located on the southern slope of Mount Arjuna (3.339 m asl) with altitudes ranging from 900 – 1.300 m asl, with an average annual air temperature of 22 °C. The research area is a degraded protected lower mountainous forest and had been largely converted into agricultural land and coffee plantations. This protected area had a slope of 40-45% with a temporary stream at the base. The study area was divided into three stations based on vegetation profile, namely intensive agricultural land (PI), abandoned coffee plantations (KTT), and remnant protected forest (HLS). The PI area was a protected forest but already converted into an area of annual crops such as carrots, greens, mustard, and coriander. Meanwhile, the KTT was protected forest area that converted and planted into a coffee plantation (Coffee arabica), aged 5-7 years with two meters in plant spacing, and an average height of 1.8-2.0 m. Forest tree stands were very scarcely found in this area, such as trete (Microcos tomentosus), bulu (Ficus drupacea) with diameter >90 cm and height of 20-30 m. The HLS area was very degraded protected forest and dominated by alang-alang (Imperata cylindrica), and there were other trees such as trete (M. tomentosus), gamal (Gliricidia sepium), pine (Pinus merkusii), avocado (Persea americana), and jackfruit (Artocarpus heterophyllus). A well conserved protected area of UBF was chosen as the reference site (RS) in this study. The condition of RS was secondary natural forest with various forest tree stands such as Ficus sp., Saurariaceae, gintungan (Bischofia javanica), trete (M. tomentosus), pasang (Lithocarpus sp.), etc with high vegetation diversity inside and close canopy cover.

2.2. Soil sampling
The soil was compositely sampled at 0 – 20 cm depth of soil from five sampling points, by using three replications in each study area. As a comparison, soil sampling was also carried out in a better-secondary forest of UBF protected areas applied as a reference site (RS). Soil properties observed in this study included soil physics (aggregate, bulk density, moisture), soil chemistry (organic matter, pH, electrical conductivity), and soil biology (soil bacteria). Soil aggregate was measured using wet sieving method, whereas soil bulk density and soil moisture were determined by soil core and oven drying (gravimetric) methods. Then, soil organic C was measured with Walkley and Black method. Soil pH and electrical conductivity were measured using portable tools, which had been calibrated and standardized in the laboratory. Soil bacteria were firstly isolated and then grown on a nutrient agar media for 24 hours.
incubation at room temperature. Bacterial colonies from soil samples were calculated using the total plate count (TPC) method.

2.3. Data analysis
All data obtained were analyzed statistically to find out whether or not the differences between study sites. Univariate statistical analysis was performed using R software version 3.6.2, and graphics were prepared using MS Office Excel 2016. While the descriptive multivariate analysis was conducted by cluster and principal component analysis (PCA) using open source PAST 3.26.

![Figure 1. Location of study site in UB Forest, southern slope of Mt. Arjuna.](image)

3. Results and discussion
Soil physics properties in the restoration area (PI, KTT, HLS) tent to be similar but its were lower compared to the reference site (RS). Soil aggregates stability did not differ at all study sites. Soil stability in these areas was classified as very stable (3-4 mm in average soil particle diameter size) (figure 2A). It seemed that the condition of the soil able to withstand the potential damage to soil structures, such as wind and water. However, even though the stability of the aggregates was relatively good, however improper and intensive soil management caused changes in the soil character [10]. Therefore, it showed great potential for erosion and landslides occurred during the rainy season, especially in the PI area. Excellent soil aggregate stability affects the ability of water infiltration, growth of plant roots, and soil biological activity. Therefore, aggregate stability is an essential indicator for evaluating soil quality [8].

Soil bulk density in the three restoration areas was similar, but its were significantly higher ($p<0.05$) compared to RS (figure 2B). Even though the soil bulk density in the restoration area was relatively low (<1 g.cm$^{-3}$), but especially the soil in the PI area was compacted by improper tillage. This low soil bulk density is a characteristic of the soils formed from volcanic ash [4]. The higher soil bulk density in the
PI than RS area is partially affected by soil organic matter (SOM), supported by the higher SOM in the RS as compared to the PI. Compact soil has a negative impact on root growth, low aeration, and porosity, and inhibited water circulation, so it affects the plant growth above the soil surface [10, 11].

![Figure 2](image_url)

**Figure 2.** Soil physical properties in each restoration area compare to the reference site (RS). PI = intensive agricultural land, KTT = abandoned coffee plantations, HLS = and remnant protected forest, RS = reference site.

The presence of vegetation cover affected soil moisture, and this could be shown in this study. Soil moisture in the three restoration areas was lower and significantly different (p <0.05) from RS (figure 2C). PI area showed the lowest soil moisture compared to other locations. It was mainly due to the absence of vegetation cover in the area. At the time of soil sampling, the PI area had just been cleared and cultivated by local farmers so that it appeared to be open, and only a small portion had been planted with annual crops. It was different from the conditions in the KTT, HLS, and RS areas. In these areas, there were still covered by vegetation composed either trees or shrubs. The presence of vegetation can maintain the availability of water in the soil so that it remains sufficient for plant growth during the dry season. The other effect of vegetation cover to soil moisture is through formation of soil pore by root. Since soil water place in soil pore, the high vegetation cover will be followed by the high rooting system resulted in increase soil pore and soil water content. Research conducted by Wang et al. stated that soil water availability was influenced by the presence and type of vegetation cover. Variation of vegetation cover caused differences in the pattern of water interception, stemflow, and root-soil characteristics [12]. Plant canopy was useful to reduce direct sunlight on the soil surface and avoid excessive evaporation. The lower soil moisture in PI as compared to RS may also related to the lower SOM in the PI site than RS (figure 3). SOM play an important role in soil moisture due to the SOM has higher surface area than clay as consequently it can hold and maintain a large of water in the soil.
In general, the soil chemical properties in the three restoration areas were significantly different from the RS (p<0.05). High soil organic matter was observed in the KTT and RS areas, while the PI area soils showed the lowest (figure 3A). The soil organic matter is influenced by falling litter and dead root from aboveground vegetation, such as trees, shrubs, and herbs, as the primary source of organic material in forest ecosystems. Forest conversion into intensive agricultural land can be the main factor of decreasing low soil organic content in the PI area. The results of this study were in line with other studies by Guimaraes et al. in Brazil, which informed that the conversion of forests into agricultural land caused changes in the fraction C of organic material and reduced soil fertility [13]. Changes in vegetation also have an impact on litter decomposition, which can not run optimally in the soils because of microclimate alteration.

![Figure 3A](image1.png)

![Figure 3B](image2.png)

![Figure 3C](image3.png)

**Figure 3.** Soil chemical properties in each restoration area compare to the reference site (RS).

Besides soil organic matter, indicators of soil fertility can be identified from soil pH. The three restoration areas showed soil pH values ranging from 5.8 - 6.2 and were classified as slightly acidic soil (figure 3B). This value was lower than the RS area. A low soil pH was assumed to be due to disturbed litter decomposition or the application of synthetic fertilizer. On the contrary, if the litter decomposition takes place normally (without any disturbances), such as in the RS area, the soil pH tent to be neutral (7.0). The neutral pH indicates that soil fertility is excellent, so it is valuable for plant growth. Changes in pH significantly may affect alterations in environmental chemistry and soil biological processes [14]. Therefore, small changes in the pH (increase or decrease) might a severe impact, especially on the soil's biological processes.

Along with pH, the soil electrical conductivity (EC) can be an indicator of soil health. The soil EC reflects the ability of the soil to conduct electrical current as an indication of the availability of nutrients. The RS area showed a higher EC value than the KTT and HLS areas but still lower than the PI area. The PI area showed the highest EC (figure 3C). The high EC value in the PI area was presumably caused by...
the application of inorganic fertilizer by farmers during crop cultivation. The application of inorganic fertilizer is possible to increase the soil EC because it contributes to nutrients improvement (anions and cations) and increases soil fertility.

Observations of soil bacterial populations based on calculations with the TPC method showed that the HLS area significantly showed the highest number of bacterial populations \((2.37 \times 10^5 \text{ cfu.g}^{-1})\), while PI had the lowest \((0.93 \times 10^5 \text{ cfu.g}^{-1})\) (figure 4A). However, a high number of bacterial populations were not always followed by soil bacteria diversity. The highest bacterial diversity was found in the KTT and RS area, with a closed correlation to vegetation cover conditions (figure 4B, 5). We assumed, one or two particular taxa were dominant there. Bacterial population and diversity were most common in soils that were not subject to many disturbances and had a lot of vegetation covers, such as at KTT, HLS, and RS areas. Rodrigues et al., in their research results, reported that forest conversion into agricultural land had an impact on soil bacteria diversity loss [15]. The existence of vegetation able to create optimal environmental conditions for the growth and metabolism of soil bacteria, and it is related to the decomposition of organic material. Thus, the characteristics of soil physics, chemistry, and biology in this study affect and closely related to each other (figure 5).

**Figure 4.** Soil biology properties based on bacteria community in each restoration plots compared to the reference site (RS).

**Figure 5.** Interaction between physical, chemical, and biological properties of the soil from each studied area based on principal component analysis (PCA) (A) and clustering (B). Notes: SoilAggr: soil aggregate; SoilBulkDensity: soil bulk density; SoilMoist: soil moisture; SOM: soil organic matter; SoilpH: soil pH; SoilEC: soil electrical conductivity; SoilBactPop: soil bacteria population; SoilBactDiv: soil bacteria diversity; PlantCover: vegetation cover on the soil surface.
Forest conversion into agricultural land or monoculture plantations showed a negative impact on soil properties. A study conducted by Liao et al. provided information that forest conversion reduced the quality and fertility of the soils in various regions [16]. Thus, the development of monoculture plantations was not recommended if the recovery was aimed at the sustainability of the forest ecosystem. Information about the initial condition of the soil in the restored forest area is necessary for determining the success of a long-term restoration program. Monitoring can be carried out periodically by using soil parameters as one of the indicators. Changes in vegetation, which initially did not exist into being or small in number, might be expected to contribute to improving the quality and health of degraded forest soils.

4. Conclusions
Prior soil condition in the restored forest area was different from the well-conserved forest. PI area had the lowest in soil quality, while the KTT and HLS tend to be equal but remains lower than the reference site (RS). Poor soil quality in the PI area was thought to be due to the impact of forest conversion and improper soil management. The existence of aboveground vegetation showed a vital role in the various process at the forest floor that affected plant growth and soil quality improvement.

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