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The sloping agricultural land management on buffer zone of Bromo Tengger Semeru National Park in Malang Regency

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Abstract. The land management in the buffer zone of the protected area has been considered important to support biodiversity in the conservational area. Many areas in the buffer zone of Bromo Tengger Semeru National Park (BTSNP) in Malang Regency, Indonesia, have been threatened by improper agricultural activity. The objective of this study was to examine the profiles of soil quality and biodiversity of several sloping agricultural land management in the buffer zone. The assessment of soil quality (pH and C Organic) and biodiversity of trees, shrubs, and herbs were done in the five land use type i.e. bare land, monoculture of chili, pine-coffee, pine-taro, and coffee agroforestry. The data were analyzed using the principal component analysis. The results showed that agroforestry with coffee as the main crop was the most appropriate land management model for biodiversity, carbon storage, sustainable agroforestry, and production profit stability.

1. Introduction

Bromo Tengger Semeru National Park (BTSNP) has high biodiversity and is the most diverse highland region in East Java Province, Indonesia, with a total area of about 50,276.3 ha. BTSNP has a sub-montana, montana and sub-alpine ecosystem with vegetation such as pine mountain, jamuju, edelweiss, and various types of small orchids. In addition, there also endemic animals, such as long-tailed macaques (*Macaca fascicularis*), deer (*Muntiacus muntjak*), red jungle fowl (*Gallus gallus*), leopard (*Panthera pardus* Melas), ajag (*Cuon alpinus javanicus*); and various bird species. The great number of flora fauna and geological phenomena has reflected the importance of biodiversity conservation [1]. Areas that play the major role to protected conserved areas from the settlement that depend on the forest product are buffer zones [2].

The conservation and optimization of buffer zones have been endangered by farmland expansion. The biodiversity of the BTSNP is fast degraded by years because of community activity around [3]. As for environmental issues, for example, the excavation of sand in the rivers and improper cultivation on the sloppy land, such as apple, chili, maize, cassava, has made frequent landslides in the sloppy land. Erosion and sedimentation threaten the sustainability of the function of water resources that many found in this area as well [4]. This land degradation going to be the decrease in quality of the catchment area, the environmental carrying capacity and biodiversity of the buffer zone [3].



The government has been issued some policy to counter this problem by the Regulation of the Minister of Forestry about forest and land rehabilitation. Some effort has been made to restore, maintain and improve forest and land functions, capacity, productive and role in supporting integrated life. As the application, they suggest farmer to apply agroforestry, an intensified land use system with a combination planting of woody plants, fruits, livestock or seasonal crops. It will provide some choice for farmers to considerate the place of growth, economic factors, and others. Agroforestry can enhance four major ecosystem services and environmental benefits: carbon sequestration, biodiversity conservation, soil enrichment and air and water quality [5]. For positively, the farmer had shown their effort to apply agroforestry in the buffer zone, but nevertheless, many had still unsuccessful in applying agroforestry [3]. The objective of study was to investigate the sloping land management in the BTSNP buffer zone based on soil quality and biodiversity profiles.

2. Materials and Methods

2.1. Study area

The study was conducted at Jajang, Sumberejo Village, Poncokusumo, Malang Regency, East Java, Indonesia (Figure 1). Mountain area with an altitude of 1000-1200 meters above sea level with average rainfall between 2300-2500 mm per year and an average temperature of 21.7°C. Most of the villagers work as farmers, while the others traders, civil servants, soldier, and others. Main cultivate commodities are apples and coffee.

The study area was selected based on differences in the main cultivar which the land categorized as a sloping land ranged between 30-45% or equivalent to 20-25°. They were 5 stations, with 2 spots in each station, respectively pine-coffee agroforestry (PC) (S 8.08585 E 112.82603) & (S 8.08567 E 112.82584), pine-taro agroforestry (PT) (S 8.08537 E 112.82769) & (S 8.08519 E 112.82785), monoculture chilli (MC) (S 8.08349 E 112.82935) & (S 8.08356 E 112.82963), bare land (BL) (S 8.08265 E 112.83538) & (S 8.08268 E 112.83543), and coffee agroforestry (CA) (S 8.08272 E 112.83571) & (S 8.08254 E 112.83581).



Figure 1. Map of sampling sites at Jajang, Sumberejo Village, Poncokusumo, Malang Regency.

2.2. Methods

The field observation held to find out the ecological conditions of the land profiles on biodiversity and soil quality. The interview also held with the land users using semi-structured questions to gain secondary data. Interviews were conducted separately, so as not to affect each other. Tools used in this research were a cutter, sampling plastic, rope, length meter, stationary, compass, hoe, and GPS.

2.2.1. Biodiversity

Biodiversity assessed by vegetation analysis. Data collection used 1x1 m plot method for herbs, 5x5 m for shrubs, and 20x20 m for trees. The biodiversity was calculated using Shannon Wiener index, Equation 1, respectively if $H' < 1.0$ means low diversity; $1.0 < H' < 3.322$ means medium diversity; $H' > 3.322$ means high diversity.

$$H' = \sum p_i \ln p_i \quad (1)$$

The entire vegetation data obtained from each group were calculated using Equation 2, 3, and 4 to identify the absolute species density value (KM), absolute species frequency value (FM), relative density (KR) (%), relative frequency (FR) (%), dominance (DR) (%) and the Importance Value Index (IVI) of each vegetation type. Tree and shrubs become one group and herbs in separated group analysis because the cultivation still enrolls for ten years.

$$KR(i) = (KM(i) / \sum KM) \times 100\% \quad (2)$$

$$FR(i) = (FM(i) / \sum FM) \times 100\% \quad (3)$$

$$IVI(i) = KR(i) + FR(i) + DR(i) \quad (4)$$

2.2.2. Soil quality

Soil quality tests include physical, chemical and biological parameters. Physical parameters included soil temperature that measured on site. Chemical parameters are soil pH meters and soil organic carbon stocks. In each plot, soil samples were collected from two randomly selected sample locations with depths of 30 cm. After collection, soil samples were transported to the laboratory, remove stones and root fragments, and air dried. Soil pH was measured as pH/H₂O by a pH meter in a suspension soil sample. Soil pH ranges as strongly acidic (pH 5.1–5.5) and moderately acidic (pH 5.6–6.0). For soil carbon concentrations, samples weighed 1 gram were oven-dried at 105° C, and after cold, the samples were weight measured again. The value of organic carbon <1 classifies as very low, 1 - 2 low, 2 - 3 medium, 3-5 high, > 5 very high. Biological parameters are vegetation analysis and earthworm (Annelida) as an indicator of soil fertility [6]. Identifications were directly on the sites and the unknown herbarium samples identified in the laboratory.

3. Result and Discussion

3.1. Vegetation analysis result

Based on the Shannon-Wiener Diversity Index (H') on different sites of agriculture land management in the BTSNP buffer zone (Table 1), the highest diversity index was in coffee agroforestry that categorized as medium diversity, so did was H' herbs in pine agroforestry. Meanwhile, the monoculture chili land had the lowest index of diversity. The H' valued zero means only planted with one kind of plant. The advantages of agroforestry systems were diverse plants can be chosen as the owner wishes [5].

Table 1. The Shannon-Wiener diversity index (H').

Sites	H'	
	Trees & shrubs	Herbs
Bare Land	0	0.867425
Coffee Agroforestry	2.067938	2.947116
Pine-Taro Agroforestry	0	1.459148
Pine-Coffee Agroforestry	0.991076	1.491115
Monoculture-Chilli	0	0

The result of the Importance Value Index (IVI) in trees and shrubs (Figure 2) found that there was only one tree on bare land (BL), at the pine taro intercropping site (PT) only dominated by pine, and at the pine-coffee intercropping site (PC) coffee and coffee was equal. Whereas, in the coffee agroforestry (CA) site mostly dominated by coffee, but there were also other trees, such as dadap (*Erythrina variegata*), banana (*Musa paradisiaca*), lamtoro (*Leucaena leucocephala*), and avocado (*Persea americana*). The IVI of monoculture chili site (MC) can't be shown, because there is no tree or shrubs. Even though growing trees on sloping land can reduce surface runoff and erosion rates [7].

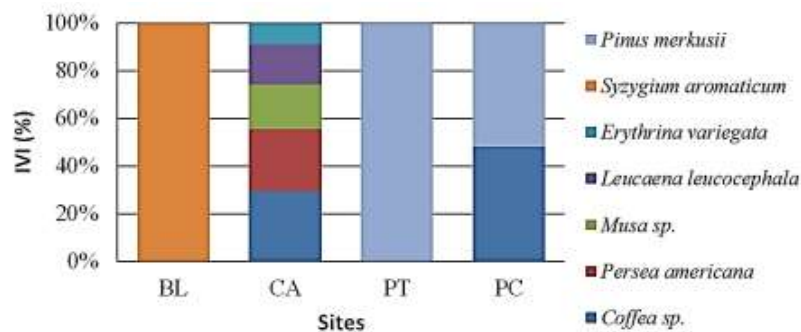


Figure 2. Percentage of important value indexes (IVI) in tree and shrubs.

The farmer planted Pine to get the sab, but this activity makes the pine trunks thinner and prone to broken due to strong winds. On coffee agroforestry, other trees such as avocados, bananas, and lamtoro acting as shade trees. Each of these plants has different harvest periods, so the land can produce a variety of results at different planting spans. Based on the interview, those coffee plants had been planted more than 10 years, and when the survey ongoing, the plant still produces a lot of fruit coffee. Meanwhile, on pine intercropping agroforestry, the crop production was not maximal because the sunlight hampered by the pine canopy [3].

The results of the IVI in herbs on different sites (Figure 3) showed Chili site (MC) implements a monoculture system so that all other plants were removed, in bare land (BL) and pine intercropping site (PC & PT) was dominated by grass. Taro in the pine-taro intercropping site (PT) was only a few, and the low price makes the owner can't gain a higher profit. Whereas, not only there are many kinds of advantages herbs in coffee agroforestry (CA) such as Sereh (*Cymbopogon citratus*), but also there are coffee seeds. The existence of coffee seedling means that the land will be sustainable for planting, so the coffee farmers do not need to buy the seed again. The sustainable management of agroforestry gives a significant contribution to the farmer's incomes and the preservation of biodiversity and environment [8].

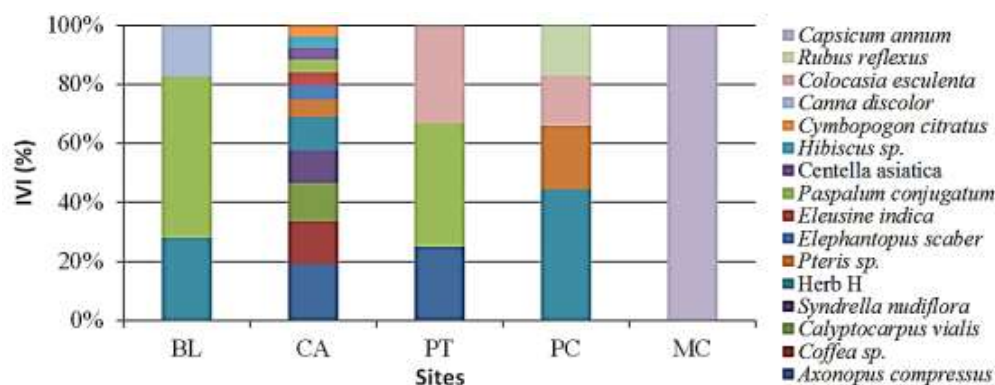


Figure 3. Percentage of important value index (IVI) in herbs.

3.2. Soil quality

3.2.1. Soil Acidity (pH)

The soil pH in all sites except coffee agroforestry was considered as moderately acidic ranged between 5.089 up to 5.917, only in coffee agroforestry soil that showed neutral 6.053. Plant growth and most soil processes, including nutrient availability and microbial activity, are favored by a soil pH range of 5.5 – 8. Acid soil, particularly in the subsurface, will also restrict root access to water and nutrients. Low pH in topsoil may affect microbial activity, most notably decreasing legume nodulation. The resulting of nitrogen deficiency lead to inhibits plant growth [9].

3.2.2. Soil Organic Carbon (SOC) Concentration

SOC is the main characteristic of the existence of organic matter in a soil that directly or indirectly influences the soil quality itself. SOC was found to be greater in sites with developed vegetation communities. The very high value of SOC at Coffee Agroforestry (8%) and Pine Agroforestry (5%) due to the condition of vegetation was still lush. This may be due to continuous of leaves, foliage and dead roots by the shade trees that become the litter and decomposed by microorganisms into soil organic matter [10]. Although monoculture-chili site had poor diversity, however it had a high value of SOC (7%) because of the use of organic fertilizer. Organic fertilizer will increase SOC value and make the land more sustainable than using the chemical ones. Meanwhile, the medium value of SOC found at the bare land (3%) that has been vegetation clearing. Land clearance resulted in the partial breakdown of aggregates, especially the less stable ones. Decreasing the number of macro-pore space due to partial aggregate destruction results in infiltration rate decreasing, so under the same rainfall conditions, surface runoff that occurs in open land becomes larger. The key to reducing SOC loss and hence in the mitigation of climate change is by planting trees [7].

3.3. The agroforestry effectiveness in BTNSP buffer zone

To analyze the effectiveness of the land use in BTNSP buffer zone based on biodiversity and soil quality, we perform Principal Component Analysis (PCA). From PCA (Figure 4), we can conclude that the most appropriate sloping agricultural land management was the coffee agroforestry.

Bare land in a sloping agriculture land causes land degradation that result in a decrease in the quality of soil physical properties. This lead to the decline infiltration capacity and soil's ability to retain water, increased density and soil penetration resistance, and reduced soil structure stability so that it can cause erosion. Land with a steep slope (30-45%) has the influence of gravity is greater than the land with the lower slope. This is due to the gravity is getting bigger in line with the increasingly tilted ground level from the horizontal plane. This weight is an absolute requirement of the process of erosion (detachment), transportation, and deposition (sedimentation). The sandy soil substrates and the acid soil pH is also an obstacle that found in this buffer zone, so bare land must be planted with trees to fit on sloping land management. Studies in agroforestry also reveal that the agroforestry systems have a significant potential to store more soil organic carbon compared to plots with no trees or crop only [10].

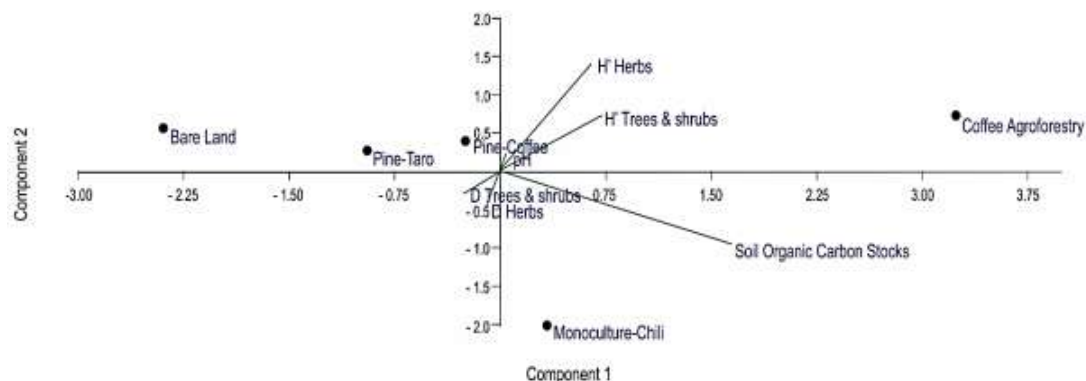


Figure 4. Principal component analysis.

Monoculture system on sloping land is not a good option although the farmer thinks that they will get a fast productive income by implementing it. Besides, vegetables are not suitable for sloping land because the roots of plants cannot grip the soil. Chili farmers also deal with unpredictable price fluctuations, competition with import product, and susceptible to the sudden change in weather and pest invasion [11]. Meanwhile, in the coffee industry, based on the trend in production on period 2014-2024, it will be increased, so it will be good to plant coffee as the main plant on agroforestry [12]. According to interviews, the forestry department provides free coffee seeds, so the farmer will only require less production fee.

Agroforestry systems which shaded perennial-crop systems, have a higher potential for sequestering carbon in the soil compared to treeless systems [10]. But, not all kinds of the tree can be planted in an agroforestry, it must accordance both trees and crops needs of sunlight. Pine is not appropriate for agroforestry, the canopy-covered ground, so the crop can grow well [3]. Some trees that can plant on tropical wet agroforestry were coffee avocados, bananas, cengkeh, and lamtoro (river tamarind). A study in pine forest shows that multi-cropping is not good even for pine itself. When the density was thinned to 70% and then differing richness and compositions of enrichment plantings were added, the pine will not reach maximum grow [13].

The high value in biodiversity, sustainable farming, normal soil pH, compatible in sloping land, and even very high SOC conduct coffee agroforestry as the ideal reference site for a sloping land management in BTSNP buffer zone. Furthermore, only in this area the fertile soil biological indicator, Annelida, had been found. This is because the organic content in coffee agroforestry is the highest value of carbon storage. Moreover, history also said that Malang highland in 19th-20th century known as the fertile coffee field [14]. Studies that compared the coffee intercropped with other trees and monoculture system show that is the agroforestry likely to benefit more from soil carbon credits. Shade trees in coffee plantations play an important role in facilitating carbon sequestration and soil conservation which promote the REDD+, CDM and other voluntary carbon schemes [10].

Coffee agroforestry systems should be prioritized as a reliable option of buffer zone conservation as its benefits to overcome the climate mitigation. This finding is expected to be a reference for the Forestry Department in making policy against buffer zone management. And for further research, there is a need to found a way to educate and implicate these findings on the local community. Changing the perception of people who depend their lives on the forest production is always uneasy; it requires cooperation from all stakeholders. And also, it would be a benefit to imply the complex agroforestry that will become the other plus incomes for the community based on local potential that found in this area, such as orchids nursery, beekeeping, or utilizing organic fertilizer.

4. Conclusion

Agroforestry with coffee as the main crop is the most appropriate for biodiversity, carbon storage, sustainable agriculture, and production profit stability, so it is the reference site for sloping land management in the BTSNP buffer zone. We suggest a policy and public education be issued to prohibit monoculture and pine as main crop in agroforestry, change cultivation into the coffee agroforestry to maintain the buffer zone ecological services.

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