Conference Paper

Land Use Change and Soil Quality in The West Slope of Bromo Mountain, East Java, Indonesia

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Abstract

Deforestation, intensive cultivation, and mismanagement in Tutur district have caused soil degradation and environmental problems. Soils which develop under secondary forests in west slope of Bromo mountain have been degraded by land-use changes (LUC). The effects of long-term LUC and cultivation were evaluated for six land-use types (LUT) including: 1) secondary forest of natural re-growth (UF), land use changes from forest to 2) vegetables, 3) apple, and 4) Coffee garden with understory plant, 5) Coffee garden without understory plant, and 6) Agro forestry. This study was aimed to identify indicators of location specific soil-quality on different land-use types. Soils were sampled from identified cropping system and from forest areas were analyzed soil chemical and physical characteristics. Important soil quality indicators were identified and was developed for the area. Result of the experiment showed that almost all of soil-quality indicators changed significantly to land use changes. Average of soil total nitrogen, Soil organicarbon, pH (H2O and KCl), water aggregate stability, cation exchange capacity (CEC), clay value were 0.04, -0.77, -0.29, -0.38, -6.49, -9.83, -36.40 respectively. While soil P, silt and sand were increased 16.50, 29.80, and 6.80 respectively. The value of CEC has positive correlation to soil clay and Org-C, and it have negative correlation to silt and sand.

Keywords: land-use change, soil degradation, soil-quality indicators.

INTRODUCTION

Soil degradation is a most serious environmental problem in many countries. Soil degradation is the sum of geological, climatic, biological and human factors which lead to the degradation of the physical, chemical and biological potential of soil, and which endanger biodiversity, land use and thus the survival of human communities. Goosen (2012) stresses that soil degradation leads to a decline in soil quality with a continuing reduction of productivity. In many cases the loss of soil productivity has been caused by overgrazing, deforestation, inappropriate agricultural practices and other human activities.

One of the most important driving forces of soil degradation are human activities. Human activities often influence the natural processes in soil. Deforestation is a perceptible aspect of human activities in environment. This change has many interlink effects that can appear through the reduction of chemical and physical qualities of the soil resources (e.g. Doran et al., 1998; Cavelier et al., 1999; Clement, 2010; Liu et al., 2002; Johnson and Lewis, 2007;

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Seeger and Ries, 2008). The term ‘quality’ generally refers to the degree of excellence, grade, distinguishing attribute or degree of conformance to a standard (Clement, 2010) In the soil context, quality (i.e., soil quality) has been defined as the ability of a soil to produce sufficient high quality food while protecting human and animal health and maintaining environmental quality (Lal, 1997). Soil quality is a key component of sustainable agriculture. It is very difficult to define soil quality because it depends on many factors such as land-use, soil management practices, ecosystems, environmental interactions, social and political priorities, etc. (Elfaki et al, 1965) Soil quality may have different meanings, depending on which term is used, e.g., for agriculture it may be the productive capacity, for environmental management it may be the biodiversity and carbon-sequestration functions of soils that have significance (Barrow, 2006; Cavelier et al., 1999) Changes and dynamics of soil quality are very complex. Land-use and cropping systems significantly change the soil physical and chemical properties, and hence plant growth and crop yields will be affected (Boivin et al., 2009) Therefore, maintenance and improvement of soil quality in continuous cropping systems are very important to sustain agricultural productivity for the future. The study aimed to identify soil- quality changes under different of land-use agriculture and that correlation to the land-use history.

METHODS

The study area is located in the Tutur regency (112° 48’00”-112° 52’30” E, 7° 48’00” -7° 57’00” S), Pasuruan District, East Java Province, approximately 850 km east of Jakarta. On the western side of Bromo Tengger Semeru national park, with undisturbed secondary forest and forests of various degrees of degradation and restoration. The area is generally characterized by a hilly topography, with undulating slopes and few flat areas. Elevations range from 500-1600 m asl for the agricultural land and about 1,300-1,600 m as for the forest areas.

The mean annual rainfall in the region is 2295 mm whereas the mean daily minimum and maximum temperatures are 13.7 °C and 25.9 °C, respectively (CBS Pasuruan, 2016). The soils in the area are dominantly brown Inceptisols, Tutur Series (Chew, 2001) or Andosol distric and Cambisol distric (Elfaki et al., 1965). Overall, the soils are low in nutrients and high in clay dispersion, pointing to inherently low fertility and high erodibility. The soils in the remaining secondary forests, including the relatively recently re-afforested areas in demarcated buffer zones, exhibit significantly higher levels of soil organic matter and lower bulk densities than the arable soils. Soil samples were collected from six locations in each of land-use types along toposequence of western side Bromo mountain.

Soil samples were air-dried in the laboratory and passed through a 2 mm sieve. Particle size distribution was measured by the pipette method (Cavelier et al., 1999; chew, 2001; Boivin et al., 2009) Cation exchange capacity was determined using NH₄OAc method. Soil organic matter was determined using the standard Walkley-Black method and total nitrogen by semi micro Kjeldahl. Soil pH was measured using the potentiometry method. Water aggregate stability was determined by single sieve method (Soil Survey Staff, 2014b). The soil physical and chemical properties of the samples is summarized in Table-1.

One way analyses of variance (ANOVA) was used to test the effect of different years of continuous cultivation following deforestation (10-40 years) on soil properties. Values of soil propeties that differed at P<0.01 were significant. The statistical calculations were performed using the SPSS statistical package and the average of frequency of samples between each land use system were compared by Duncan’s new multiple range test (MRT) with p<0.01 as thelevel of significance (Table 2).

RESULT AND DISCUSSION

The land-use history profiles revealed that permanent agriculture had been practiced in the area since the 1960s, when large parts of the original secondary forest were converted to agricultural land. Five typical land-use successions for the arable land and secondary forest were identified (Table 1, 2 and 3).
Table 1. Soil physical properties

| No. | Land use symbol | Clay | Silt | Sand | Texture | WAS (w/w) |
|-----|----------------|------|------|------|---------|-----------|
| 1   | T1             | 56   | 33   | 11   | Silty loam | 95.45     |
| 2   | T2             | 36   | 52   | 12   | Silty loam | 57.86     |
| 3   | T3             | 17   | 66   | 17   | Silty loam | 64.19     |
| 4   | T4             | 11   | 72   | 17   | Silty loam | 65.20     |
| 5   | T5             | 18   | 68   | 14   | Silty loam | 62.42     |
| 6   | T6             | 16   | 59   | 25   | Silty loam | 72.64     |

Note: T1 = mixed garden (agroforestry), T2 = Coffee garden without under-story plant, T3 = Coffee garden with understory plant, T4 = Vegetable garden, T5 = Apple garden, T6 = Secondary forest of natural re-growth

The clay particle was significantly (p<0.01) higher in sites mixed garden, coffee garden without under-story plant, Apple garden, Coffee garden with understory plant, Secondary forest of natural re-growth and vegetable garden; respectively. and significantly affect the aggregate stability of the soil in each land use. This may be attributed to different water aggregate stability (Table 1 and Figure 1).

![Figure 1. Clay particle distribution and water aggregate stability (WAS) on each LUT](image)

**Soil pH**: Regarding soil pH, there were non-significant differences (p<0.01) between the cultivated sites and secondary forest sites (cf. tab. 2 and fig 2). The low pH values of the all soils are due to the intensive application of nitrogen fertilizers and volcanic ash raw material. Also this is attributed to the addition of litter and plant residuals to the soils under cultivated farmland. In addition, the oxidation of nitrogen and sulfur could result in an intensified decomposition of soil organic matter subsequent a reduction in the soil pH.
Table 2. Soil chemical properties

| No. | Land use symbol | pH H₂O  | pH KCl  | SOC (%) | Total N (%) | CEG (Cmol.kg⁻¹) |
|-----|----------------|--------|--------|---------|-------------|-----------------|
| 1   | T1             | 5.56   | 4.28   | 1.89    | 0.13        | 46.95           |
| 2   | T2             | 5.30   | 4.21   | 2.21    | 0.14        | 48.21           |
| 3   | T3             | 5.13   | 4.26   | 2.95    | 0.18        | 55.87           |
| 4   | T4             | 5.16   | 4.42   | 1.95    | 0.20        | 58.74           |
| 5   | T5             | 5.46   | 4.62   | 2.80    | 0.17        | 40.75           |
| 6   | T6             | 5.68   | 4.94   | 3.24    | 0.20        | 63.98           |

Note: T1 = mixed garden (agrostry), T2 = Coffee garden without under-story plant, T3 = Coffee garden with understory plant, T4 = Vegetable garden, T5 = Apple garden, T6 = Secondary forest of natural re-growth.

Soil organic carbon Land-use changes and subsequent changes in soil organic carbon has strongly affected soil structure and other soil properties, which in turn have feedback effects on soil microbial activity and soil organic carbon dynamics (Bovin, et al., 2009). The total content of soil organic carbon in the upper 15 cm of the soils under vegetable plantation was significantly lower than the organic carbon content of the secondary forest soils (40 per cent less; cf. table 2 and fig 2). The content of soil organic carbon near the soil surface is significantly higher in natural forest ecosystems than in soils under apple garden, coffee garden, vegetable garden because more organic carbon is produced under forest. Agricultural activities, especially the export of leaves, have caused lower contents of soil organic carbon in the soils of the coffee plantations. The significant difference (p<0.01) in soil organic carbon content between coffee and secondary forest sits indicates a reduction in the nutrient supply, structural stability and cation exchange capacity of the soils under agriculture framland. With respect to global climate change the destruction of forests by human activities and the enforced processes of organic carbon decomposition contribute to increased emissions of CO₂ into the atmosphere (Barrow, 2006).

![Figure 2. Soil pH, organic carbon and total nitrogen on each LUT](image-url)
**Total nitrogen**; The change of total nitrogen content (Tab. 2 and fig 2) followed a similar pattern as the organic matter change. The nitrogen contents of the coffee plantation soils are significantly (p<0.01) lower compared with the forest soils (25 to 35 per cent less). Since most soil nitrogen is bound in organic matter the result was expected (Chew, 2001). It is following deforestation and then intensive agricultural activities. Higher rates of microbial decomposition and nitrogen transformation took place at the coffee plantation sites.

**Cation exchange capacity**; The cation exchange capacity of the studied soils was significantly (p<0.01) lower under coffee than secondary forest (reduction of 6.0 to 10.3 Cmol kg⁻¹: cf. tab. 2)This can be attributed to the relatively high total organic content and low pH (Barrow; 2006; Chew, 2001) in the soil under investigation.

**Soil microbia**, Regarding soil microbia decomposer, the diversity of main soil microbia decomposer significant difference (p<0.01) in all sites (cf. Tab. 3 and Fig. 3). The major kinds of soil microbia decomposer higest on secondary forest sites (cf. Tab. 3 and fig. 3), except for Actinomycetes sp.

### Table 3. Soil microbia decomposer diversity

| Site | Bacillus sp. | Aspergillus sp. | Pseudomonas sp. | Streptomyces sp. | Actinomycetes sp. |
|------|--------------|-----------------|-----------------|-----------------|------------------|
| T1   | 5.88         | 3.95            | 5.14            | 0.71            | 3.60             |
| T2   | 3.75         | 3.65            | 6.22            | 0.79            | 5.97             |
| T3   | 4.82         | 3.93            | 6.54            | 0.82            | 5.37             |
| T4   | 4.87         | 2.30            | 5.30            | 0.72            | 3.84             |
| T5   | 4.96         | 0               | 6.13            | 0.79            | 6.37             |
| T6   | 5.04         | 3.78            | 8.76            | 0.94            | 4.77             |

![Figure 3. Soil microbe decomposer on each LUT](image)

**CONCLUSION**

Based on the data of research result obtained from this study can be concluded several things including: Organic matter, water aggregate stability, cation exchange capacity, total organic carbon, total nitrogen, cation exchange capacity and soil microbe decomposer community measurements show clear degradation effects caused by deforestation and subsequent intensive cultivation practices. The comparison between soil properties in the different
land use systems and cultivation management indicate that the topsoil horizons under cultivated farmland has a considerably lower quality than the secondary forest soils. The results prove higher contents of total nitrogen and of organic carbon in the topsoil horizons under secondary forest than in coffee plantation, apple garden and vegetable garden, respectively. Long-term vegetable cultivation reduced soil organic carbon content of the soil surface.

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