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Land use affects soil biochemical properties in Mt. Kilimanjaro region

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ABSTRACT

Microbial parameters have been used to monitor changes in soil quality. Soils from four land use systems common in East Africa and present in the Mt. Kilimanjaro region: (1) montane forest, (2) savannah (3) maize fields and (4) *Chagga* homegardens were used in laboratory incubations to assess the effects of landuse changes on soil quality. Soil organic matter mineralization and the following microbial parameters: microbial biomass C, mineralization quotient, metabolic quotient and activities of four enzymes: β-glucosidase, cellobiohydrolase, phosphatase and chitinase were determined. Microbial biomass C content, β-glucosidase, cellobiohydrolase and chitinase activities were higher in natural systems compared to agricultural soils. High phosphatase activity observed in all land use types reflected strong phosphorus limitation in andic soils of the Mt. Kilimanjaro region. Chitinase activity in montane forest soils was 3 times higher than in *Chagga* homegardens. Mineralization quotient and cellobiohydrolase activity best exhibited the effect of land-use changes on soil quality in the Mt. Kilimanjaro region. Cellobiohydrolase activity was up to 3 times higher under natural ecosystems compared to agroecosystems. A high percentage of microbial biomass C content in total organic C and low metabolic quotient were observed in *Chagga* homegarden soils. Soil enzymes (especially cellobiohydrolase) best distinguished between natural and agricultural ecosystems, and are therefore useful for monitoring changes in soil quality. In conclusion, the measured microbial parameters clearly show that the microbial organisms in traditional *Chagga* homegardens system have high substrate use efficiency. This demonstrates that traditional agroforestry systems promotes soil fertility and are more suitable for agricultural production in the tropics compared to monocropping systems like maize plantations.

1. Introduction

Conversion of natural ecosystems for agricultural production is changing the world's landscapes in pervasive ways (Foley et al., 2005). Mountain ecosystems in the tropics are experiencing extensive land-use changes (Mugagga et al., 2012). Nearly 60% of new agricultural land in tropical Africa is derived from intact forests and 35% from disturbed forests (Gibbs et al., 2010). Encroachment for cultivation in the Mt. Elgon region in East Africa has destroyed 25,000 ha of forest land, equivalent to one fifth of Mt. Elgon's total forest cover. Virtually all of the forest cover below an elevation of 2000 m has been removed for agricultural production (Mugagga et al., 2012). Similarly, coffee plantations have expanded at the expense of forests on the southern slopes of the Mt. Kilimanjaro region (Pabst et al., 2013; Hemp, 2006).

African savannahs are also under great pressure from agricultural intensification (Grace et al., 2006). In Kenya, 8.4% of rangelands have been subject to a decrease in vegetation cover over the last two decades (Serneels and Lambin, 2001). Cassava, millet, sorghum, beans and maize fields dominate the landscape in the foothills of Mt. Kilimanjaro. Expansion of maize plantations to marginal lands on the southern slopes of Mt. Kilimanjaro, Tanzania, has contributed to the rapid disappearance and fragmentation of the savannah woodland vegetation. Riverine woodland has been reduced to a few rows of trees (Soini, 2005).

There has been a global concern that such continued agricultural expansion and intensification could change the soil quality irreversibly. This is because agricultural intensification contributes to losses of soil organic matter (SOM) as a result of reduced input of organic matter (OM), increased decomposability of organic inputs and accelerated SOM biodegradation (Lagomarsino et al., 2011). Conversion of natural systems to croplands also contributes to changes in the composition and activities of microbial communities and biogeochemical processes affecting soil quality. Soil quality has been defined as the "continued capacity of the soil to function as a vital living system to sustain biological activity and supply of ecosystem services" (Schloter et al., 2003). Soil microorganisms regulate ecosystem processes such as nutrient cycling through the breakdown of litter and SOM and release nutrients, making them available to plants. Soil microbial biomass is the eye of the needle

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