The effect of land use change on the belowground carbon stock of the Miombo Woodlands

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Abstract

In the Miombo Woodlands Region of south-central Africa, it is estimated 50-80% of the total system’s carbon stock is found in the top 1.5 m belowground. Human population pressure in south-central Africa, with rising demand for productive soils causes increasing deforestation and land degradation. We studied soil carbon stocks within the miombo woodlands region to understand alterations in soil carbon levels caused by each dominant land use: woodland, agriculture, and fallow. At 23 sites, soil samples were collected in 4 1 m² pits (depth of 150 cm) at 6 depth intervals. Soil carbon (SOC) levels varied considerably in the top 10 cm even within the same land use type. Surface carbon levels in Miombo soils varied from 1.2-7.7%. Agricultural soil carbon was depressed with surface layers ranging from 0.3-1.2%. Bulk density differences of falls to areas are also used for grazing and firewood collection and this use has kept SOC levels degraded at most sites, (surface soils 0.65-2.3% C). On average, agricultural soils contain 40% less soil carbon than the natural miombo woodlands.

Introduction

• Rising populations in south-central Africa are generating greater deforestation rates, reduced or no fallow periods, and widespread land degradation. Research is greatly needed in the Miombo Region to understand how the natural systems respond to this land use conversion.

• Soil organic carbon (SOC) levels are an easily measurable way of assessing soil quality and therefore the capacity of a system to be productive, sustainable, and resilient to disturbance. Additionally, SOC helps to maintain soil productivity therefore farmers are interested in land use (LU) management that will enhance SOC.

• The Miombo Woodlands occupy 2.8 million km² of south-central Africa (Desanker et al 1997) and are an open woodland with 20-60% canopy cover and a tall grass understory (Rodgers 1996). Soils are mostly highly weathered Ferralsols and Luvisols with low nutrient and CEC levels (McFarlane 1990).

• In order to further explore the influence of agriculture on SOC levels, soil carbon and nitrogen levels within the dominant land use types (miombo, agriculture, and fallow fields) were compared in Malawi at the Chimaliro Forest Reserve and surrounding villages.

Methods

Soil samples were collected within natural Miombo Woodlands sites, agricultural fields of increasing ages (1, 5, 10, 15, 20, 30, 40 year old fields) and fallow fields of different ages (10, 20, and 40 years of fallow). At each site, four 1 m² soil pits were dug and composite samples for each pit were taken at 6 depths to 150 cm. Bulk density samples were taken at one pit per site. Soils were dried and sieved to 2 mm and soils for C:N analysis first had carbonates removed by adding 10% HCl. An automated elemental analyzer was used for C and N determination. Carbon density (gC/m²) was calculated by multiplying 5.4 %C by bulk density. Farmers had used low amounts of fertilizer on all agricultural fields examined. The fallow areas left to recover are managed by the farmer and grazing and firewood collection does occur within most fallow sites.

Results

Land Use –Overall Differences

• Carbon levels are highest at the surface and decline in a log C density –log Depth regression. This function was also seen to characterize the soil databases compiled by Jobbagy and Jackson (2000). Within each LU, the variability between sites is largest at the surface. The differences between the Miombo sites may be due to clay content and differing levels of cattle grazing or fire frequency at the site.

Proportional Distribution

• The land uses did not have significantly different vertical distributions, although the Miombo sites had proportionally more carbon at the surface than agric. or fallow (Fig. 3). This Miombo vertical distribution has slightly more carbon in the top 20 cm than Jobbagy and Jackson (2000) found for tropical deciduous forest or savanna but less at the surface than the researchers found for agricultural fields.

Conclusions

Because of the positive impact of clay content on carbon levels, for this data to be extrapolated to a larger area, the soil texture across the region must be known. Agricultural management in this region depletes carbon levels quickly, as has been seen in other studies worldwide (Houghton 1983). Overall, the fallow system in the study region does not appear to be functioning well to improve soil health. However, a few of the fallow sites were much shallower than other sites and perhaps are areas with naturally lower fertility levels and although they entitled by farmers as fallow areas, may be used only for firewood collection and grazing.