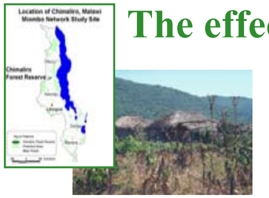

The effect of land use change on the belowground carbon stock of the Miombo Woodlands

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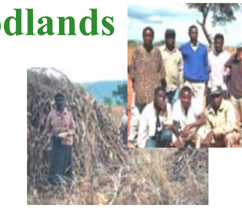

Abstract

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 25 sites, soil samples were collected in 4 $1m^2$ pits (depth of 150cm) at 6 depth intervals. Soil organic carbon (SOC) levels varied considerably in the top 10cm even within the same land use type. Surface carbon levels in Miombo soils varied from 1.2%-3.7%. Agricultural soil carbon was depressed with surface layers ranging from 0.35-1.2% carbon. Due to land pressures 'fallow' 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 km^2 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 Ferrasols 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, and 40 year old fields) and fallow fields of differing ages (10, 20, and 40 years of fallow). At each site, four 1 m^2 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 CN analysis first had carbonates removed by adding 10% HCl. An automated elemental analyzer was used for CN determination. Carbon density (gC/cm^3) was calculated by multiplying %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.

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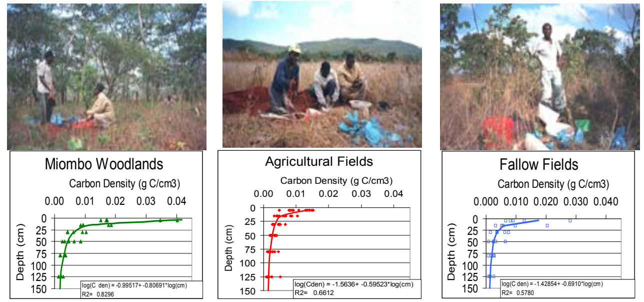


Figure 1. The Influence of Land Use and the Pattern of Carbon Density with Depth at each study site in Chimaliro, Malawi

• The Natural Miombo LU has the highest soil carbon levels, especially at surface. No significant difference between LUs below 60 cm exist (Fig. 1) Within each soil texture class, the miombo sites generally have the highest carbon values at all depths above 60 cm (Fig. 2).

• The age of agricultural field has only a small effect on SOC. Only in oldest fields (>30 years) is surface SOC significantly different from other agricultural field ages. Therefore it seems most of the carbon due to conversion is lost in the first few years of agriculture.

• The soil carbon in fallow sites was not significantly different from agriculture. This is probably because grazing and firewood collection is performed w/in most fallow sites, reducing C inputs.

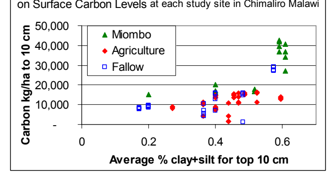
Influence of Soil Texture

• Soil texture is not significantly different between each of the land uses, although fallow sites on average have lower clay levels.

• Clay content was lowest in the top 20 cm at most sites and then continued to increase slightly with depth

• As is commonly found, % clay and % clay+silt were strongly positively correlated with SOC and carbon density (%C*BD) levels in the top 60 cm (Fig. 2). This SOC-clay correlation declines in strength within agriculture, and especially in the older agricultural fields. Agricultural plow action which breaks up soil aggregates, probably exposes more of the clay-humus complexes protecting carbon in the soil.

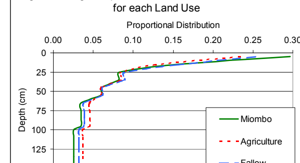
Figure 2. The Combined Effect of Soil Texture and Land Use on Surface Carbon Levels at each study site in Chimaliro Malawi



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.

Fig. 3. Average Proportional Vertical Distribution of Carbon for each Land Use



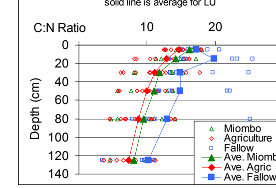
Bulk Density

• BD levels were lower in natural Miombo than agric. in the top 20 cm. Fallow sites were on average higher for all depths. Plowing and hoof action from grazing can compact the soil. In the top 40 cm, sites with lower BD also had higher carbon levels.

C:N Ratio

• The C:N ratio in all land uses declines some with depth, as was seen by King and Campbell (1996) who also investigated LU differences in Miombo but who found larger C:N ratios in Zimbabwe. The C:N ratios of agriculture and Miombo are not sign. different from each other, although on average agric. has a slightly lower ratio. The older agricultural fields generally had smaller C:N ratios than the younger fields in the top 40 cm, perhaps due to the successive years of fertilizer additions. The fallow field ratio was significantly different from both miombo and agric except at the lowest depth. System nitrogen may be immobilized in vegetation as the biomass of the fallow areas increases.

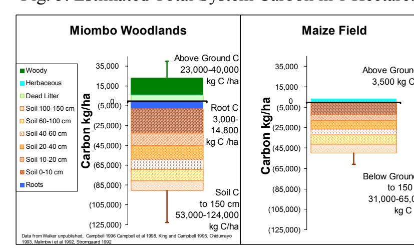
Fig. 4 The C:N Ratio within each Land Use with Depth solid line is average for LU



Impact on Total Carbon Budget

• Even within the natural Miombo, the belowground carbon budget is dominant. By converting the land to agriculture, the aboveground carbon stock drops to less than 4,000 kg/ha increasing the SOC dominance. The soil carbon stock is reduced by an average of 30,000 kg/ha or a roughly 50% reduction in total carbon stocks when the land is converted to agriculture.

Fig. 5. Estimated Total System Carbon in 1 Hectare:



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 sandier than other sites and perhaps are areas with naturally lower fertility levels and although idv entified by farmers as fallow areas, may be used only for firewood collection and grazing.