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Effect of land-use change on soil organic carbon stocks in the Eastern Usambara Mountain (Tanzania)

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A soil organic carbon (SOC) inventory, covering 10 sites with 5 different land-use systems (primary forest, secondary forest, tea plantation, home garden, and cropland) was conducted in the tropical monsoonal Eastern Usambara Mountains (EUM), NE Tanzania. At all sites the environmental factors such as climate and parent material, for soil formation (gneiss), as well as elevation and slope position are highly comparable. The evergreen submontane primary rain forest, which still exists in vast areas in the EUM and the well-known land-use history there provide nearly optimal conditions for the assessment of land-use change effects on soil properties, notably the SOC stocks. We collected horizon-wise samples from soil pit profiles. In addition, samples from fixed depth-intervals were taken from 8 augering points located systematically around each soil pit. The sampling scheme yielded a unique set of soil information (pedological, chemical, and physical) that favours a reliable assessment of SOC stocks and future analytical work on SOM quality and binding mechanisms.

The investigated soils are characterized by high clay contents, which increase with depth. Soil pH varies between 3.5 and 5.4 over all land-use systems and horizons, higher pH values could be detected for the agricultural systems in the topsoil, the differences between agricultural and forest systems decrease in the subsoil. The potential cation exchange capacity is in most cases < 24 cmol$_c$ kg^{-1}, furthermore the base saturation is always < 50 % in the subsoil. Thus, based on that analytical data all soils can be classified as Acrisols revealing the high comparability of the investigated sites. This is an excellent prerequisite for the 'false chronosequence' approach applied.

Organic carbon (C) stocks in the soils from the investigated land-use systems cover a wide range between 17.1 and 24.2 kg m^{-2} (0-100 cm). Variability is even high in the subset of the 3 primary forests. Statistically significant differences between the forest and cropland systems occur in the uppermost depth interval 0-10 cm. Furthermore, the primary forests have higher, but not significantly different SOC stocks in the topsoil (0-40 cm) compared with the cropland systems. In all investigated soils the SOC stocks for the entire soil profiles (0-100 cm) are in a narrow range. This may give a hint on SOC relocation from the topsoil to the subsoil when forests were converted to cropland systems. Our results reveal that this land-use change has led to a shift in above- and belowground litter distribution and amount. Also slash and burn practises as well as burning of plant residues in arable farming are common in the EUM. Both phenomena may control SOC relocation as they are associated with a changed C input and/or the formation of C compounds that can be relocated in the profile. In all investigated soils high concentrations of dithionite- and oxalate- extractable iron and aluminum were analyzed. Hence, interaction of SOC with oxides formed by the two metals is here probably one of the main stabilization mechanisms of SOC.

The relocation and stabilization processes of SOC are the key functions for the implementation of sustainable agriculture in the EUM, and the conducted study provide a suitable basis for our ongoing research in this region of the wet tropics of Africa.