Tropentag, September 16-18, 2026, hybrid conference

"Towards multi-functional agro-ecosystems
promoting climate resilient futures"

Decoupling soil quality improvement from short-term crop productivity in tropical agroecosystems

Masabo Jean Luc Tuyisenge[1], Guggenberger Georg[2], Clemens Wollny[3]

[1] *University of applies science Trier - Umwelt campus Birkenfeld, Germany, International material flow management, Germany*

[2] *Leibniz University of Hanover, Institute of soil science,*

[3] *Technical University of Applied Sciences Bingen, Life Sciences and Engineering, Germany*

Abstract

Soil quality improvement is commonly expected to enhance crop productivity, particularly where organic amendments are used to increase soil organic carbon (SOC) and restore degraded soils. However, field evidence often shows that improvements in soil properties do not immediately translate into higher crop biomass, especially under diverse crop sequences and contrasting site conditions. This study examined the extent to which improvements in SOC were associated with short-term biomass responses in two long-term field trials in Rwanda representing contrasting agroecosystems. The Huye trial involved compost and biochar combinations, while the Musanze trial consisted of different organic and mineral amendment strategies without biochar application. Due to differences in treatment structure, both sites were treated as independent experiments. Soil fertility indicators including SOC, total nitrogen, available phosphorus, potassium, and cation exchange capacity were evaluated alongside biomass data collected across sequential crops. Heatmaps, ANOVA, regression analysis, Tukey post-hoc tests, and mixed models were used to assess treatment effects and identify key drivers of biomass variation. Results revealed that amendment treatments improved SOC significantly in Huye ($F = 5.05$, $p = 0.00021$), with the highest treatment mean reaching 2.79 % SOC compared with 1.24 % in the control. Musanze showed weaker treatment responses and greater system stability, indicating stronger buffering by baseline soil fertility. However, biomass responses were not consistently aligned with carbon increases. Crop type explained most of the biomass variation, while potassium emerged as a stronger predictor of biomass than SOC in regression models. In particular, SOC was not a significant direct predictor after controlling for crop effects ($p = 0.901$), whereas potassium remained significant (coefficient = 18.87, $p = 0.001$). The final biomass model explained 87.6 % of variation ($R^2 = 0.876$). These findings indicate that soil quality improvement and short-term crop productivity can be partially decoupled in tropical agroecosystems. Sustainable soil fertility strategies should therefore move beyond carbon accumulation alone and incorporate nutrient-specific mechanisms and site-dependent responses to support multifunctional and climate-resilient agroecosystems.

Keywords: P : Statistical P-value, sOC: soil organic carbon

Contact Address: Masabo Jean Luc Tuyisenge, University of applies science Trier - Umwelt campus Birkenfeld, Germany, International material flow management, 41, 30167 Hannover, Germany, e-mail: msty3086@umwelt-campus.de