Using soil health parameters as indicators of sustainable management in semi-arid soils

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Introduction

- The total estimated amount of severely degraded soils in Sub-Saharan Africa (SSA) is approximately 350 million (M) ha or 20-25% of the total land area, of which 100 M ha is estimated to be severely degraded due to agricultural and other anthropogenic activities. [1] .
- The hilly landscapes of semi-arid area of northern Ethiopia have witnessed remarkable level of degradation due to change in land use and unprecedented agricultural intensification for the past three millennia [2] and unsustainable management practices [3].

This study was conducted to assess the effect of land use systems on selected soil health indicators as reliable source of soil assessment and monitoring in semi-arid environments of northern Ethiopia.

Material and methods

Land use types/soil types across locations (Figure 1)

Desa'a and Hugumburda

- Forest, Grazing land and Cropland

Geregera and Hugumburda

- Exclosure, Grazing land and Cropland

Soil types

- Cambisols: Predominant in Hugumburda, Haihkihelet and Geregera
- Vertisols: Predominant in Desa'a

Soil sampling depth:

- 0-30, 30-60, 60-90 cm, in 3 replicates

Soil health parameters:

- Soil organic carbon (SOC)
- Microbial biomass carbon (MBC)
- Water extractable organic carbon (WEOC)
- Particle size distribution and bulk density (BD)

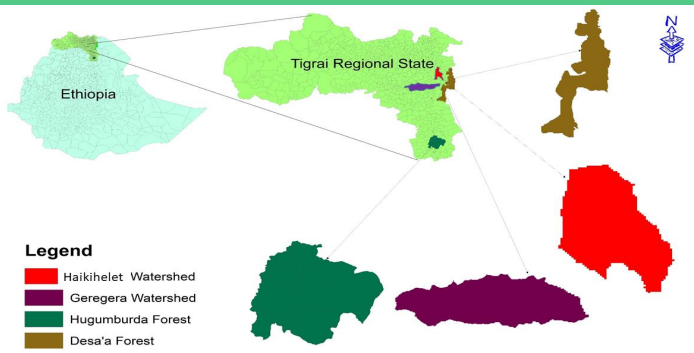

Figure 1 : Location map of the study area

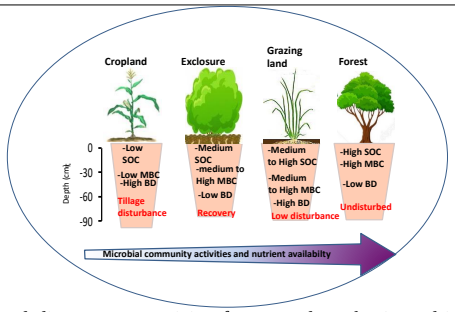

Figure 3: Conceptual diagram summarizing factors and mechanisms driving soil health indicators under different land use types in semi-arid area of northern Ethiopia.

Results and Discussion

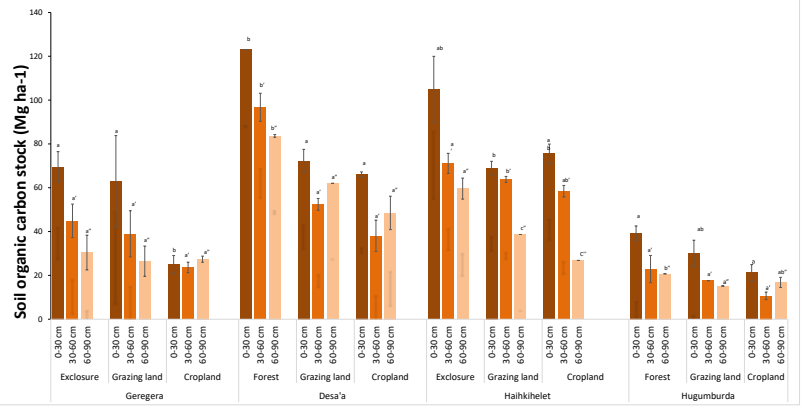

Figure 2: Soil organic carbon concentration depending on land use and soil depth at Geregera, Haikihelet, Desa , and Hugumburda. Error bars represent the standard error of means. Letters above the error bars indicate significant differences ($p<0.05$) between land uses at 0 – 30 cm (a), 30 – 60 cm (a') and 60 – 90 cm (a").

- The MBC and total SOC concentrations were high in natural forest, intermediate in exclosure and grazing land, and low in croplands, and generally decreased with increasing depth in all land use types.
- Sandy soils permited seepage and leaching of WEOC into lower layers thus promote subsoil microbial communities.
- Bulk density (BD) differed significantly ($p \leq 0.05$) with depths across different land use types. Similarity existed between topsoil BD of grazing land and cropland with high BD values while forest land recorded low BD values.

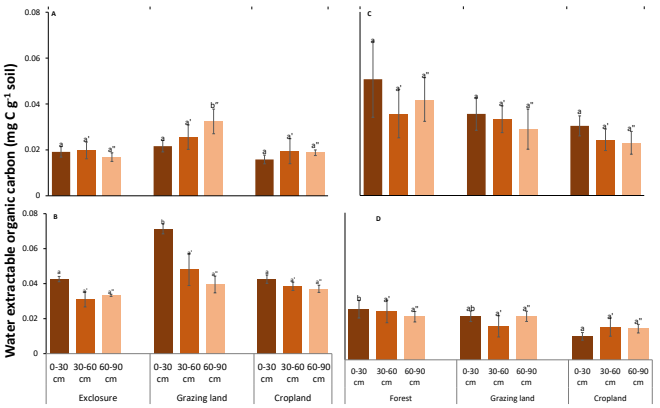

Figure 4: Water extractable organic carbon depending on land use and soil depth at Geregera (A), Haikihelet (B), Desa'a (C), and Hugumburda (D). Error bars represent the standard error of means. Letters above the error bars indicate significant differences ($p < 0.05$) between land uses at 0–30 cm (a), 30–60 cm (a') and 60–90 cm (a").

Conclusion

- Significant difference in microbial biomass carbon (MBC), water extractable organic carbon (WEOC), soil organic carbon (SOC) and total nitrogen (TN) concentrations was observed among various land use types across depths, with clear differences in distribution trend across locations.
- Conversion of forest to cropland resulted to obstruction of microbial activities, and significant losses of MBC, SOC and TN while exclosure establishment supported restoration of degraded grazing lands with recovery of MBC and SOC concentrations especially in topsoil layers.

References

[1] Stockmann, U. *et al.* The knowns, known unknowns and unknowns of sequestration of soil organic carbon. *Agric. Ecosyst. Environ.* 164, 80–99 (2013).

[2] Okolo, C. C., Gebresamuel, G., Zenebe, A., Haile, M. & Eze, P. N. Accumulation of organic carbon in various soil aggregate sizes under different land use systems in a semi-arid environment. *Agric. Ecosyst. Environ.* **297**, 106924. https:// doi. org/ 10. 1016/j. agee.2020. 106924 (2020).

[3] Chan, Y. Increasing soil organic carbon of agricultural land. *Primeface* 735, 1–5 (2008).

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