Storage and distribution of soil organic carbon, total nitrogen and CO_2 emissions in semi-arid soils

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Introduction

- Globally, the soil remains a vital carbon sink [2344 Gt of organic carbon (OC) sequestered] and is considered the principal terrestrial pool of OC [1] .
- Human activities and land use change tend to affect the size of SOC pool [2] with more than 50% of the soil organic carbon (SOC) stock estimated to be found in the subsoil [1].
- This study was conducted to assess the effect of land use systems on SOC and total nitrogen (TN) concentrations and stock, CO_2, particle size distribution in semi-arid environments of northern Ethiopia.

Material and methods

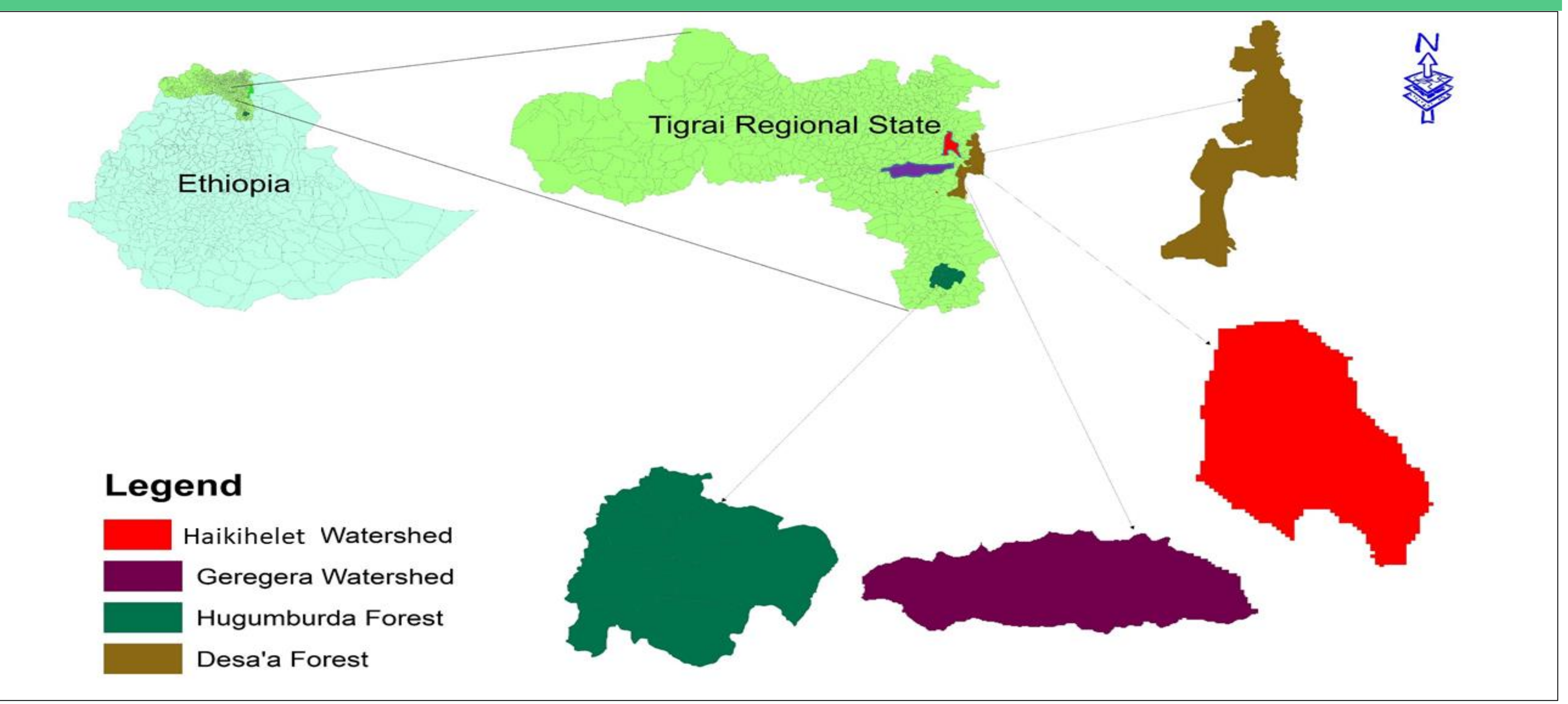

Figure 1 : Location map of the study area

Land use types/soil types across the studied 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

- At three depths: 0-30, 30-60, 60-90 cm, in 3 replicates

Soil physicochemical analysis: SOC, TN, particle size distribution and bulk density were determined using routine laboratory procedures

Calculation of soil carbon stock:

$$SOC\ or\ TN\ (Mg\ C\ ha-1) = concentration \frac{\%}{100}\ x\ bulk\ density \left(\frac{Mg}{m3}\right) x\ area\ (ha)\ x\ soildepth\ (m)$$

- **CO_2 emission:** Established on the basis of the underlying SOC and CO_2 relationship as stated by [3], which states that 1 Mg ha^{-1} increase in soil carbon signifies removal of 3.67 Mg of CO_2 from the atmosphere**.**
- **Climate data:** Mean Annual Precipitation (MAP) and Temperature (MAT)

Results and Discussion

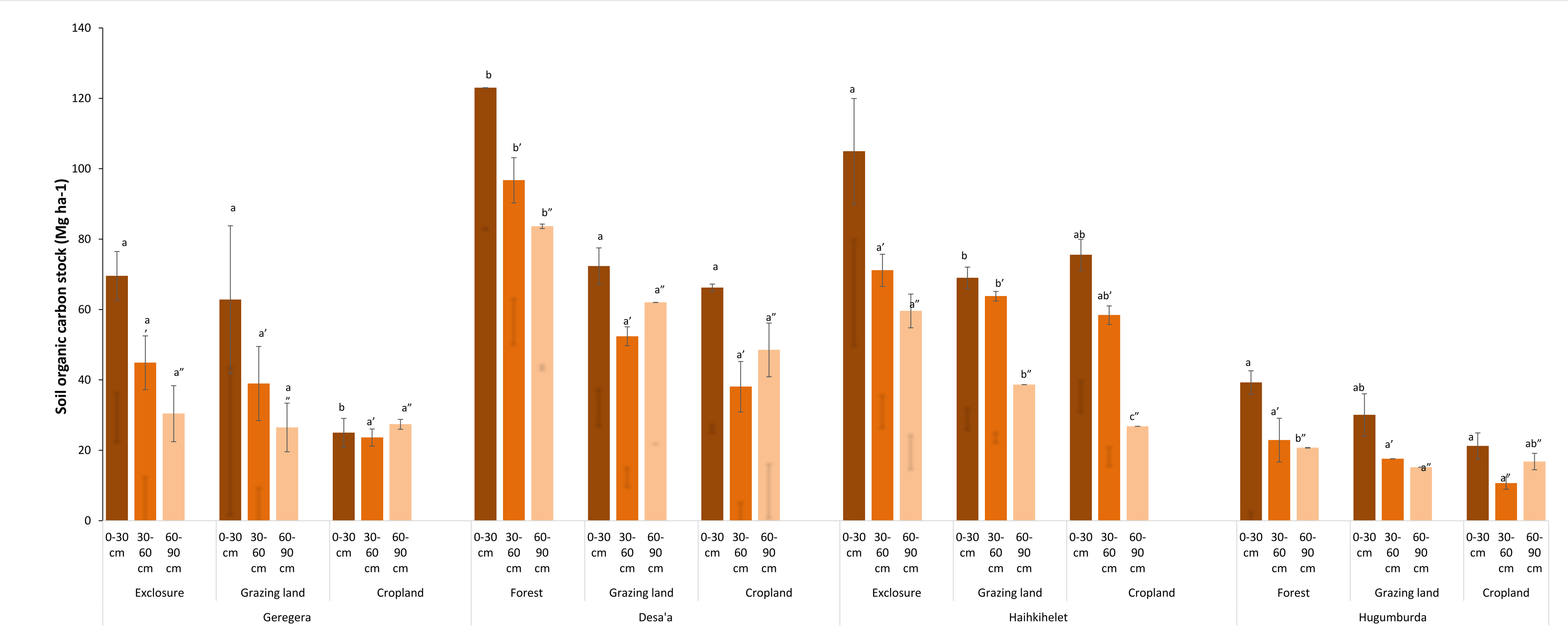

Figure 2: SOC stock depending on land use and soil depth at Geregera, Haikihelet, Desa , and Hugumburda. Error bars represent the standard error of means. Letters above the error bars indicate significant differences ($p<0.05$) between land uses at 0 – 30 cm (a), 30 – 60 cm (a') and 60 – 90 cm (a").

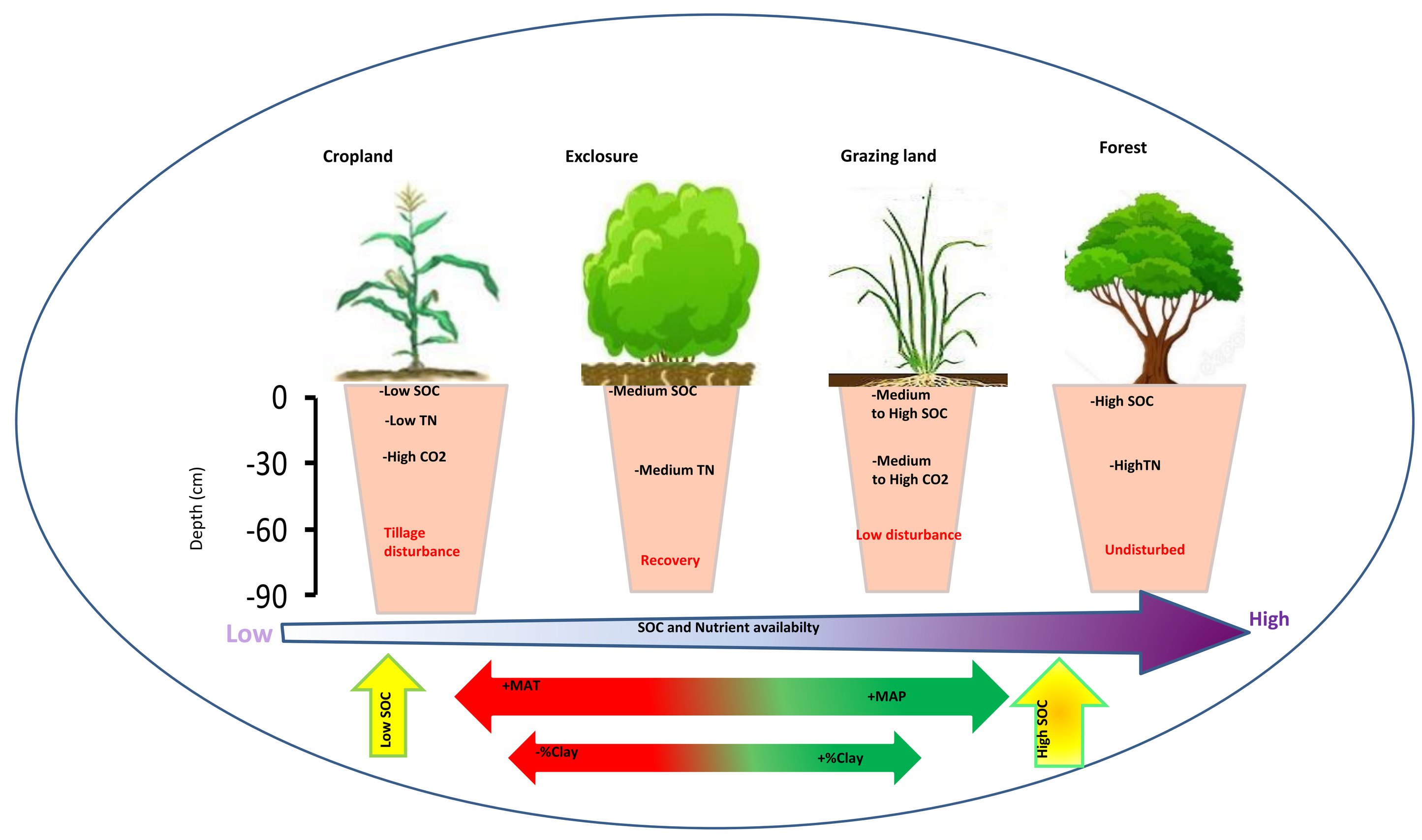

Figure 3: Conceptual diagram summarizing factors and mechanisms driving SOC distribution under the different landuse. The nutrient availability arrow illustrates the concentration pathway and distribution of SOC and TN contents. The double-headed arrows indicates the direction of both MAT and % silt in modulating SOC.

- Significant difference in SOC and TN stocks was observed among various land use types across depths, with clear differences in distribution trend across locations, while C:N ratio showed no distinct distribution pattern.
- Most of the SOC and TN stocks losses were in the 0–30 cm topsoil layer.
- Exclosures on degraded grazing land accounted for SOC stock accumulation while conversion of forest to cropland and grazing land accounted for huge depletion of SOC and TN stocks, and CO2 emission.

Conclusion

- SOC and TN concentrations and stocks were high in natural forest, intermediate in exclosure and grazing land, and low in croplands, and generally decreased with increasing depth.
- Clay content and MAP rather than C:N ratio were the most meaningful indices for SOC storage and soil quality assessment.
- Conversion of forest to cropland resulted to significant losses of SOC and TN with considerable amount of CO_2 emission which contributes to change in climate while exclosure establishment supported restoration of degraded grazing lands with recovery of SOC and TN stocks especially in the topsoil layer

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. *Primefact* 735, 1–5 (2008).

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