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Runoff, Soil loss, and soil properties as influenced by land use and management practices: Case study from the Upper Blue Nile basin, Ethiopia

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1. Introduction

•Land degradation by soil erosion is among the critical problems worldwide; it is, however, most pressing in developing countries where soil erosion by water is accelerated by population pressure and improper land use practices (**Fig.1,** left).

•Huge financial and labor resources have been invested for the implementation of sustainable land management (SLM) practices in Ethiopia (**Fig.1**, right) to mitigate soil erosion; relevant studies are, however, limited particularly for the actively eroding regions.

•The objectives of this study were to (i) quantify runoff and soil loss (SL) under different land use and management practices; and (ii) explore the variation in key soil properties as influenced by land use and management practices.

2. Study area

- The study was conducted at three agro-ecologically different sites in the Upper Blue Nile Basin of Ethiopia (**Fig. 2**). These sites were selected in the view of representing different the biophysical features of the basin (**Table 1)**.

Table.1 Altitude and climatic features of the study sites.

Sites	Elevation (m.a.s.l)	Mean daily Temp.(ºC)	Mean annual rainfall (mm)
Guder	2489–2882	9.4–25.0	2454
Aba Gerima	1912–2126	11.8–27.5	1343
Dibatie	1487–1718	13.1–28.2	1022

3. Methods

•Runoff and soil loss (SL) were measured using 42 bounded runoff plots (6 m x 30 m) in three land use types: cropland (CL), Grazing land (GL) and bushland (DBL). Five SLM practices were evaluated for two seasons (2015 & 2016): Soil bund (SB), *Fanya juu* (F), and soil bund reinforced with grass (SBG) for CL, and exclosure (E), and exclosure with trenches (E+T) for GL and BDL (**Fig. 3 and Table 2**).

•A total of 162 topsoil (0–20 cm) samples were analyzed for nine soil quality indicators – texture, bulk density (BD), pH, electrical conductivity (EC), cation exchange capacity (CEC), total nitrogen (TN), soil organic carbon (SOC), available phosphorus (Pav), and available potassium (Kav).

Table 2. Characteristics of runoff plots at the study sites, and some of the physical and chemical properties for initial soil samples* (range of values for a specific land use).

Land use	Slope (%)	Treatments	Bulk density (gm/cm³)	Silt +clay (%)	pH	CEC ($cmol_c\ kg^{-1}$)	SOC (%)	P_{av} ($mg\ kg^{-1}$)
CL1	5	C, SB, F & SBG	1.09 –1.30	71–86	5.05 –5.83	28.40 –40.40	0.08 –2.65	0.34–11.10
CL2	15	C, SB, F & SBG	1.11–1.34	55–84	5.01–5.85	37.60–46.80	0.19–2.34	1.34–10.20
GL	15	C ,E, E+ T	1.03 –1.44	64–84	5.40 –5.88	35.60 –50.00	1.17 –2.38	1.69–6.87
DBL	35	C, E, E+ T	0.83 –1.40	52–76	5.58 –6.10	40.00 –58.00	2.03 –2.56	0.62–30.89

Fig.1. Major causes of soil erosion and counter measures implemented in the highlands of Ethiopia. The black arrows indicate the slope direction.

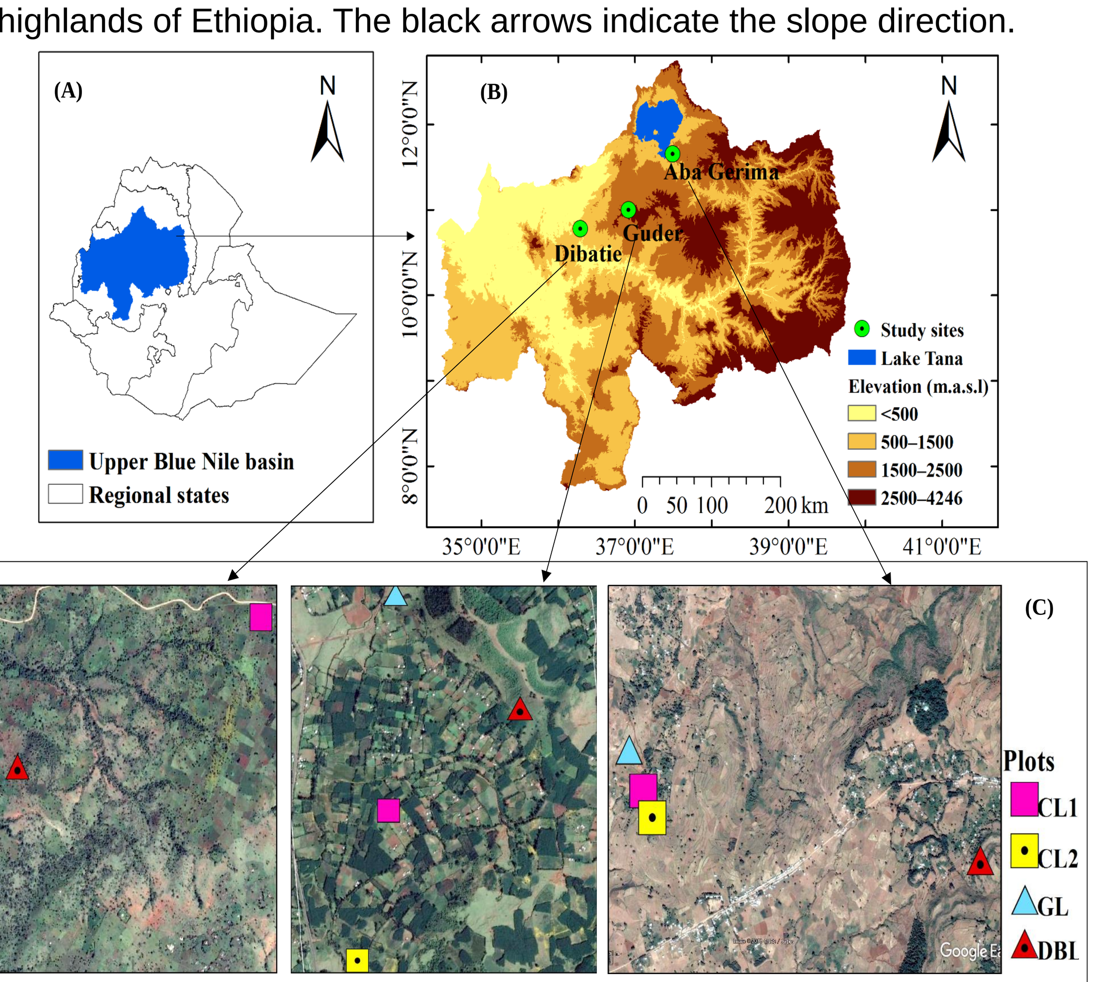

Fig. 2. Map of the study area: (A) Ethiopia, (B) Upper Blue Nile basin, and (C) sampling plots in different land use types at Dibatie (left), Guder (middle), and Aba Gerima (right) sites.

Fig. 3. Partial view of monitoring runoff plots on cropland (CL), grazing land (GL), and bushland (DBL), the treatments and other detailed characteristics are given in **Table 2**. The photo of GL was taken from Guder, while others were from Aba Gerima.

4. Results and discussion

4.1. Effects of land use and management practices on runoff and soil loss

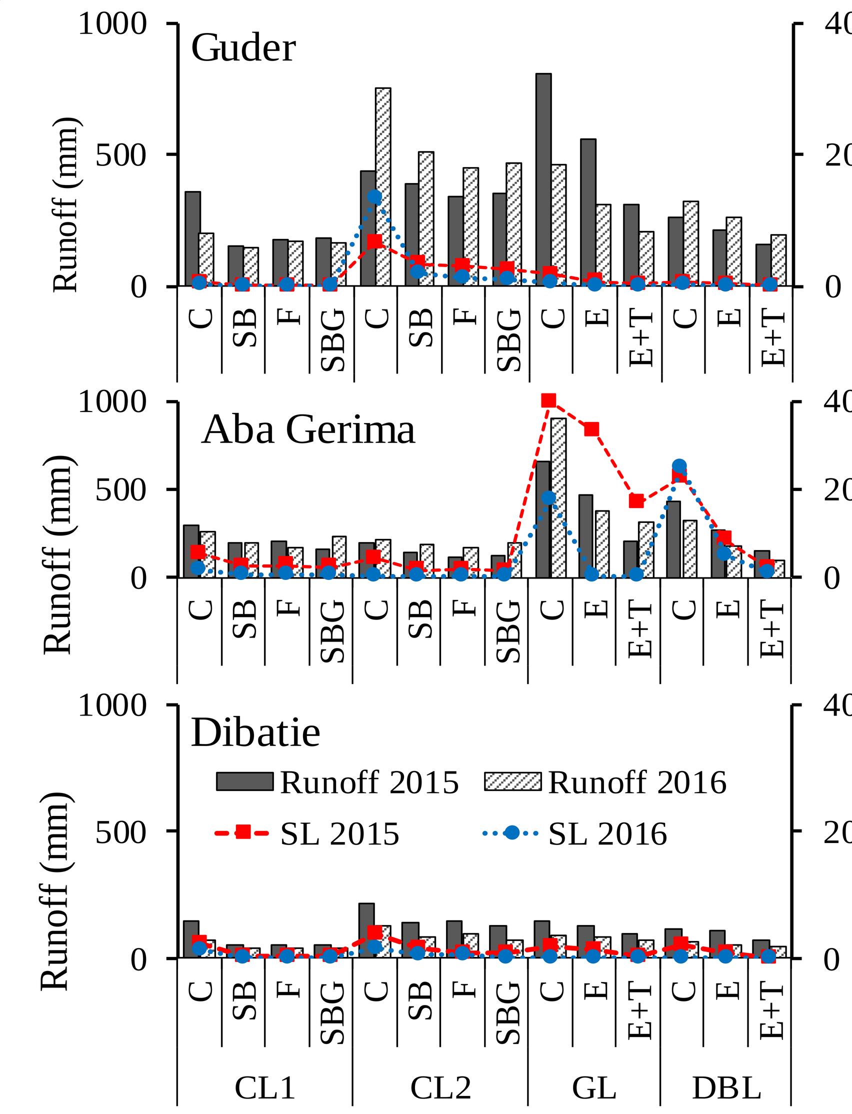

Fig. 4. Seasonal runoff and soil loss (SL) amounts under different land use and SLM practices.

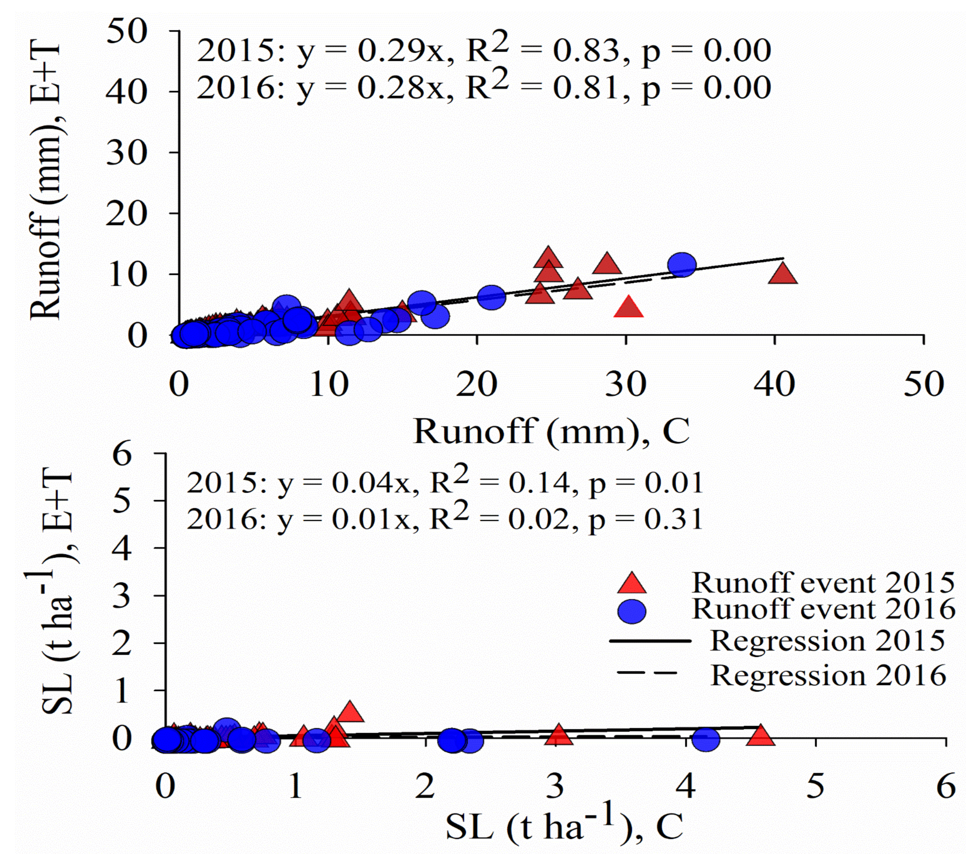

Fig. 5. Regression curves fitted to daily runoff and SL data for plots without (C) versus with SLM practices (SBG, and E+T) in grassland.

5. Conclusions

• Runoff, soil loss, and soil properties substantially varied across different agro-ecologies and land use types, suggesting that management interventions should be based on land use and location-specific information.

• The studied SLM practices significantly reduced runoff and soil loss, and improved soil quality properties.

•Soil bund reinforced with grass and exclousre were found to be the best SLM practices. However, further investigation is needed in consideration of ecological succession, and other possible effects such measures might have, for example, effects on biodiversity and productivity.

4.2. Effects of land use and management practices on soil properties

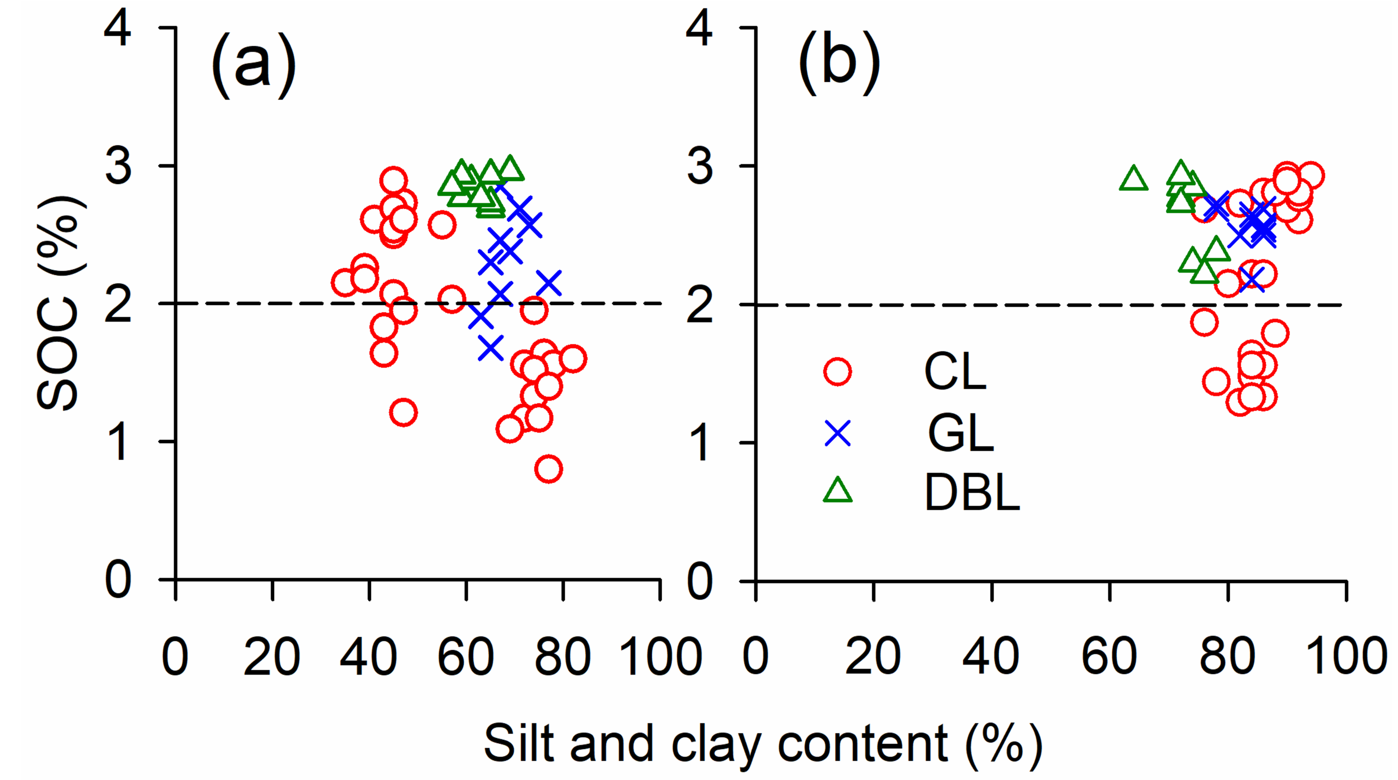

Fig. 6. Scatter plots of SOC and as a function of silt and clay (S+C) contents in different land uses at Aba Gerima (a) and Dibatie (b) sites. The dashed horizontal lines indicate the critical levels of SOC, according to Wasa et al. (2013), and Musinguzi et al. (2016).

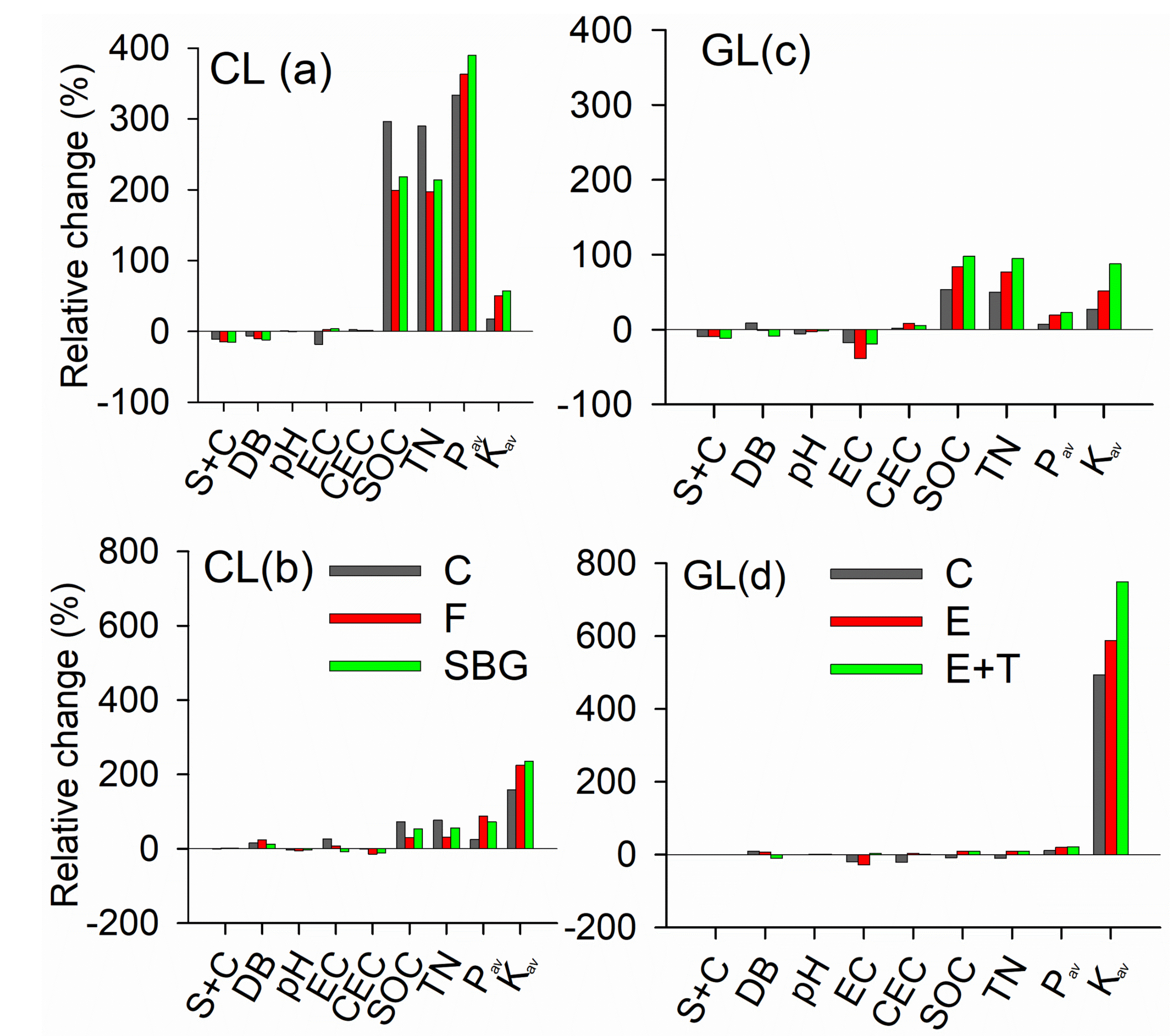

Fig. 7. Relative changes in soil properties three years after the implementation of different management practices in croplands and grazing lands at Aba Gerima (a & C) and Dibatie (b & d) sites. The relative change values were calculated in 2018 using the actual values obtained for samples of initial year (2015) as a baseline data (**Table 2**).

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