

Assessing Soil Properties and Landforms in the Mai-Negus Catchment, Northern Ethiopia



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ABSTRACT

Soil degradation is a serious environmental problem in Ethiopia. However, little information is documented on indicators such as variations in soil properties across different landforms in a catchment. This study was aimed to assess soil properties and their changes across sites with different erosion statuses, and identify landscape positions that require prior management attention in the Mai-Negus catchment, northern Ethiopia. Three types of erosion-status sites (stable, eroding and aggrading) were identified using reconnaissance surveys, and then the corresponding soil samples were collected and analyzed. The major soil properties were significantly varied ($P \leq 0.05$) among the three erosion-status sites. The highest soil pH, organic carbon, total nitrogen, cation exchange capacity, iron and zinc were recorded from the aggrading sites in the reservoir and valley landforms of the study catchment. A higher bulk density was generally recorded in the eroding sites, whereas a lower value was observed in the aggrading sites. The highest sand content was observed in the eroding sites of the mountain followed by the central ridge landform. The paired mean difference and the correlation matrix of most soil properties between the different erosion statuses also showed significant differences. About 95% of the erosion-status sites were correctly classified by the discriminant function, indicating that the field survey-based classification was acceptable for decision making. On the basis of this study, suitable interventions should thus be introduced to the prioritized landforms, which are the mountain and central ridge, and eroding sites with severely degraded soil properties across the catchment.

Key Words: aggrading site, discriminant function, eroding site, erosion status, landscape, soil property variability, stable site

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Land degradation in terms of soil fertility or nutrient deterioration is a major threat to food security and natural resource conservation in Sub-Saharan Africa (Bationo *et al.*, 2007). Soil erosion is the most serious cause of such environmental degradation, which constrains agricultural production and food security (UNEP and UNESCO, 1980; Eswaran *et al.*, 2001; Haregeweyn *et al.*, 2008). In relation to this, various studies indicated that Ethiopia is one of the countries most severely affected by erosion in Sub-Saharan Africa (FAO, 1986; El-Swaify and Hurni, 1996). Out of the 60 million ha of agricultural productive areas in Ethiopia, nearly 27 million ha have experienced erosion, 14 million ha have been severely eroded and requiring rehabilitation, and 2 million ha have lost top soil with an average soil loss of about $100 \text{ t ha}^{-1} \text{ year}^{-1}$ from cultivated lands (FAO, 1986; Mekonen and Tesfahunegn, 2011). Erosion is especially severe in the Tigray region of the northern Ethiopia, with an average soil loss from cultivated land of $> 49 \text{ t ha}^{-1} \text{ year}^{-1}$

(Tamene, 2005), exceeding the average soil loss of $42 \text{ t ha}^{-1} \text{ year}^{-1}$ for the whole of Ethiopia (Hurni, 1993).

Soil degradation by water erosion is a major constraint to the sustainability of agricultural production since it influences several soil properties such as topsoil depth, soil organic carbon, nutrient status, soil texture, soil structure, water-holding capacity and water transmission characteristics (Haileslassie *et al.*, 2005; Zougmore *et al.*, 2010). For Ethiopia, Stoorvogel and Smaling (1990) predicted negative national nutrient balances due to erosion: -47 kg ha^{-1} for nitrogen (N), -15 kg ha^{-1} for phosphorus (P_2O_5) and -38 kg ha^{-1} for potassium (K_2O), while inflows from fertilizers are very low ($< 10 \text{ kg ha}^{-1}$). This prediction is twice as high as the average nutrient depletion values for Sub-Saharan Africa, indicating a severe problem in Ethiopia. Haileslassie *et al.* (2005) also estimated soil nutrient depletion rates of $122 \text{ kg N ha}^{-1} \text{ year}^{-1}$, $13 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1} \text{ year}^{-1}$ and $82 \text{ kg K}_2\text{O ha}^{-1} \text{ year}^{-1}$ in Ethiopia. These studies indicated that soil erosion is

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the major cause of such soil nutrient depletion, but its impact significantly varied among different landscape areas (Hailelassie *et al.*, 2005). Nevertheless, degradation by soil erosion is often assessed in terms of loss of soil mass using erosion models rather than variability in soil nutrients and other soil properties (Pierce and Lal, 1994; Haregeweyn *et al.*, 2008). In addition, little information is available on the spatial variability of soil physical properties and fertility/nutrients across different landforms at different levels of soil erosion. However, such information is crucial for developing soil management strategy targeted to hotspots of soil degradation (Pennock, 1998; Lal, 1999).

Studies elsewhere have shown that erosion processes contribute significantly to the variability of soil properties and the associated nutrients within complex topography (*e.g.*, Stone *et al.*, 1985; Kreznor *et al.*, 1989). Soil erosion and sediment delivery processes, which export sediment-bound nutrients to deposition areas, are influenced by landscape characteristics such as terrain, vegetation cover and soil erodibility (Withers and Lord, 2002; Muchena *et al.*, 2005; Haregeweyn *et al.*, 2008). Such soil depletion could be a fundamental cause for declining food production (Hailelassie *et al.*, 2005; Haregeweyn *et al.*, 2008).

Furthermore, assessing soil property variability in relation to site characteristics such as landform units and soil erosion statuses is critical for predicting rates of ecosystem processes (Schimel *et al.*, 1991) and understanding how a particular ecosystem works (Schimel *et al.*, 1991; Kosmas *et al.*, 2000). Despite of these facts, little is also understood and documented about the link between soil nutrient losses and landforms in Ethiopian catchments. The objective of this study was to bridge such research gaps by assessing

variability in soil properties at sites with different erosion statuses and identifying landforms that require management attention in the Mai-Neguse catchment of northern Ethiopia.

MATERIALS AND METHODS

Study area

This study was conducted in the Mai-Negus catchment ($38^{\circ}37'0''$ – $38^{\circ}41'0''$ E and $14^{\circ}7'0''$ – $14^{\circ}9'30''$ N) of the Tigray region, northern Ethiopia (Fig. 1a). The catchment has an area of 1 240 ha and altitudes ranging from 2 060 to 2 650 m above sea level (Fig. 1b). Mean annual temperature in the study area is 22 °C and Mean annual precipitation is 700 mm. Most rainfall (> 70%) occurs between July and August (Ethiopian Meteorology Agency, Mekelle Branch). Cultivated land dominates over the other land-use types, with t-eff (*Eragrostis tef*) being the major crop in the study area. There are pastures and scattered patches of trees, bushes and shrubs. The catchment is dominated by lava pyroclastic and meta-volcanic rocks. Soils are mainly Leptosols on the steep slopes, Cambisols on the relatively gentle slopes and Vertisols on the flat areas (FAO, 1998).

Landscape assessment

Reconnaissance surveys were executed to get an overview about the general catchment characteristics and erosion statuses. Such data were collected from June to December 2009. Field observed data, information from a topographic map and preliminary report by Ethiopia Ministry of Water Resources (EMWR, 2002) were used to classify the catchment into different landforms (Fig. 1a). Considering elevation, slope and geo-

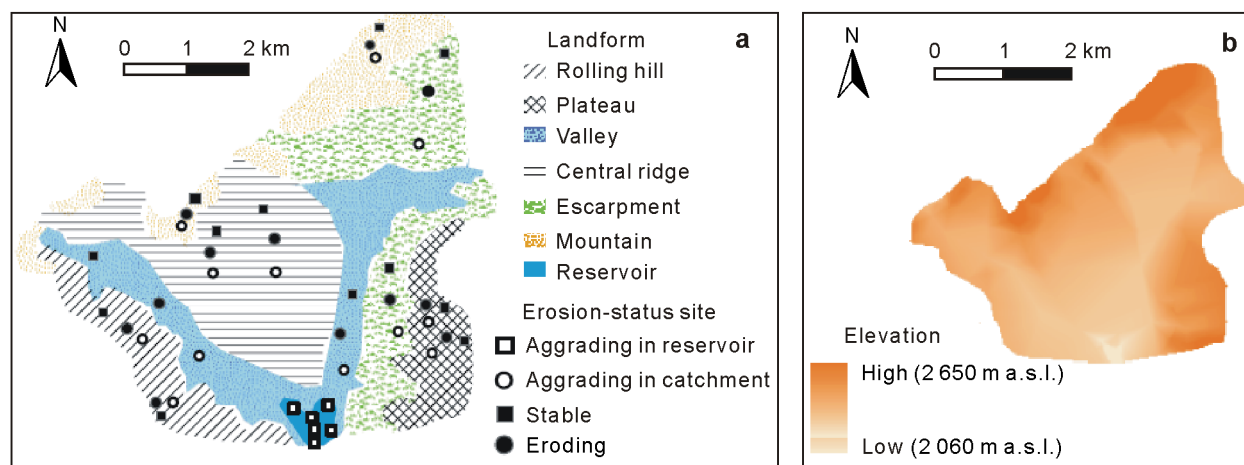


Fig. 1 Representative soil sampling points in different erosion-status sites in the Mai-Negus catchment of Tigray, Ethiopia (a) and the spatial distribution of elevation in the study catchment (b). a.s.l. = above sea level.

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