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Effects of topography and land use on soil characteristics along the toposequence of Ele watershed in southern Ethiopia

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ABSTRACT

Information on soil properties and distribution is critical for making decisions with regard to crop production and mitigating land degradations. A reasonable way of deriving the information is using proxy environmental characteristics that have demonstrated relationships with soil properties. A field study was conducted to evaluate the relationship between topography, land use and soil properties. Three slope classes were considered and a total of three pedons, one on each slope class, were opened and described at the Ele watershed in southern Ethiopia. Soil samples collected from identified horizons of each pedon were analyzed for physicochemical properties. Additionally, random soil samples were collected from adjacent cultivated, grassland and forest soils; and three composites were made for each land use type within the three slope classes. All three pedons showed remarkable variability in physical, chemical, and morphological characteristics of the soils. The field as well as laboratory textural class determinations revealed the dominance of clay fraction in the soils. The existence of buried horizons with abrupt textural as well as sharp changes in color both in dry and in moist showed the occurrence of lithological discontinuity. Both soil pH and EC were low for steep slope and highest for the middle slope class, whereas the organic carbon (OC), total N (TN) and available P decreased down the slope. Gentle and moderate slope classes had the highest exchangeable bases, while the steep slope had the lowest owing to the removal and deposition of exchangeable bases by water erosion. The chemical properties of the soils were also significantly affected by land use. The highest values of both pH and EC were obtained in cultivated land, whereas grassland had relatively more OC, exchangeable Ca, Mg, K and available micronutrients than the other land use types.

1. Introduction

Understanding the distribution and properties of soils is necessary to planning and implementing sustainable land use and/or rehabilitation of degraded lands (Ali et al., 2010). Knowledge about the properties of soils can be generated directly through field observation, though soil properties are extremely variable in space and time (Korres et al., 2013). A better mechanism for predicting adequate and yet reproducible soil information is by using proxy lands' biophysical and climatic characteristics that have established strong relationships with soil properties (Fantaw et al., 2006; Moore et al., 1993).

Several studies have been conducted to determine dominant controlling factors of soil properties on the landscape (Brubaker et al., 1993; Fantaw et al., 2006; Miller et al., 1988; Mulugeta and Sheleme, 2010; Sheleme, 2011; Wang et al., 2001). For instance, Wang et al. (2001) regarded topography as the dominant factor influencing soil property variation due to its influence on runoff, drainage, microclimate and soil erosion, and consequently on soil formation under a hill slope in semi-arid small catchment of the loess plateau of China. Similarly, Mulugeta and Sheleme (2010) recounted that most of the important soil quality indicators were affected by different landscape positions, particularly at the surface horizons. Significant variation in soil properties with respect to aspect and vegetation communities were also noticed by Fantaw et al. (2006) in the highlands of southeastern Ethiopia. Moreover, many soil properties including particle-size distribution, pH and organic matter content vary with slope position (e.g., Miller et al., 1988; Mulugeta and Sheleme, 2010; Sheleme, 2011; Wang et al., 2001). A common denominator of all these studies is a demonstrated strong relationship among topographic positions, soil properties and vegetation composition, such that the distribution of a particular soil property may vary with topographic attributes and vegetation types.

Understanding the dynamics and distribution of the soil characteristics as influenced by landscape features is critical for assessing the effect of future land use changes on soil use and management (Kosmas et al., 2000). In Ethiopia, the body of knowledge that governs soil and landscape relations, in particular, the unique interaction of landforms and environmental factors such as climate, hydrology, lithology, organisms

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and vegetation to determine soil types and properties, is not fully developed. Additionally, soil types and characteristics show great variations across the various regions and accounting for these variations is essential for assessing the state of soil resources, dynamics and needs of the best management practices thereby promoting a crop production that is more sustainable and yet meets the needs of the growing population. Sustainable management practices that are based on the understanding of the soil systems are not available for most parts of the country (Ali et al., 2010). Moreover, past soil survey activities are mainly conducted at regional and small-scale, which are inadequate in providing basic soil data that can help to manage soils according to the local variability (i.e., watershed or farm scale). Therefore, this study was initiated: i) to characterize the morphological, physical and chemical properties of the soil along a toposequence of the Ele watershed located in southern Ethiopia; and ii) identify the influence of different land uses on the chemical properties as well as fertility of the soils in the watershed at the scale of landscape (hillslope).

2. Materials and methods

2.1. Description of the study area and soil sampling

The study was conducted at the Ele watershed located in southern Ethiopia at 08° 06′N and 38° 24′E. The watershed covers about 12.4 km^2 with altitude ranging between 1840 and 2100 masl and having different land forms (Fig. 1; Table 1). The morphological, physical and chemical properties of the soils of the watershed were studied through field observation and laboratory analyses. Following the Guidelines for Field Soil Descriptions (FAO, 2006), the toposequence was divided into three slope categories: flat to gentle slope (0–5%), sloping to strongly slopping (5–15%), and moderately steep to steep (15–60%). Three representative pedons, one in each slope category, were excavated on the toposequence, and soil samples were collected from the entire area of all identified horizons, and nine composites were made for laboratory analyses. Representative pedons were selected based on site and soil profile characterization with the help of the Guidelines for Field Soil Descriptions (FAO, 2006). Accordingly, first, the watershed was delineated on the top-sheet following the identified boundary line, and was used as a base map. The land units were identified on the basis of topographic features and land/soil characteristics using field observations and topographic maps. Soil auger observations were implemented, using an 'Edelman auger' to identify variations in soil depth and texture characteristics along the slope gradient. Points with the same soil depth class and surface soil texture in a given slope class were considered as a pedon. Pedon-1 (EP-1) was located in the upper slope, pedon-2 (EP-2) in the middle slope, and pedon-3 (EP-3) in the lower slope categories (Fig. 1). The soil profiles of all the pedons were described in situ following the Guidelines for Field Soil Descriptions (FAO, 2006) and using the Munsell chart to identify soil colors. There were a total of 12 soil descriptions, on average 4 per pedon (soil profile), corresponding to respective diagnostic horizons.

To identify the influence of land uses on the chemical properties as well as fertility of the soils in the watershed, the dominant land uses of the area, namely, cultivated land, grassland and forested land (mainly Eucalyptus) were selected within each slope category. The cultivated lands were used for maize (*Zea mays*) and tef (*Eragrostis tef*) before sampling. Twelve random soil samples (0–30 cm) were collected and three composites per land use type were made for each slope category.

2.2. Laboratory and statistical analyses

The soil samples collected from every identified horizon and the composite samples from the different land uses were air-dried and ground to pass through 2 mm sieve. For the determinations of total N and organic carbon (OC), a 0.5 mm sieve was used. Analyses of the physicochemical properties were carried out following standard laboratory procedures.

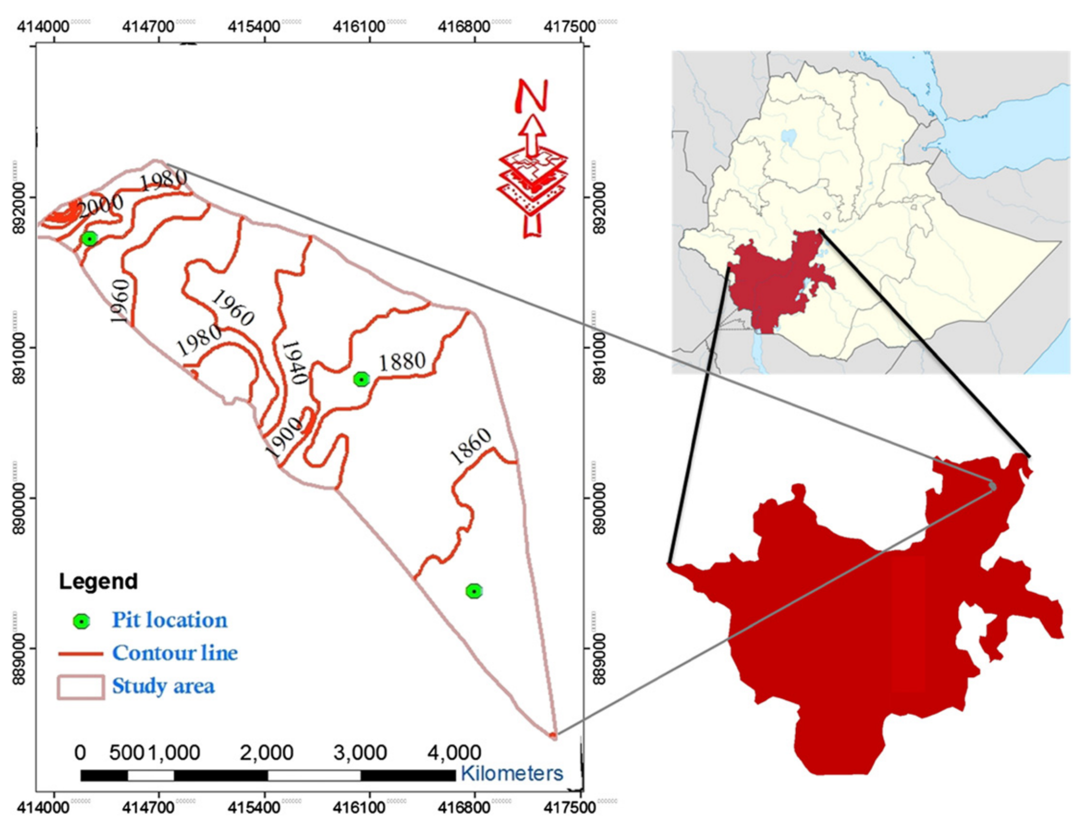

Fig. 1. Location map of the Ele watershed in Ethiopia.