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Soil classification of humid Western Ethiopia: A transect study along a toposequence in Didessa watershed

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ABSTRACT

Little has been studied on genesis and properties of soils in Western Ethiopia. This study was conducted to understand the pedogenesis, and to classify benchmark soils in Didessa watershed along a toposequence. The six soil profiles are representative of low, mid and highland positions within an elevation range from 1273 to 2700 m above sea level along a 53-km long transect. Their pedological processes, soil properties and classification are discussed in context of soil forming factors and sustainable soil use. Melanization, cheluviation (chelation) of organo-mineral substances, oxidation of iron and leaching of iron compounds and basic cations, clay translocation, de-alkalization, and acidification were major pedological processes at the upland soils while erosion took place at shoulder positions. Calcification and pedoturbation (vertization) were major pedological processes in the lowland and melanization was also observed there. The surface horizons of these very deep soils had loam a loamy texture while the subsurface horizons were clayey. Leaching of basic cations increased with elevation. The U.S. Soil Taxonomy classification identified a soil sequence consisting of Typic Hapludults, Typic Ferrudalfs, Typic Rhodudalfs and Typic Hapluderts while the World Reference Base classified the corresponding soils as Ferric Rhodic Alisols, Ferric Rhodic Luvisols, Ferric Chromic Luvisols, and Calcic Pellic Vertisols. Numerical hierarchical cluster analysis identified similar and dissimilar horizons in the soil catena. Ultisols were developed on tertiary basalt at midland, Alfisols were developed on tertiary basalts and granitic gneisses at midland and highland, and Vertisols were developed on alluvium and colluvium at lowland. The relief characteristics, lithologic units, agro-ecology and land use covered by the current study are typical of much of the Western and Southwestern Ethiopia. The study indicated that Didessa toposequence has three soil orders (reference groups) that need different management requirements for sustainable soil use. Thus, the transect serves as a model of soil development and soil management in humid Western Ethiopia.

1. Introduction

Ethiopia has a diverse geological structure and physiography that exhibit remarkable variety and mosaic of landscapes (Henricksen et al., 1984; Schluter, 2000). The country has the elevation range from 180 m below sea level in Danakil depression and costal lowlands to interior highlands that reach 4260 m in Semen Mountains. Climate varies from arid to per humid. Varying combinations of elevations and climatic regimes have resulted in a large number of agro-ecological regions with contrasting physiographic elements and conditions for agricultural production. The diverse soil forming factors and pedogenic processes in turn give rise to different soil groups (Goebel and Odenyo, 1984; Hurni, 1998). The genesis and distribution of soils of Ethiopia are influenced by agro-ecological zones underlain by geology and physiography (Bruggeman, 1984; Henricksen et al., 1984).

Several studies have been conducted to figure out dominant factors controlling soil properties in different physiographic regions of Ethiopia (Gebrekidan and Mishra, 2005; Yimer et al., 2006; Fritzsche et al., 2007; Wauw et al., 2008; Ali et al., 2010; Desalegn et al., 2015). The studies show that soil development along the main Ethiopian rift valley was influenced mostly by relief and climate. In Bale Mountain most of the soil properties were related to topographic aspect and vegetation communities. Topography controlled soil development and characteristics in Southern Ethiopia (Ali et al., 2010). Some studies were also undertaken to investigate the effect of parent materials and moisture regimes on soil development and characteristics. For example, in basalt dominated highland of Tigray of Northern Ethiopia, geology, mass movement and erosion predominantly influenced soil development and

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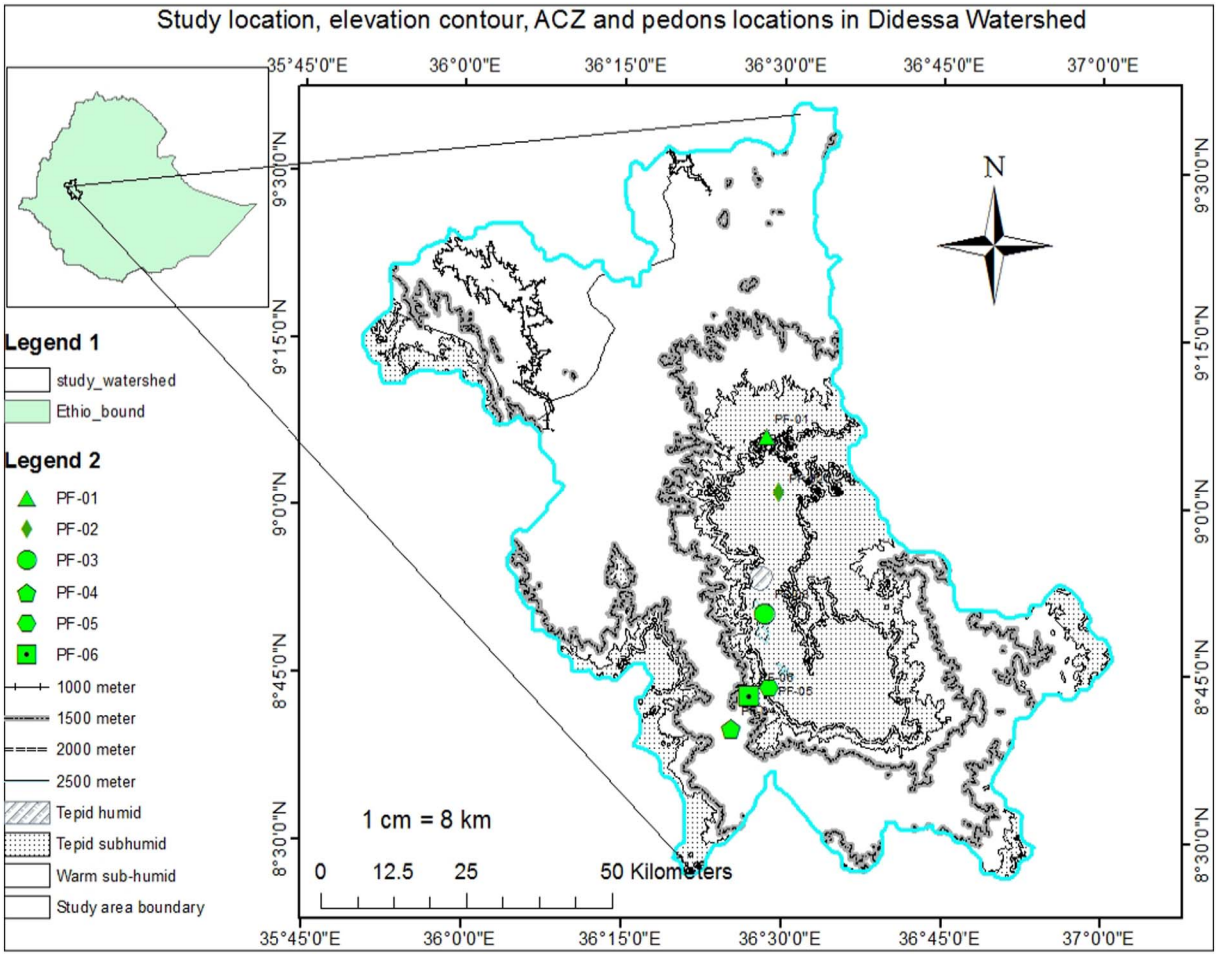

Fig. 1. Location of Didessa watershed, agroecologies and pedons locations along a study transect with 250 meter elevation contour intervals.

variability (Wauw et al., 2008). Essayas et al. (2006) also investigated the effect of ignimbrite and basaltic rocks on genesis and classification of soils in sub-humid tropical highland of Southern Ethiopia. They found formation of Oxisols under udic moisture regime from ignimbrite and basaltic rocks, and Ultisols and Alfisols under ustic moisture regime from ignimbrite parent materials. The studies showed that soil development, expression of pedogenic processes and properties varied with topography, climate, parent materials, vegetation, land use and local site characteristics across varying physiographic regions and agro-ecological zones. The humid physiographic regions of Western and Southwestern Ethiopia have contrasting features from other physiographic regions of the country. Soil developmental studies and properties in these regions are lacking.

The physiography of Western and Southwestern Ethiopian highland regions exhibit unique characteristics in terms of mountainous topography, severe dissection and incision of landforms. The regions receive high precipitation over 240 days per annum and include numerous humid agro-ecologies zones. Intensive network of rivers has exposed diverse rock units of variable lithology and chronology (Henricksen et al., 1984; Hurni, 1998). Various studies conducted in these regions have identified a great number of geomorphic processes involved in landform genesis and parent materials of varying origin and chronology (Henricksen and Wijntje-Bruggeman, 1984; Ayalew and Moore, 1989; Solomon and Mulugeta, 2000; Tadesse and Tsegaye, 2000; Tadesse, 2014.). Schists and gneisses of Precambrian Basement, Paleozoic-Mesozoic rocks, Tertiary volcanics and Quaternary sediments of Cenozoic periods are the major soil parent materials in the region (Ayalew and Moore, 1989; Solomon and Mulugeta, 2000; Tadesse and Tsegaye, 2000; Tadesse, 2014). Topography affects climate, vegetation, movement of materials and energy (Jenny, 1945). Landscape of Western and Southern Ethiopian highlands used to be covered with dense forest and now have become forest free. This is due to expansion of agriculture into marginal steep and forest lands due to population pressure and food insecurity. Almost all landscape positions have become under agricultural crop and livestock production. Land degradation, particularly soil erosion and chemical soil infertility, has become rampant (Conway, 2000; Sima, 2011; Deressa, 2013; Deressa et al., 2013; Oromia Rural Land and Environmental Protection Bureau, 2014a; Oromia Rural Land and Environmental Protection Bureau, 2014b; Siraj et al., 2015).

The soil potentials and vulnerabilities of different landscape positions determine the land use systems. Sustainable land use systems require proper land use planning, secure food production and conservation practices to counteract environmental degradation. Soil properties are the product of soil forming factors and pedogenic processes undergoing in landscapes (Schaetzl and Anderson, 2005). Understanding of pedogenic processes and soil properties are essential for land use planning and prerequisites for proper landscape management. Soil properties and pedogenic processes involved in landscape with multiple state factors (climate, parent materials and topography) can be best studied by soil-landscape interrelationship. A transect study along toposequence is one of the best ways to discern interrelationship between soil properties and landscape positions (Schaetzl, 2013). Land use related analysis and multiple aspects of landscape positions are the current approaches to investigate the poorly described pedogenic processes and soils properties in Western Ethiopia. Didessa watershed is identified as having a suitable landscape for studying the effect of multiple factors on genesis, properties and soil classification.