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Characterization of landscape features of soils of Konso Woreda, Southern Ethiopia

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ABSTRACT

Understanding of the landscape features of agricultural lands and farmers soil management practices is pertinent to verify the potential and limitations of the soil resources; and for devising relevant soil management strategies. In view of this a study was conducted to characterize the landscape features and to identify the local soil management practices in agricultural lands of Konso woreda, Southern Ethiopia. Field survey was conducted and 225 geo-referenced surface soil samples were collected during the off-season of 2014/2015. Semi structured questionnaire was used to collect the required data at the filed level. For data analysis descriptive statics were employed. Results revealed that agriculture has been practiced on diverse slopes (0-95%). The soil fertility management practices indicated the presence of continues cultivation and low rate of nutrient replacement. The mean values of clay, silt and sand contents of the soil samples were 37.92, 24.47 and 37.60% respectively. In conclusion, most of the sampled cultivated fields were managed without fertilization and dominant agricultural land use types were rain-fed cultivation. The contents of silt in the soils were also very low compared to clay and sand separates in the study area. Finally the author recommend, environmentally and socially acceptable integrated nutrient management practices like agro-forestry systems, crop rotation, use of organic inputs, chemical fertilizers, and improved crop varieties that can be adapted to local farming situation should be implemented for sustainable agricultural development in the study area.

Keywords: *Soil fertility mapping, Geo-referenced, ArcMap, MIR spectral and Konso Woreda*

INTRODUCTION

Ethiopia is a land-locked country known as 'Horn of Africa'. It has diversed topography, encompassing mountains over 4000 m above mean sea level, high plateaus, deep gorges cut by rivers and arid lowlands (Ininda and Befekadu, 1987). The country's location in the tropics coupled with impressive altitudinal variations within a short distance allows the country to enjoy both temperate and tropical climates, which gives rise to wealth of biophysical resources (Gashaw, 2015). Similarly, the great variability of Ethiopian highlands gives rise to the formation of different physical landscapes which are in turn the causes for the variations in soil parent materials, agro ecological zones, flora and fauna (Mishra et al., 2004; FAO. 2016). On other hand with an expanding population and the associated intensive land use practices, the highlands are also increasingly under pressure such that land degradation on the form of erosion and top soil loss is wide spread (Dessalegn, 1991). Regardless of these small holder farmers on densely populated highlands of the country produce everything from the soil and very little remains to re-invest in soil fertility replenishment for the following year (IFPRI,2010).Therefore, the success of agricultural production in the Ethiopian highlands is strongly influenced by these unique topographic settings and the underlying biophysical features (Chamberlin and Emily, 2011). In such physiographical heterogeneous Ethiopian highlands which have been extremely disturbed by human interferences, uneven spatial and temporal distributions of agricultural potentials are expected (Belayneh, 2009, Diwediga, 2015). The implication of such heterogeneity is that within a given change in landscape positions and land use types, it is likely that the direction and magnitude of soil properties will also be changed. Generally, many study results revealed that the amount and distribution of most nutrient elements were found to be higher on flat slope categories than steeper slopes (Ali et al., 2010 and Fanuel, 2015). The Southern Nations, Nationalities and

Peoples Regional State (SNNPRS) in Ethiopia is characterized by immense ecological diversity ranging from arid and semi-arid conditions to cool temperate zones. Konso people are own for their traditional land management and conservation practices in mixed farming systems. Despite their long standing traditional land management practices, which are still in use, the land scape features of their agricultural lands was not studied in the woreda. However, the information on landscape feature of Konso Woreda in relation to agricultural productivity not well documented. Therefore, the aim of this research was to characterize the agricultural landscape features of Konso woreda by identifying landscape positions, local knowledge of farmers in soil classification, soil fertility management practices and the textural classes of the soils.

Material And Methods

Description of the Study Area

Location

Konso woreda is one of the126 woredas or administrative districts found within the Southern Nations, Nationalities, and Peoples' Regional State (SNNPRS) of Ethiopia. It is located at the south western part of the country, laying roughly between 5° 15′ 0″ North latitudes and 37° 29′ 0″ East longitudes, at about 600Kms from the national capital Addis Ababa (Figure 1). The name Konso belongs to both the people and the woreda , which covers about a total land area of 2,354 Square kilometers. Total population of the woreda is recently estimated to be about 250,750, from which the male population is estimated to be about 120,693 and the female population is 130,057 (KDA, 2014). Currently, these people live divided into 41 rural kebeles of the woreda, with a population density of about 106 persons per square kilometer area. Livelihood of the people, (well over 96% of the population), is dependent on a agriculture (KDA, 2014).

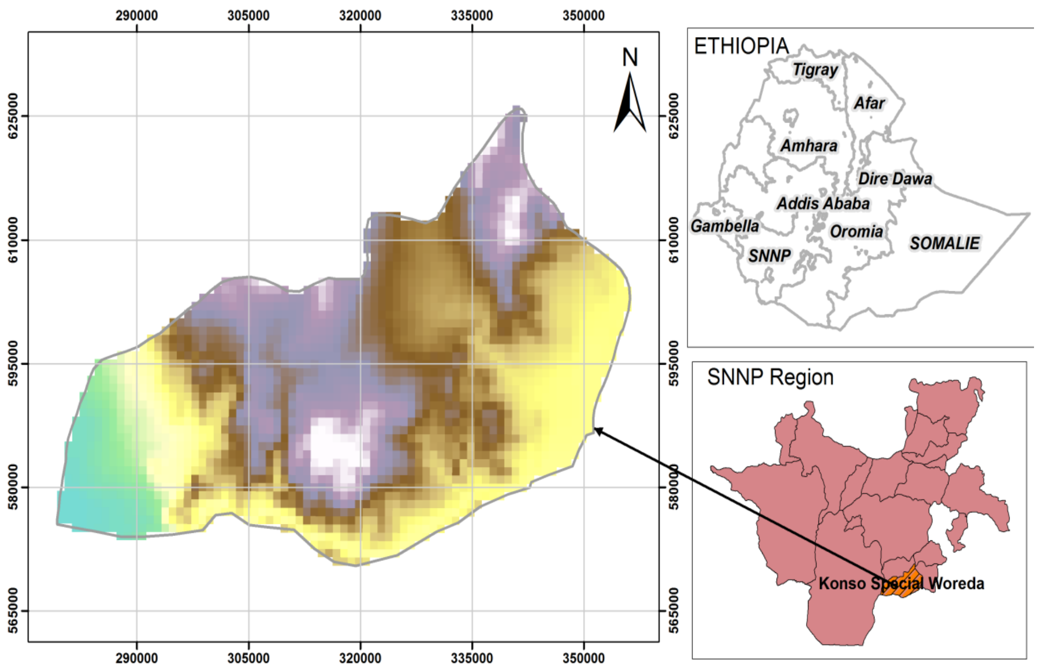

Figure1. *Location of Konso Woreda within the Southern Nations, Nationalities and Peoples Regional State (SNNPRS) of Ethiopia*

Climate

As mentioned by the Konso woreda agricultural office, climate of the woreda in a considerable portion is Kolla or arid (70%) and Woina dega (sub-humid) which is 30% of the total area. The temperature of the area is mostly hot and warm (Ethiopian National Meteorological Agency, 2008). Rainfall distribution follows a bimodal pattern and hence, the woreda has two raining seasons per year. The first raining season (i.e., the main raining season) is from mid February to end of April whereas the second is between August and October. However, despite its pattern, the annual rainfall of the woreda is widely known for its high variability and the poor status in general. The average total annual rainfall of the area is only about 550mm, with the annual rainfall variations between 280 and 880mm (Tadesse, 2010).

Agricultural system of the area is unique. The most immediate and notable feature of their renowned agricultural system is its traditional terracing constructed over large tracts of the rugged landscape. Besides terracing, the most striking features of the agricultural system is, its multiple cropping approaches, which incorporates a combination of different crop varieties, trees and livestock. According to the woreda's agricultural office information, the Konso people practice a mixed farming system. They grow a great variety of cereals such as sorghum, maize, millet, teff, wheat and barley, pulse crops such as haricot beans, pigeon beans, lablab, peas, chickpeas and cowpeas, root crops such as cassava and cash crops such as coffee and chat (chata edulis) together in the fields, while also combining these crops with trees and shrubs (i.e. as in a traditional agro forestry system), they also keep cattle, small ruminants, chicken and donkeys. Livestock is mostly kept in stables and stall-fed from harvests of agro forestry products and mixed agriculture. Generally, the agricultural cycle of the woreda is very much dependent on rainfall. Land preparations start with the first rains in January/February and between August and October. The main cultivation tool is a double-bladed hoe.

Due to the mountainous nature of the woreda and small terraces, ox ploughing is not widely practiced, particularly in the highland areas.

Field Survey and Soil Sampling Techniques

In order to attain the objectives and as the same time to improve the internal validity of the findings, this study was employed under two sequentially operating phases. The first phase generally consisted of using topographic maps, the X, Y coordinate system data, and the GIS and remote sensing applications from the ATA/EthioSIS galleries and open access internet libraries, respectively. Moreover, it helped build a comprehensive picture of the sampling sites and sampling design before field study conducted in the area.

This is because a preliminary site selection was carried out using the X, Y coordinate system data and topographic base map of the study area. 519 tentative sampling data points were generated on the base map of the study area using an equilateral grid sampling design. These pre-defined sampling data points were further stratified into agricultural and non-agriculture lands, assisted by the Google Earth remote sensing pictures. In this way, finally, 313 sampling data points were initially set at every two kilometer radius on the base map of the study area. The sampling data points were distributed in order to represent only the agricultural and/or potential arable land units in the study woreda. Therefore, in order to validate this and also to accomplish the site sampling design, compass aided field survey was carried out in the area from April to August 2014. During the field surveys, history of each sampling site including local name of the sampling site, central GPS location (i.e., lat/long), topography, elevation, slope, existing land use/land cover, surface soil depth, the soil color and its local name, type of fertilizers used, last date and rate of fertilization, crop rotation and the crop residue management practices, estimated yield with and without fertilization and many other features were carefully described and recorded from only 225 sampling data points as showed with the figure below. The remaining 88 were discarded due to their limited representation to the intended sampling land unit.

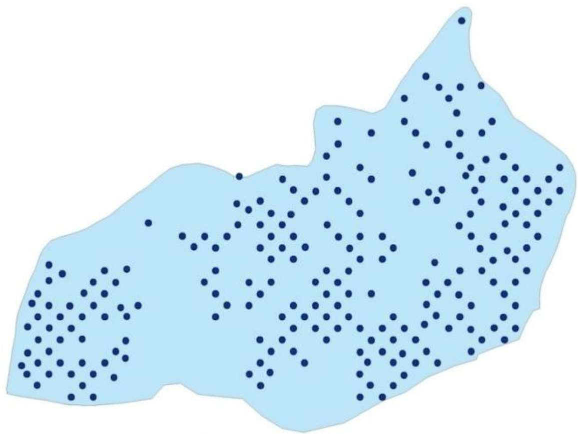

Figure2. *Map showing distribution of sampling points across the Konso Woreda district, SNNPR, Ethiopia.*

The data collection and sampling site description was carried out using a standard data recording and site description template that was adopted from the Ethiopian Agricultural transformation Agency (ATA), EthioSIS Project (Appendix Table 1&2). Based on the list of arranged questions, key informants particularly farmers and development agents (DAs) were interviewed at every sampling point mainly to gather basic information about the history of land use/land cover and soil fertility management practices. A hand held GPS tablet was used to record the easting (longitude), northing (latitude) and elevation points. Slope was measured by clinometer. The soil colors of the sites were recorded through visual observation.

Soil Sampling

From each site, soil sampling was carried out through a composite sampling technique. To make one composite soil sample, eight sub-sampling plots were systematically placed in 15m radius from each central point in equal distance from the centre in a spatially stratified manner (i.e. as indicated in Figure 3). In this way, to make one composite soil sample, 9 subsamples including from the central point were augered from the surface soil (20cm) and well mixed in a bucket. Totally, 225 composite soil samples each weighing about 1kg was collected from the study area and taken to laboratory for processing and analyses. The soil samples were taken considering locations having similar soil types, topography and history of similar land use or land utilization type (LUT).

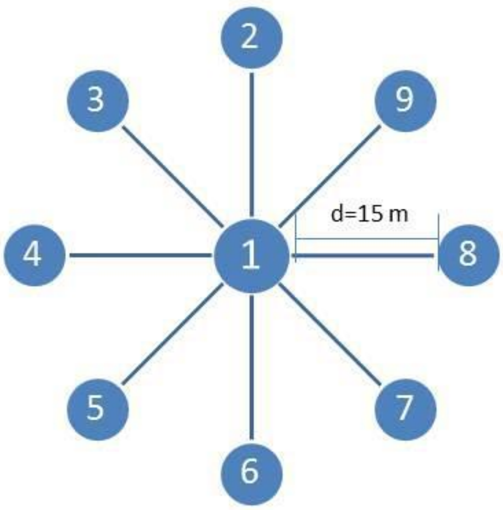

Figure3. *Diagram showing the soil sampling design (adopted from EthioSIS)*

Soil Sample Analysis

All soil samples collected from the study area were air-dried, ground, and passed through a 2 mm diameter sieve for the analyses of different parameters using conventional and state of the art laboratory methods. The laboratory analysis was carried out both in the National Soil Testing Center (NSTC) of Ethiopia and at the Yara International laboratory in London.

Among the major soil parameters analyzed at the NSTC were soil texture, pH, Electrical Conductivity (EC), soil organic carbon and total nitrogen contents. Soil texture was analyzed by the lazer diffraction method as described by Agrawal et al. (1991). The pH of the soils were measured in water and potassium chloride (1M KCl) suspension in a 1:2.5 (soil:liquid ratio) potentiometrically using a glass-calomel combination electrode (Van Reeuwijk, 1992). The electrical conductivity (EC) of the soils was measured from a soil water ratio of 1:2.5 socked for one hour by electrical conductivity method as described by Sahlemdhin and Taye (2000). In addition, the soils were ground with mortar grinder to powder the soil to very small size less than 0.5mm. The ground samples were loaded in well and for one sample there were four consecutive wells of an aluminum micro plate having 96 wells and smoothed on the surface with glass rod. Absorbance spectra of entire soil samples were measured using OPUS version 7.0 software in the middle infra red (MIR) spectral range of 2500-25000nm, which were used to analyze additional soil properties.

Data Analysis

In this study, the results of the survey studies on field topographic characteristics, land use/land cover features and soil fertility management practices were used to characterize the physiographic features, and the results of soil laboratory analyses were used to characterize and rate the soils fertility status based on the EthioSIS guideline. Descriptive statistics such as frequency, minimum and maximum values, mean, standard deviations, coefficient of variation (CV), and percentage values were computed for the different variables. All the statistical analyses were carried out using Microsoft excel and statistical package for social sciences (SPSS) software version 20. And the results were presented using tables.

Results And Discussion

Physiographic Features of the Study Landscape

Field Topography

Descriptive summary of topographic parameters are presented in Table 1. Visual interpretation of the results indicates that, out of the total sampled landscape points (n=225), about 11.1% were found to be flat plains with a surface slopes of 0-1%. The remaining 88.9% included almost flat plains with long smooth slopes of 2-3%, gentle grounds with long smooth slopes of 4-8%, undulating areas with short slopes of 6-8%, strongly sloping grounds with long smooth slopes of >8% and hilly slope grounds with the surface slopes of >16% (Table 1). The result showed that the minimum and maximum elevation points of the study fields ranged from 541 m to 1805 m above sea level (Table 1).

Table 1. *Descriptive summary of topographic parameters in Konso Woreda, Southern Region, Ethiopia. Source: My personal computation.*

Land Forms	Frequency (n)	Percentage of total	Surface slope (in %)			Elevation	
			Min.	Max.	Average	Min.	Max.
Flat plain	25	11.1	0	1	0.80(±0.41)	541	1611
Almost flat plain	40	17.8	2	3	2.60(±0.50)	556	1795
Gently sloping ground	36	16.0	4	8	6.42(±1.48)	544	1743
Hilly sloping ground	59	26.2	18	95	40.29(±17.46)	553	1805
Strongly sloping ground	60	26.7	8	16	12.38(±2.38)	560	1803
Undulating short slope areas	5	2.2	6	8	7.20(±1.10)	955	1440

Min=Minimum, Max=Maximum, and n=total number of observations. The average surface slope gradient values were presented along with the standard deviations

Land Use/Land Cover Features of the Study Area

Based on the data obtained from the total number of surveyed fields, six major agricultural and/or potential agricultural land use/land cover features, namely rain-fed cultivation, irrigated cultivation, fallow lands, grazing lands, bush lands and shrub lands were identified (Table 2). It is observed that the most dominant agricultural land use type of the study area is rain-fed cultivation which includes sorghum, teff and maize monocropping, and also mixed crop fields of these annual cereal crops with different pulse crops such as pigeon pea, haricot bean and cowpea and tree species like Moringa (local cabbage), Terminalia spp., Chat (Chata edulis), coffee, fruit trees and Acacia species. In total, 52.2% of the sampled landscape units belonged to this land use/cover type, and very little space is occupied by grazing areas (i.e about 2.2%), irrigated fields (8.4%) and fallow lands (8.4%) (Table 2).

Table2. *Summary of existing agricultural and/or potential agricultural land use and land cover features by topographic categories in Konso Woreda, Southern Region, Ethiopia.*

Land use	Dominant cover crops	Frequency	Percentage
Fallowing lands	Fallow	19	8.44
Grazing lands	Grasses	5	2.22
Irrigated Cultivations	Maize	19	8.44
Bush lands	Bushes	33	14.67
Rain-fed Cultivations	Maize	8	3.56
	Sorghum	60	26.67
	Teff crops	13	5.78
	Mixed; S+M, S+M+T, S+M+ pulse crops + different tree plantations	32	14.22
Shrub lands	Shrubs of Acacia species	36	16.00

S=Sorghum, M=maize, and T=teff.

Soil Fertility Management Practices of the Study Area

In the study area, the soil fertility management practices have also different patterns in accordance with the differences in use of the land use type. However, in general, the findings of this study indicated that small amount of farmers (20.89%) practiced crop rotation to maintain the positive effects of fertilizers for better growth and yield of crops. The result in the present finding indicated that 42.2 % of crop residues were removed from sampled agricultural fields and limited amount (40%) of the sampled cultivated fields were remained the crop residue in the soil system that could replenish the soil. This implies a negative impact on the building up of soil OM and plant nutrient restoration processes, as residues are important for recycling of plant nutrients into the soil system (Gajic et al., 2006; Buyinza and Nabalegwa, 2011). The low soil OC contents than adequate level in the study area (Table 6) also confirms this speculation. Overall, about 3.56 and 18.67 % of sampled cultivated fields were managed with inorganic (Urea & DAP) and organic (FYM) fertilizer types, respectively. And the rest 77.78% of sampled cultivated fields were managed without fertilization (Table 3).

Table2. *Soil fertility management practices by land use categories in Konso Woreda, Southern Region, Ethiopia. Source: my personal computation.*

Soil fertility management practices	Number of observations by the land use categories						Total number of observations	Percentage
	FL	GL	IC	BL	RC	SL		
Crop Rotation (N=225)								
Yes	0	0	0	0	47	0	47	20.89
No	16	0	19	0	61	0	96	42.67
No Answer	3	5	0	33	5	36	82	36.44
Crop residue management (N=225)								
Clear	1	3	18	0	73	0	95	42.22
Burn	0	0	0	8	28	4	40	17.78
Remain on the field	18	2	1	25	12	32	90	40.00
Soil fertilizer usage (N=225)								
Inorganic fertilizers (Urea & DAP)	0	0	1	0	7	0	8	3.56
Organic fertilizers (FYM)	0	0	0	0	42	0	42	18.67
No fertilization	19	5	18	33	64	0	175	77.78

FL= Fallow land, GL= Grazing land, IC= Irrigated cultivation, BL=Bush land, RC=Rain fed cultivation, and SL=Shrub land.

Status of Soil Variables

Soil Particle Size Distribution of the Study Area

The mean values of clay, silt and sand contents of the soil samples collected in the woreda were 37.92, 24.47 and 37.60%, with standard deviations of 21.85, 8.55 and 22.28%, respectively. The clay content ranged from 8.10 % to 93.48 % indicating an increase towards the middle and lower elevation sites. Generally, clay size fraction followed by sand fraction dominated the study area. According to Buol et al. (2003), high clay content is an indication of complete alteration of weatherable minerals into secondary clays and oxides. On the other hand, the contents of silt in the soils were very low compared to clay and sand separates (Table 4).

Table 3. *Descriptive statistics for soil particle distribution in Konso Woreda, Southern Ethiopia*

Soil particle size distribution (%)	Statistics (N=225)			
	Minimum	Maximum	Mean	Std. Deviation
Sand	1.69	82.00	37.60	22.28
Silt	3.23	59.24	24.47	8.55
Clay	8.10	93.48	37.92	21.85

N=total number of observation

Conclusions And Recommendations

In conclusion, most of sampled cultivated fields were managed without fertilization. Most dominant agricultural land use type of the study area is rain-fed cultivation. The contents of silt in the soils were very low compared to clay and sand separates in the study area. The soils of the study area were identified moderately alkaline and neutral in reaction.

The variations of soil chemical properties among different Land Utilization Types indicate the risk to the sustainable crop production in the area. Therefore, findings of more research work on nutrient management with indigenous practices such as, composting, crop rotation, biomass transfer, etc. and improved practices such as chemical and organic fertilizers and improved crop variety complemented with strong land use policy and alternative rural energy sources should be integrated into a strategy for sustainable agricultural development in the Konso Woreda.

Creating public awareness about integrated and sustainable soil fertility management in general, maintenance of soil OM in particular, has to be done. Moreover, environmentally and socially acceptable integrated nutrient management practices like agro-forestry systems, crop rotation, use of organic inputs, chemical fertilizers, and improved crop varieties that can be adapted to local farming situation should be implemented for sustainable agricultural development in the study area.

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LIST OF ABBREVIATIONS (ACRONYMS)

- AB-DTPA - Ammonium Bicarbonate-Diethylene Triamine Pentaacetic Acid
- ARCCH - Authority for Research and Conservation of Cultural Heritages
- ATA-Ethiopian Agricultural Transformation Agency
- CaC_{O4} - Calcium carbonate
- CSA -Central Statistics Agency
- EDTA -Ethylene Diamine Tetraacetic Acid
- EthioSIS-Ethiopian Soil Information System
- FAO - Food and Agriculture Organization
- GIS - Geographical Information System
- IFDC--International Fertilizer Development Center
- IFPRI-International Food Policy Research Institute
- MIRS -Mid-Infrared Spectroscopy
- PADEP-Peasant Agricultural Development Program
- PIF - Policy and Investment Framework
- SG200 - Sasakawa Global 2000
- SNNPR-South Nation, Nationalities and Peoples Region
- *SSA-Sub-SaharaAfrica*

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