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Evaluating the effect of agroforestry based soil and water conservation measures on selected soil properties at Tembaro district, SNNPR, Ethiopia

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Research Paper

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This study was aimed at evaluating the changes on bulk density, and soil moisture content. Three residence time Soil-water conservation (SWC) structures and control land use type: Agroforestry based SWC for 7 and 3-years residence, physical barriers of SWC for 3-years residence and non-SWC land use types with three replications from the sampling frame. Soil samples for bulk density, and moisture content determination were collected from upper, middle, and lower positions of the structures by using an 'X' design and then averaged for each experimental plot. The results showed that except for bulk density which was significant only in the 30-60cm depth layer in case of no-SWC land use type's soil moisture content showed significant variations. However, there was no interaction effect between land use types and depths across all the parameters considered. Soil moisture content generally conservation of 7-years residence land use types with low increased in the Agroforestry based soil and water values of bulk density. In contrast, no-SWC land use type showed the lowest value in moisture content but with highest bulk density value. The significant variations in soil moisture content among the treatments can be attributed to differences in soil carbon contents, and other soil attributes found within the Agroforestry based land use systems compared to the conditions in the non- Agroforestry based practices. It can therefore be recommended that effective SWC measures should be integrative systems where one can integrated both the physical and biological SWC practices simultaneously for improved land health.

Key words: Agroforestry, soil and water conservation, bulk density, soil moisture.

INTRODUCTION

In Ethiopia, population increases in alarming rate and this increasing population pressure is identified as the major driving factor of deforestation (Badege and Abdu, 2003). Poverty and natural resources/environmental degradation tend to negatively reinforce each other; that is, as the land is degraded, agricultural productivity is lowered, resulting in decreasing incomes and food security and vice versa (Wakene and Heluf, 2000). This has resulted in migration of rural poor to urban centers; increased cultivation of marginal lands; encroachment into forest regions; and depletion of land resource base of small holders (Demel *et al.,* 2000). Moreover, the country's topographic nature has made it more liable to degradation (Girma, 2000).

Degradation of land is a vital issue throughout the world with the particular references to African countries as it threatens agricultural productivity. In recent years the effects of inappropriate agricultural, pastoral, and silvicultural practices throughout the world have become increasingly apparent. Erosion as one of a number of forms of soil degradation, including deterioration of physical, chemical and biological properties, all of which require attention (Young, 1989). Therefore, the problem of soil erosion could be socio-economic and/or environmental issue, (Morgan, 1995). Bureshi and Tian (1998) reported that the loss of soil fertility, soil erosion, and land degradation, has forced to search for more sustainable systems.

Agroforestry as, a land use system is receiving greater attention in many countries to protect the land from various types of degradation. AF technologies/practices offer considerable benefits for the long term agricultural sustainability (ICRAF, 2004), it is a tool for achieving sustainable agricultural farming and improving the quality of life of the affected communities while simultaneously reversing the process of environmental as well as land degradation (UNCCD, 2003), it is a dynamic ecologically based natural resources management system (Young, 1989).

Agroforestry approaches is one of the best management practices of natural resources (Mohan *et al.,* 1999) which can be foundations for improving economic growth as well as environmental protection. Agroforestry has also the potential to increase the production of food, fuel wood, building materials, and fodder while arresting soil erosion and fertility decline (Young, 1989;Nair, 1993) that is why it is an integrated approach that satisfies all the needs of farmers (Abdu,1997). There are different kinds of AF systems like improved fallows, contour hedgerows and others involving permanent cover play an important role in arresting and reversing land degradation via their ability to improve chemical as well as physical properties of the soil (Young, 1989; Styczen, 1985; Nair, 1993; Rao *et al.,* 1998; Udawatta *et al*, 2002) forinstance, two and three-year *Sesbania sesban*-based crop production have proved highly effective in soil fertility restoration in Zambia (Chinangwa, 2006),leguminous trees based agricultural systems has potential to reduce soil erosion(Young, 1989; Nair, 1993). Similarly, Lal (1997) reported that the cover measure involving the use of vegetation for soil protection, maintains the hydrological balance in which the surface run-off component in the hydrological cycle would be minimized. In the same way, Juo and Thurow (1998) reported that from their findings the vegetative barriers are generally used in combination with mechanical land treatments such as micro catchments and trees/shrubs improve the physical properties of soils e.g. soil aggregation is higher in fields where trees are being grown which enhances water infiltration and water holding capacity of soils (Ajayi *et al.,* 2008), AF systems also enriches the soil fertility by providing organic matters which helps water to infiltrate, increasing soil fauna and flora, lower bulk density when compared to the bare soil (Karlen and Stott, 1994; Rao *et al*, 1998; Dexter, 2004; Fikadu, 2006; Acharya and Kafle, 2009) and improves the chemical eproperties of the soil such as organic matter has long been recognized to improve soil fertility that is why it plays a pivotal role on essential soil functioning (Lal, 1997; Maritus *et al*., 2001;Brady and Weil, 2002). Gruhn (2000) reported that AF practices that add organic matter reduce erosion, improve infiltration; etc will generally improve soil physical (Bureshi and Tian, 1998Haynes, 1999; Brady and Weil, 2002;Ouedraogo, 2004;) and chemical properties (Juo and Thurow, 1998;FAO, 2001; Martius *et al*., 2001; Udawatta *et al*, 2002;Hasani *et al.,* 2006). Therefore, management of soil organic matter is important in alleviating land degradation and improving crop performance (Sanchez and Miller, 1986; Rao *et al.,* 1998). In the Tembaro district in southern Ethiopia where the present study was carried out, virtually null studies have been undertaken on integrated biological and physical SWC activities. Tembaro district is experiencing an ongoing destruction of natural resources and aggravated land degradation. Soil erosion is a major constraint to natural resources management and sustainable agriculture in Tembaro district where the landscape is very undulating. Consequently, soil erosion goes unabated resulting in declining productivity of the subsistence farming on which the majority of the population depends on. While agriculture remains the basis of the economy, productivity is significantly limited because of the severe land degradation. In the district, to curb the problems, several approaches such as rehabilitation of degraded lands, reforestation, and integrated physical and biological SWC practices were introduced to the area by governmental and non-governmental organizations of which MERET project (WFP) is one. Integrated SWC activity was one of the paramount components of the project: an approach that uses agroforestry multipurpose trees and shrubs (banana, *Gravelia robusta*, *Cajanus cajan*, *Susbania susban*, *Cordia africana*, in combination with grasses (disho grass which is the native grass of Ethiopia) etc were planted with integration of physical structures (soil bund, *Fanaya juu*, trench…etc) to form developed terraces.

The objectives of this study was to evaluate changes on SOC under different land residence types with and without AF based SWC measures and to assess the effects of AF based SWC measures on some selected physical soil properties(bulk density, soil moisture content and soil water infiltration. Research hypothesis was: AF based SWC practices will promote positive impacts on soil property dynamics in highly impacted environments.

MATERIALS AND METHODS

Study site and Experimental lay out

The study was carried out in Tembaro district, Kembata

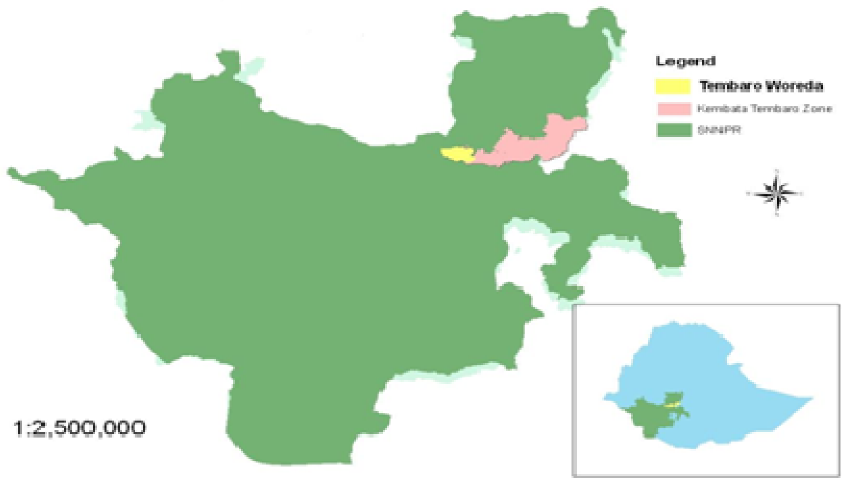

Figure 1.Map of the study area.

and Tembaro zone, Southern, Ethiopia. Tembaro district is located at about 410km and 180km south of Addis Ababa and south west of Hawassa respectively and geographically, it is located between $32^{0}98'$ E to $34^{0}29'$E and $8^{0}08'$N to $8^{0}9'$N. The altitudinal range of the study site is between 659 and 2600 meter above sea level and has a mean annual precipitation varies from 935 mm to 1877 mm. The estimated mean annual temperature ranges from 20^{o}c to 30^{o}c.

The common soil of the district is alfisols (BoFED, 2004), soils with a base saturation of 50% or more through the argilic B-horizons within 125cm of the surface (Mesfin, 1998). Alfisols is the soils with wide range of parent materials such as volcanics, metamorphics, and granites materials, sandstones and limestone (Mesfin, 1998; Brady and Weil, 2002). Alfisoils is one of the most intensively utilized bodies of soils in Ethiopia. In nature, alfisoil has high weathering property, so it needs immense management practices that probably ensure the protection of soil from erosion and maintenance of overall soil quality (Brady and Weil, 2002). This has great implications to conservation of alfisols (Mesfin, 1998). Tembaro district was known by its natural forest mainly found in the periphery of Omo River and near to the main town of the district ('Lamo' natural forest,) and the plantation forests in degraded areas.

The native forest of this study area is dominated by *Cordia africana*, *prunus africana*, *Albizia gummifera*, Eucalyptus species, Ficus species, *Croton macrostachus*, *Gravelia robust*a, Acacia species, and other various native vegetations are also found widespread in the area. Virtually, at high land mid land agro-ecology the ground cover is rich in herbaceous plants and the farming systems combines' crop and animal husbandry with grazing carried out mainly on the communal grazing fields and on farm land after harvest (Figure 1).

Field sampling sites were selected within three peasant association. From the selected sites three residence time SWC structures and control land use type: AF based SWC for 7-years residence (T1), AF based SWC for 3-years residence (T2), physical barriers of SWC for 3-years residence (T3), and non-SWC land use types (T4) with three replications from the representative sites were used. The experiment was laid down in randomized complete block design (RCBD) with simple factorial design with three replications where locations served as blocks containing all treatments. The experiment had a total of 72 (4trs*3rpn*3slope positions of the structures *2 depth layers) sampling units on which soil samples for studying bulk density was collected. Similarly, the same locations were used to collect data from measurements on moisture content using TDR.

Sampling design and analysis

Determination of soil bulk density

To determine the soil bulk density, soil samples from undisturbed soil by using augur were taken and then oven dried to determine the bulk density of the representative land use system from two depth layers (0-30 and 30-60 cm) across all treatments and replications.

Determination of soil moisture content

The data collection for soil moisture change was done simultaneously with data collection for soil bulk density in all land uses in each of the respective sites. The moisture

Table 1. Mean values of BD and MC at the soil depths across different residence time for SWC structures.

Soil properties	Depth(cm)	Treatments				
		T1	T2	T3	T4	ANOVA
BD (gcm^{-3})	0-30	$1.127{+}0.010^{a}$	$1.120{+}0.020^{a}$	$1.140{+}0.020^{a}$	$1.187{+}0.030^{a}$	ns
	30-60	$1.137{+}0.010^{b}$	$1.150{+}0.040^{b}$	$1.170{+}0.030^{b}$	$1.233{+}0.010^{a}$	*
MC (%)	0-30	$18.500{+}3.090^{a}$	$15.567{+}1.970^{ba}$	$10.967{+}1.700^{c}$	$19.967{+}2.77^{a}$	**
	30-60	$19.633{+}1.970^{a}$	$19.967{+}2.77^{a}$	$15.767{+}1.440^{a}$	$18.533{+}2.500^{a}$	ns

** and * denotes highly significantly and significantly different respectively and ns denotes not significantly different at $p < 0.05$ T1, T2, T3, and T4: agroforestry based SWC for 7-yrs residence, agroforestry based SWC for 3-years residence, physical barriers for 3-yrs residence, and control land use type respectively.

content of the soil was measured using Time-Domain Reflectometry (TDR). Soil moisture was measured at two depth layers (0-30 and 30-60 cm) and three sites within the respective plots and a mean of the measurements was used as the moisture content for the described treatment (land use). The TDR reading was registered directly on the field.

Statistical analysis

Statistical differences were tested using two way analysis of variance (ANOVA) following the General Linear Model (GLM) procedure of SAS version 9 for windows (SAS, 2004) .Least Significant Difference (LSD) test was used for mean separation when the analysis of variance showed statistically significant differences (P<0.05) between the investigated parameters with in treatments.

RESULTS

Soil Bulk density and Moisture content

There were no significant differences (*P<0.05*) in bulk density across all treatments and depths except for the 30-60 cm depth in the no-SWC plots. The 30-60 cm depth showed marginally significant higher values compared to the other treatments. All in all, the AF based SWC with 7-years residence time had the lowest bulk density with values (1.127±0.010, 1.137±0.010) at 0-30 cm and 30-60 cm respectively while the no-SWC had the highest bulk density with values (1.187±0.030, 1.233±0.010) at 0-30 cm and 30-60 cm respectively. Generally, the bulk density values were low in value (1.120±0.020 to 1.233±0.010) showing less comparison problems due to mainly alfisols of volcanic origin.

The soil moisture content differed significantly (*P<0.05*) for plots of AF based SWC with 7-years residence time compared to other treatments at the upper soil layers (0-30 cm). Likewise, there was also significant differences (P<0.05) between the 3-years AF based SWC treatments with values (13.767 ± 1.870) and plots with no conservation measures with values (10.967±1.700) for top soil depth layer (0-30 cm). Since the differences in bulk density is not significant among the treatments except for 30-60cm depth layer in no-SWC land use types, the SWC difference could be attributed to difference on the level of organic matter in the soil of the different SWC structures residence time (Table 1).

DISCUSSIONS

Bulk density and moisture content

The results revealed that land use types had no significant effect on bulk density for both depth (0-30 and 30-60 cm) layer except for 30-60 cm depth in no-SWC land use types. Probably, this can be attributed to the soil origin of the volcanic nature.

Although no statistically significant difference in bulk density was observed between the land uses types, high bulk density value for non-SWC land use types was recorded while AF based SWC for 7-years had lowest values. This is in line with the findings which indicated bulk density decreases as organic matter increases (Heuscher, 2005). Because soil bulk density is greatly influenced by tree based systems (Jiregna *et al*., 2005) and generally, as reported by (Gebeyahu, 2007) who noticed that management practices that can accumulate organic matter on the soil and modify soil properties such as bulk density which is in agreement with this study.

Vegetated land uses are expected to have comparatively healthy soil characteristics that may affect both the soil infiltration and water holding capacities. The increases in the soil moisture, although bulk density remained similar, can be attributed to the presence of litter in the AF based SWC plots. The addition of organic matter through the litter fall from tree and shrubs had improved the soil physical conditions which in turn had increased the water holding capacity and thus the soil moisture content.

The results obtained from this study are in agreement with the findings reported by other researchers (Hurni, 1993; Thierfelder and Wall, 2009; Reicosky, 2005 cited by Gebeyehu, 2007). The organic carbon in managed farming system influences the physical conditions of a soil in several ways which increase soil moisture content. Ajayi *et al* (2008) reported that organic matter in tree based systems leads to increases in soil water retention capacity. Thus, aggregation is higher in trees/shrubs AF system and this enhances water infiltration and water holding capacity. (Acharya and Kafle, 2009; Kandji *et al.,* 2006) reported that soils under tree/shrub based systems enriched in organic carbon (OC) can retain soil moisture which makes the water table high.

The soil moisture content at 30-60 cm depth was consistently higher than the soil moisture content at 0-30 cm soil layers in all the treatments. This may be partly due to loss of soil water by evaporation because of exposure. In line to this, Fua (2004) who indicated that the sub soil moisture content was greater as compared to topsoil layers owing to evaporation**.**

CONCLUSION

The results of this study elucidated that AF land use has a significant effect on the different soil physical properties such as, bulk density, and soil moisture content. AF based systems have showed significant improvement in the selected soil properties as compared to the physical barriers for SWC and no-SWC land use types. Moreover, the long lived of AF based systems affect more positively the soil properties as compared to the rest of the land use types but, AF based SWC and physical barriers of SWC for the same 3-years have showed more or less similar results in soil moisture content. Contrary to this, high bulk density, and low soil moisture content were recorded for the no-SWC land use types. Generally, the effects of AF based SWC land use types on soil conservation, particularly early managed tree/shrub based land use types at Tembaro district were found to have pronounced effects on soil properties.

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