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Effects of integrating different soil and water conservation measures into hillside area closure on selected soil properties in Hawassa Zuria District, Ethiopia

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Land degradation is a serious global problem. Pursuant to the alarming environmental degradation, the government and non-governmental organizations have implemented various land rehabilitation programs. Among this the predominant one is area closures, through tree-planting and physical conservation measures such as terracing. This study was designed to investigate the impact of integrating soil and water conservation (SWC) measures into the area closure on the selected soil properties based on comparative analysis between closed area with SWC, closed area without SWC and open grazing land. A total of 30 composite soil samples from 0 to 15 cm depth were collected with 10 replications from each land uses. Soil parameters such as bulk density (BD), soil moisture content (MC), soil organic matter (SOM), total nitrogen (TN), pH, electrical conductivity (EC) and texture were analyzed. Data was analyzed statistically by using SPSS software packages. Mean comparison were made by using Tukey HSD test at P = 0.05. Results showed that higher mean MC, SOM and TN were recorded under closed area with SWC than closed area without SWC and open grazing while mean EC and pH were comparatively lower under closed area with SWC. Texture, BD and C/N ratio shows no significant variation with land uses. These results indicated that integrating SWC measures into area closure have a potential to improve soil properties. The findings generally suggest that integrating SWC measures into area closure was found to be the better option to improve physico-chemical conditions of degraded lands. Additional research was also recommended for practical generalization considering other variables like vegetation parameters that were not addressed in this study.

Key words: Area closure, soil and water conservation, grazing land, soil, degradation.

INTRODUCTION

Land degradation is a serious global problem, which causes the world's 8.7 billion ha of agricultural land, pasture, forest and woodland that accounts nearly 2 billion ha (22.5%) have been degraded since 1950

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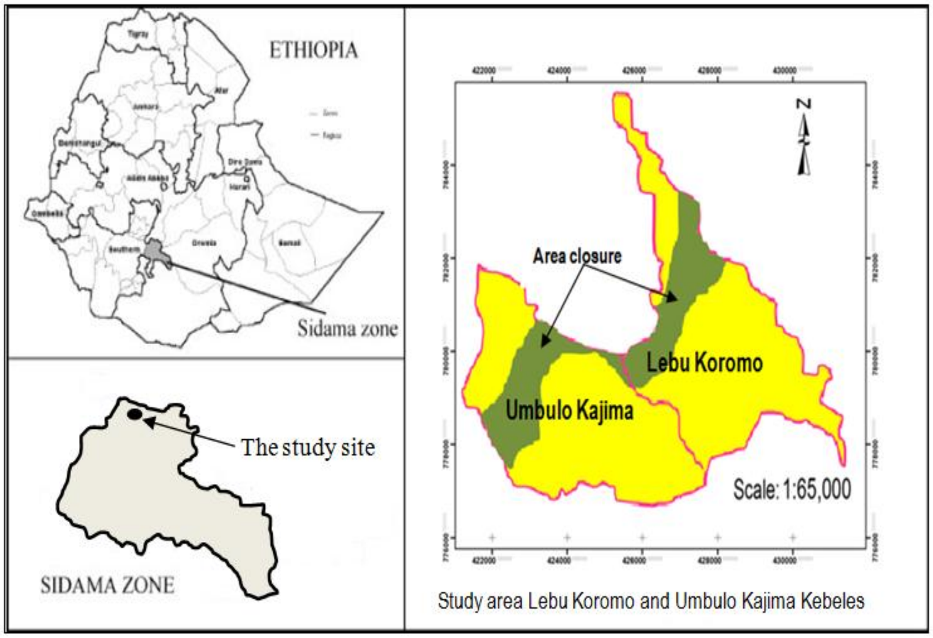

Figure 1. Map of the study area.

(Buckwell, 2009) and 5 to 10 million ha (0.36 to 0.71% of global arable land) are lost every year to severe degradation (WEF, 2010). Scherr and Yadav (1996) indicated that if such a severe trend of land degradation continues, 1.4 to 2.8% of the total agricultural, pasture and forest land will be lost by 2020.

Ethiopia has to struggle with numerous socio-economic and environmental challenges to achieve sustainable development. Land degradation is a typical phenomenon in many parts of the country. The expansion of agriculture, especially towards the steeper slopes due to ever-growing population, has accelerated soil erosion and land degradation (Daniel, 2002; Descheemaeker et al., 2006; Menale et al., 2008). In order to address the problems due soil degradation, biomass scarcity and loss of biodiversity, the reforestation/afforestation of degraded lands is often seen as the most effective rehabilitation technique in the tropics in general and Ethiopia in particular (Mulugeta and Demel, 2004). Among the various techniques of rehabilitation used, the predominant one probably is area closures, through tree-planting and physical conservation measures.

Ethiopian highlands in general and Hawassa Zuria in particular are susceptible to land degradation on account of climate, topography and population pressure. For centuries, people have exerted large-scale changes on the hill side landscapes, primarily through deforestation, uncontrolled grazing, and agriculture practice. These anthropogenic impacts have resulted in heavy degradation mainly on the hilly landscape of Hawassa Zuria. Large scale deforestation on hilly slopes generates soil erosion which results in loss of nutrient-rich top soil and thereby reducing the crop yield. At the same time rapid run-off would reduce recharge of ground water, while siltation affects water reservoirs and lakes as it is the upper catchment of Awassa lake. Cultivated lands are also affected by wide and deep gullies. Hilly areas are severely degraded, rocky outcrops are commonly observed. Consequently the local community faces food insecurity, shortage of water, forage and fuel wood (MoWR, 2009).

To solve these problems a project known as "Sustainable Management of Soil, Forest and Water Resources as a pilot model for the rural development in SNNPR, Ethiopia" was imitated by CDA in 2008. The project aims were oriented on the application of area closure to enhance soil protection against water erosion through biological and physical measures and support water management. Therefore, this study intended to investigate the effect of integrating physical and/or biological SWC measures into the hillside area closure to restore the degraded area in the Umbulo Kajimma and Labu Koromo kebeles, Hawassa Zuria District.

METHODOLOGY

Description of the study area

This study was carried out at Umbulo Kajimma and Labu Koromo kebeles in Hawassa Zuria District, in the southern Ethiopia. Umbulo Kajimma kebele and Labu Koromo Kebeles are located in (7° 1' 45'' N, 38° 16'30'' E) and (7° 6' 30'' N, 38° 22'45'' E) (Figure 1). The total population in the area is rural dwellers with a population density of 465.5 people/Km^2 (MoWR, 2009). In terms of agro-climatic zone, Hawassa Zuria district falls within dry *woina-dega* (or mid altitude) category. There is no river that flows through the district. The only water resource available is Lake Hawassa, one of the biggest lakes within the rift valley. The mean altitude of the district is 1,700 m above sea level and the annual rainfall ranges between 900 to 1400 mm. The rainy season spreads from March through September. Mean annual temperature ranges from 23 to 27°C (EOSA, 2007). Well drained eutric and hablic cambisol are the dominant soil types and excessively drained, deep to very deep, medium and course textured vitric Andosols are also developed on flat to gently undulating topography and rolling plain. The major landforms identified in the study area are level plains, rolling plains, hills, elongated escarpments and mountains with slopes ranging from level to very steep slopes (0 to 30%) (MoWR, 2009).

The natural vegetation in the area can be described and characterized in to two distinct categories. The one is dry afro montane vegetation occurring at higher altitudes of the hilly slopes. The second vegetation type is the lowland acacia woodlands occurring at the lower landscape of the hilly sides. Those woodlands in the highlands have a remnant tree also of high forest species which are sparsely available. However, because of high population pressure and extreme land shortage these forests are seriously threated by agricultural conversion and over grazing. The major woody species dominating the area are acacia species, *Albizia gummifera, Albizia schimperiana, Balanites aegyptiaca, Croton macrostachyus, Ficus sycomorus*, *Maytenus undata, Rhus natalensis* are common (Figure 1).

Sampling and data collection method

A reconnaissance survey was conducted to get the general overview of the area and to identify the study site containing both biophysically conserved and non-conserved adjacent areas having similar histories. According to the information provided by local elders, 50 years ago the whole hillside was fully covered with forest that has been degraded with time due to lack of ownership. Peoples of the Hawassa Zuria District and peoples from adjoining district have exploited the forest for construction, fuel wood and fencing. Expansion of cultivation land as the number of population increase was also led the residents to clear the forest and to put the area under severe degradation. The area closure was established 8 years ago on some part of the degraded hillside and some part of the hillside is still under severe degradation due to overgrazing.

For the purpose of this research some part of the area closure and the adjacent open grazing land which have the same slope, soil parent material and history but with different management intervention were selected. Then, the selected site was categorized in to three management units (closed area with SWC, closed area without SWC and open grazing land). The open area was included for the purpose of comparison as a control. Basically, the sites which were classified as closed area with SWC was (the site closed from interference of animals at which both biological (like enrichment planting) and structural (like bunds, trench, check dams, pits, ditches, gabions and ponds) SWC measures were commonly implemented), while closed area without SWC was (the site which was simply closed from the interference of human practice and livestock at which there is no management practices) and adjacent open grazing land.

Selected soil parameters sampling and measurement

To collect data from each land management units transects were established at a minimum distance of 70 m from each other. Along each transect, a 10 m * 10 m soil sampling plot were set with 50 m interval. Soil pits were dug at the middle point of each plot to collect undisturbed soil samples by core sampler for bulk density and moisture content determination. Before digging the pit surface soil 0 to 15 cm depth was collected by auger from each corner and the center of the plot. The collected samples from the three sites were mixed thoroughly and separately to form a composite soil 30 samples (3 land use × 10 replication). From each 1 kg of mixed samples was taken to Oromia National Soil Laboratory Ziway Soil Research Center for further analysis. Major live plants materials (roots and shoots) in each sample were separated by hand and then, soils samples were air dried, and pass through a 2 mm sieve for determination of selected soil properties. Particle size analyses were determined by using the Hydrometer method (Gee and Bauder, 1982), soil bulk densities were determined from the oven dry (at 105°C for 24 h) mass of soil in the core sampler and volume of the undisturbed soil cores using core sample method (Landon, 1991) and soil moisture content were determined gravimetrically by using core sample method. Organic carbon was determined by using Walkley-Black method and total nitrogen was determined by Kjeldhal Method (Bremmer and Mulvaney, 1982), pH was determined in water suspension with soil to water ratio 1:2.5 by pH meter and electrical conductivity was determined in water suspension with soil to water ratio 1:2.5 by Conductivity meter (Rhoades, 1996).

Data analysis method

Statistical analyses were performed to test the influence of soil and water conservation measures on soil properties using one-way ANOVA, and mean comparisons were made using the Tukey HSD test with $p < 0.05$. Pearson correlation was also used to correlate different soil parameters. The analysis was done by statistical software for social science (SPSS) version 17.

RESULTS AND DISCUSSION

Impacts of soil and water conservation measures on soil properties

Soil physical properties (texture, bulk density and moisture content)

Sand, silt and clay fractions and soil bulk density showed no significant difference with land uses while moisture content varied significantly ($p = 0.0004$) with land uses (Table 1). The soil under the three land use types was categorized as sandy clay loam textural class. Bulk density was not significantly affected with land uses. This may be due to the course textural nature of the soil of the study site or may be due to the age of the area closure. Wolde (2004) found that coarse-textured soil bulk densities were not affected by grazing intensity but, the slight difference found in this study can be explained by their difference in SOM content and compaction due to livestock trampling effect. Mulugeta and Karl (2010) and Yihenew et al. (2009) also reported that soil under non-conserved treatment was found to exhibit higher soil bulk density than treatments by SWC structures. The non-significant difference in texture may be due to the age of the area closure which was five years that can't make significant change on weathering.

The findings also indicated that mean soil moisture content under closed area with SWC (17.65±0.69) was

Table 1. Mean values (±SEM) of selected soil physical properties of 0 to 15 cm soil depth at different land uses.

Land use	Soil parameter				
	Sand (%)	**Clay (%)**	**Silt (%)**	**BD (g/cm^3)**	**MC (%)**
Open grazing	55.33(±2.290)[a]	34(±2.309)[a]	10.67(±0.989)[a]	1.053(±0.049)[a]	11.422(±0.897)[b]
Closed without SWC	54.33(±2.092)[a]	37(±1.528)[a]	8.67(±0.667)[a]	1.024(±0.031)[a]	13.562(±0.951)[b]
Closed with SWC	51.33(±1.978)[a]	38.67(±1.520)[a]	10(±0.730)[a]	0.927(±0.029)[a]	17.65(±0.692)[a]
P-Value	0.405	0.2193	0.2363	0.0729	0.0004**

** Significantly different at the 0.01 level; Bulk density (BD); soil moisture content (MC).

higher than under closed area without SWC (13.56±0.95) and open grazing land (11.42±0.9) which may be a result of water conservation structures which reduces runoff and evaporation and increases infiltration and soil moisture content (Stroosnijder and Hoogmoed, 2004). Other studies also showed that soil water content is a factor that can be affected by land use type because of changes produced in infiltration, surface runoff, and evaporation (Zhai et al., 1990; Demir et al., 2007). It may also be due to higher organic matter content in closed area with SWC which is positively and significantly correlated with soil moisture content. Overgrazing and trampling by cattle and other unsustainable land management practices have resulted in the expansion of degraded landscapes with a sealed surface soil that impedes water infiltration and reduces the moisture content as a result of exposure of the soil to the sun emanated from the reduced ground cover (Mando et al., 2001; Maitima et al., 2009). Morgan (2005) also showed that the loss of vegetation due to overgrazing increases the rate of run off and erosion and decreases the amount of water in the soil.

Soil chemical properties

The total nitrogen ($p = 0.0002$), soil organic matter ($p = 0.0139$) and total carbon ($p = 0.0139$) were varied significantly with land uses. The mean TN, SOM and TC were higher under closed area with and without SWC than in under adjacent open grazing land. The carbon to nitrogen ratio (C/N) did not show significant difference with land uses (Table 2). The electrical conductivity (EC) and pH shows significant difference ($p = 0.0285$) and ($p = 0.0332$), respectively, with land uses and the mean EC and pH under closed area with SWC were lower than in open grazing land while no significant difference ($p > 0.05$) was observed between closed area with and without SWC and also between closed area without SWC and open grazing land (Table 2). SOM, TN, TC and soil moisture content were positively correlated with each other. EC and pH also have significantly positive correlation ($p = 0.01$) with each other while negatively correlated with TC, SOM and TN (Table 3).

The mean SOM and TC contents under closed area with SWC were higher than the contents under closed area without SWC but mean SOM and TC under closed area with and without SWC were higher than in adjacent grazing land which may be due to the higher accumulation of organic materials as a result of increased plant biomass. SWC practices can bring current land use systems to a higher above and below ground biomass (and hence SOC) level by enhancing better ground cover. Stroosnijder and Hoogmoed (2004) also reported that the rainwater conserved through SWC structures is used for higher biomass production which in turn increases the organic matter content in the soil through litter and root decomposition. Dereje et al. (2003) reported similar result that inputs from the vegetation can have a positive impact on the organic carbon concentrations into the soil system. A study conducted by Wolde et al. (2007) shows soil organic matter and soil nutrients under area closure are significantly different compared to the adjacent free grazing lands. Studies by Yihenew et al. (2009) and Kebede et al. (2011) on crop field also reported that the non-conserved fields had lower SOC as compared to the conserved fields with different conservation measures. Mulugeta et al. (2005a, b) supported this result by reporting the decrease in vegetation cover and disturbance of the natural ecosystem have caused wide spread soil degradation, with an attendant decline in concentrations of soil organic matter (SOM). Dereje et al. (2003) indicated that temporal change in vegetation diversity and richness from lower to higher degree can change SOM concentration through the enhanced sediment trapping efficiency. Similar results were reported by Descheemaeker et al. (2006) in Tigray. The studies by Wolde and Veldkamp (2005) in Tigray on a semiarid continental climate indicated significant improvement in SOM and in total N an area closed for 5 years.

Lal and Bruce (1999) also generally indicated technologies for restoration of degraded soils by establishing ecological-based vegetation cover, using appropriate soil and water conservation measures, adopting water harvesting measures, enhancing nutrient recycling mechanisms, and controlling stocking rate. Adoption of these management practices increases the SOC stock through creating conducive medium for increasing above ground biomass and enhancing its

Table 2. Mean values (±SEM) of selected soil chemical properties of 0 to 15 cm soil depth at different land uses.

Land use	Soil parameter					
	TC	SOM	TN	C/N	EC	pH
Open grazing	0.593(±0.207)[b]	1.022(±0.357)[b]	0.071(±0.003)[b]	8.123(±2.521)[a]	0.207(±0.037)[a]	7.86(±0.205)[a]
CA without SWC	1.251(±0.161)[a]	2.155(±0.277)[a]	0.150(±0.006)[a]	8.264(±0.923)[a]	0.176(±0.031)[ab]	7.48(±0.188)[ab]
CA with SWC	1.387(±0.158)[a]	2.391(±0.273)[a]	0.138(±0.017)[a]	10.387(±0.919)[a]	0.093(±0.008)[b]	7.11(±0.144)[b]
P-value	0.0139*	0.0139*	0.0002**	0.5622	0.0285*	0.0332*

**Significantly different at the 0.01 level; * significantly different at the 0.05 level. Electro conductivity (EC) in (mmhos/cm), Total nitrogen (TN) in (%), Total carbon (TC) in (%), Soil organic matter (%) and carbon to nitrogen ratio (C/N).

humification (Singh and Lal, 2005).

The overall total nitrogen (TN) was higher under closed area with SWC than in soil under closed area without SWC. Mean TN under closed area with and without SWC was higher compared to the content under adjacent grazing land. The lower TN under open grazing land was due to lower organic matter content. Total N showed a significant correlation with SOM (+0.75, $p \leq 0.01$) (Table 3). Study by Kumlachew and Tamrat (2002) also reported that the total nitrogen content of the soil in different communities vary with the amount of organic matter. Mulugeta and Karl (2010) also reported that the land with physical SWC measures have high total nitrogen as compared to the non-conserved land. Million (2003) found that the mean total N content of the terraced site were higher than the average total N contents in the corresponding non-terraced sites. As carbon to nitrogen ratio (C/N) is an index of nutrient mineralization and immobilization where by low C/N ratio indicates higher rate of mineralization (Brady and Weil, 2002), rate of soil organic matter mineralization is lower under closed area with SWC. In addition, the lower C inputs because of less biomass C return on free grazing lands caused the reduction of SOM and TN (Girma, 1998). The most evident impact of grazing is the removal of a major part of above ground biomass by livestock that decreases the input of aboveground litter to the soil. Any reduction in litter inputs may have important consequences for soil nutrient conservation and cycling (Shariff et al., 1994).

The soil pH and EC under closed area with SWC were significantly lower than the soil under open grazing land which may be the result of relatively higher organic matter content in the closed area with SWC that increase H^+ in the soil that resulted into increase in soil acidity and reduces pH values. FAO (2005) showed that important chemical properties of soil organic matter are due to the weak acidic nature of humus. The higher EC under open grazing land may be as a result of higher evaporation rate that increase soil salinity level. This finding was supported by Seifi et al. (2010) report in that an increasing concentration of electrolytes (salts) like calcium salt (calcium carbonate) in soil will dramatically increase soil EC. Corwin and Lesch (2005) also showed that in arid climates, plant residue and mulch help soils to remain wetter and thus allow seasonal precipitation to be more effective in leaching salts from the surface and at the same time they reported that poor water infiltration can lead to poor drainage, water logging, and increased EC.

Conclusion

The result of the study indicated that soil parameters MC, SOM, TN, EC and pH show significant difference ($p<0.05$) while texture, BD and C/N ratio showed no significant variations with land uses. The soil properties in the area closure with SWC improving in some measured parameters such as moisture content, total nitrogen, soil organic matter, pH, EC as compared to closed area without SWC and open grazing land. Therefore, even if simple area closure without SWC can be an effective method to rehabilitating degraded hillsides incorporating SWC measures is the preferable way to speed up rehabilitation period. Generally, ecological rehabilitation/restoration can be an urgent and essential measure to solve the wide spread land degradation problems in Ethiopia. The present study also clearly indicated that to improve ecological components like soil it is more essential to incorporate different SWC measures in to the

Table 3. Correlation between selected soil properties.

	TC	SOM	TN	C/N	EC	PH	Clay	BD	MC
TC	1								
SOM	1.0(**)	1							
TN	0.751(**)	0.751(**)	1						
C/N	0.677(**)	0.677(**)	0.058	1					
EC	-0.667(**)	-0.667(**)	-0.412	-0.525(*)	1				
PH	-0.666(**)	-0.666(**)	-0.574(*)	-0.361	0.829(**)	1			
Clay	0.422	0.422	0.197	0.444	-0.390	-0.445	1		
BD	-0.625(**)	-0.625(**)	-0.517(*)	-0.410	0.594(**)	0.601(**)	-0.068	1	
MC	0.563(*)	0.563(*)	0.578(*)	0.209	-0.519(*)	-0.525(*)	0.187	-0.786(**)	1

Number of observation N= 30, ** Correlation is significant at the 0.01 level. * Correlation is significant at the 0.05 level.

area closure to foster the rehabilitation of degraded lands.

RECOMMENDATIONS

The present study has made the following recommends which could be helpful for the success of area closures as a means of rehabilitating degraded areas:

(i) Protecting the open degraded areas from interference of local people and animal grazing is the good option to assist the improvement soil physical and chemical properties.
(ii) Since carbon losses are related with loss of vegetation cover and soil erosion, management interventions that slow or reverse these processes can simultaneously achieve carbon sequestration. Area closure, thus, can be the good option to increase the stock of carbon in the soil and have the potentials of involving in carbon trading as a new forest valuation for sustainable natural resource management.
(iii) As SWC practices including area closure could protect and improve land resource, decrease sediment in downstream areas including lake Hawassa and improve hydrological condition and water quality of rivers, reduce disastrous flood and water logging, which could protect safety of lives and property through improvement of ecological conditions governmental and NGOs (especially, Lake Hawassa stakeholders) should give due attention to rehabilitate the whole hillside areas of the catchment.
(iv) Additional research is needed to more understand the interactive relationships among landscape positions, soil nutrients, management interventions, land uses and its history since vegetation and soil attributes depend on those factors.

Conflict of Interest

The authors have not declared any conflict of interest.

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