Vol-3, Issue-5 PP. 345-354 ISSN: 2394-5788

GLOBAL JOURNAL OF ADVANCED RESEARCH
(Scholarly Peer Review Publishing System)

STUDY ON SELECTED SOIL PHYSICOCHEMICAL PROPERTIES OF REHABILITATED DEGRADED BARE LAND: THE CASE OF JIGESSA REHABILITATION SITE, BORANA ZONE, ETHIOPIA

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ABSTRACT

The aim of the study was to determine selected soil physicochemical properties of degraded bare land, rehabilitated degraded bare land and natural grassland and make comparisons among the soil properties; and estimate soil carbon stock of the land use types. Standard procedures were employed for the analyses of soil parameters. The soil organic carbon stock was estimated from the bulk density of 0-5 cm soil depth. One way ANOVA was employed to compare the soil parameters at particular soil depth. The rehabilitation of degraded bare land had influenced most of the soil properties at 0-10 cm soil depth. The soil moisture content of the rehabilitated degraded bare land had increased when compared with the degraded bare land. The bulk density of the rehabilitated degraded bare land soil was significantly lower (1.21 ± 0.04 g/cm3) than the degraded bare land soil (1.31 ± 0.02 g/cm3). The OM, TN, pH, CEC, Ex. Ca and soil organic carbon stock of the rehabilitated degraded bare land soil were improved when compared with degraded bare land soil. Av. P content and Ex. K of the rehabilitated degraded bare land soils were lower at 0-10 cm when compared with the degraded bare land. The soil organic carbon stock of natural grassland > rehabilitated degraded bare land > degraded bare land. Most of the soil chemical properties of the rehabilitated degraded bare land under study are still very low to medium except Ex. K.

Keywords: Degraded bare land, Rehabilitated degraded bare land, Natural grass land, Soil properties, Soil organic carbon stock

1. INTRODUCTION

The semi arid areas of Africa particularly Sub-Saharan Africa (SSA) have fragile soils and get low input from agriculture, as a result they are vulnerable to degradation (FAO, 2001; Maganga et al., 2010). The East Africa rangelands have soils of inherently low fertility (Coppock, 1994). The removal of soil vegetation cover will, therefore, aggravate the inherent low fertility characteristics of the soil. Cognizant of land degradation problem in semi-arid environment of sub-Saharan Africa there is a practice to combat land degradation and ensure the long term productivity of land. Kenya, for instance, has been practicing grass reseeding technology to fight land

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degradation although the technology faces challenges from low amounts of rainfall. Reseeding of grasses such as buffel grass (*Cenchrus ciliaris*), maasai love grass (*Eragrostis superba*) and bush rye (*Enteropogon macrostachyus*) failed due to low rainfall (Maganga et al., 2010).

The main contributing factors for rangeland degradation in Borana have been identified to be recurrent and prolonged drought, bush encroachment and overgrazing. In Borana rangelands the abundance of non palatable species, increase in woody species and bare grounds have been noticed. These are also indicators of rangeland conditions according to the Borana people (Solomon et al., 2007; Homann et al., 2008). The Borana perceptions of rangeland degradation are in line with the perceptions of Hamer, Benna and Tsemay pastoralists in south Omo zone (Admasu, et al., 2010). As noted in Solomon et al. (Solomon et al., 2007) deferred grazing has also been practiced in Borana in order to improve an overgrazed area by allowing for rest periods in a succession of growing seasons although failure on bare land at Jigessa site was observed (Bedasa et al., 2013, unpublished). Shift to sedentary life style that has been practiced in Borana has created pressure on rangeland vegetation, deterioration in some areas. The settlement affects the seasonal movement of livestock which result in overgrazing in the settlement area. The two grazing seasons, dry season and wet season, allow spatial distribution of grazing pressure on rangelands in Borana (Solomon et al., 2007; Homann et al., 2008 and Dabassoo et al., 2012).

In many studies there are issues of land use/land cover changes which might be the conversion of forest land to crop land or grassland to crop land or others (Sintayehu Mesele, 2006; Abbasi et al., 2007 and Zeng et al., 2009), however the land cover change in Dugda Dawa district of Borana is beyond these, it is without vegetation cover. As a result, there is a concern on degraded land management in Borana zone. Degraded bare land rehabilitation has been started in Borana in order to make rangeland productive. The Jigessa degraded bare land has been rehabilitated with minimum tillage and manure application (10 ton/ha) by using perennial grass, rhodes grass (Bedasa et al., 2013, unpublished). Although soil data on degraded bare land can be used in soil management system to prevent further degradation (FAO, 2006; Hazelton and Murphy, 2007); there is no study conducted on soil physicochemical properties of Jigessa degraded bare land and rehabilitated degraded bare land. There is a knowledge gap on the improvement of selected soil physicochemical properties after rehabilitation of degraded bare land in the study area. Rehabilitation of degraded land could improve forage availability, soil physicochemical properties and sequester carbon dioxide in to soil simultaneously. Therefore, this study avail data on selected physicochemical properties of rehabilitated degraded bare land, degraded bare land and natural grassland soils; and estimate their soil organic carbon stock.

2. MATERIALS AND METHODS

2.1 Soil Sample Area Description

Dugda Dawa is one of the districts of Borana zone having its capital at Fincha. The area has mean annual rainfall of 700 mm and the rainfall delivery is bimodal with the long rainy season expected between March and May and the short rainy season during October and November. The climate is generally semi-arid (Coppock, 1994). The study sites had almost similar topography.

2.2 Soil Sampling

The soil samples were taken before the onset of the long rainy season, during February, 2013. The soil sampling points were taken in a zig-zag fashion using a 25 cm X 25 cm X 30 cm pit. From each sampling point soil samples were cut out with shovel from three soil depth ranges from 0-10, 10-20 and 20-30 cm. Fifteen soil sub samples from each soil depth were taken and composited. Samples were taken in triplicates for each site. For soil bulk density analysis undisturbed soil samples were taken from the three sites. Five core samples were taken from each sites using core sampler. Core samplers of 100 cm^3 were used.

2.3 Sample Preparation

Air dried soil samples were ground by using porcelain mortar and pestle and the fine ground soil samples were passed through 2 mm sieve (Stainless steel). The required soil samples were taken by thoroughly mixing on a sheet of plastic and quartering.

2.4 Analytical methods

Particle size distribution was analysed using hydrometer method as described by Jones (2001) and soil bulk density was analysed following standard procedures (Bashour and Sayegh, 2007). Soil pH was analysed using 1:2.5 soil water ratio, for soil organic carbon Black and Walkely method was used as described by Sahlemedhin and Taye (2000). Conversion factor 1.724 (Van Bemmelen factor) was employed to convert the organic carbon to organic matter. Kjeldhal method was used to determine the total nitrogen content and Av. P was analysed using Bray II method as described by Sahlemedhin and Taye (2000). Exchangeable basic ions were extracted

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using 1 M ammonium acetate at pH 7. Ex. Ca and Ex. Mg were analysed by FAAS with their respective hollow cathode lamps where as Ex. K and Ex. Na were analysed by flame photometer. For cation exchange capacity analysis, residual ammonium acetate from the soil was washed with ethanol and the soil leached with 10 % NaCl. The leachate was transferred to kjeldhal flask and distilled to sulphuric acid as described by Sahlemedhin and Taye (2000).

2.5 Data Analysis

One way ANOVA was employed to compare selected soil physicochemical properties of degraded bare land, rehabilitated degraded bare lands and natural grass lands along similar soil depth using the statistical analysis system version 9.0 (SAS, 2002).

3. RESULTS AND DISCUSSION

3.1 Selected soil physical properties

3.1.1 Soil particle size distribution

Clay contents in the degraded bare land and rehabilitated degraded bare land soil were not significant at the respective soil depth (at P = 0.05) (Table 1). Sand particles at 0-10 cm soil depth were significant at P = 0.05 for rehabilitated degraded bare land and natural grass land. In general, there were no significant changes in particle size distribution between the rehabilitated degraded bare land and degraded bare land soil except for silt and sand fractions at 20-30 cm soil depth. This is due to the fact that particle size distribution takes time to be altered (Brady, 1990; Osman, 2012). The increase in clay content with depth was similar with other finding (Awdenegest et al., 2012). The textural classes of the studied soils were clay types. This result was not in line with the study conducted by Sintayehu. In his study on the land use/land cover change, Sintayehu obtained the textural class of soil under degraded bush land different from grassland soil (Sintayehu M., 2006). The nature of land degradation and soil texture type before land degradation could be attributable to the difference.

3.1.2 Soil bulk density

The bulk density of soil could be affected by soil texture, organic matter and land use type. Although the degraded bare land of the study area was deprived of plant cover, the bulk density was good from agriculture point of view. Brady noted that the bulk density of clay and silt loam surface soil usually range from 1.0 to 1.6 g/cm^3 (Brady, 1990). In the present study, the soil bulk density of rehabilitated degraded bare land was significantly lower than degraded bare land and natural grassland at P = 0.05 (Table 1). When compared with the degraded bare land the bulk density of rehabilitated degraded bare land decreased by 7.6 %.

The lower soil bulk density of the rehabilitated bare land could be due to the incorporation of root system into the soil, soil organic matter (Haynes and Naidu, 1998) and minimum tillage practice prior to reseeding. The later factor had less contribution since the practice was not recent and of about two years ago. Soil returns to its original compaction level before the next tillage (Osman, 2012). In the present study, the rehabilitation of degraded bare land improved the bulk density of soil systems.

3.1.3 Soil moisture content

Soil moisture content affects plant growth and other soil properties. In this study moisture contents of the soil of different land use types were significant (at P = 0.05) at a given soil depth (Table 1). When compared at the similar soil depth, soil moisture contents of the rehabilitated degraded bare land were greater than that of soils of natural grassland and degraded bare land. Assuming the degraded bare land was the base for the rehabilitated bare land soil, there were about 128.9, 15.3 and 12.4 % percentage increases of soil moisture along the land use types in the 0-10, 10-20 and 20-30 cm soil depth respectively.

There was soil moisture improvement for rehabilitated degraded bare land which could be attributable to different factors. In the first case, the degraded bare land was completely deprived of vegetation which could result in large evaporation rate from the bare land compared to the rehabilitated bare land. Even though the rehabilitated degraded bare land faces both evaporation and transpiration, the water loss from both effects could not outweigh a single factor – evaporation. In the absence of plant cover, water infiltration rate during rainy season decreases due to rainfall loss through runoff (Sadeghi et al., 2007) which directly affects soil moisture. The increase in soil moisture as vegetation cover increase is reported by other researcher (Duma, 2000). The significant soil organic matter could also be responsible for the increase in soil moisture, the hydrophilic properties and the improvement of soil structure by organic matter plays crucial role (Haynes and Naidu, 1998; Kimble et al., 2007).

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Table 1. Comparison of soil physical properties of different land use types at the same soil depth

Soil depth (cm)*	Land use types	Soil moisture (%)	ρ_b (g/cm^3)	Particle size distribution		
				Clay (%)	Silt (%)	Sand (%)
0-10	Bare land	3.98 ± 0.18^{a}	1.31 ± 0.02^{a}	46.8 ± 1.8^{a}	11.6 ± 1.4^{a}	41.6 ± 3.1^{ab}
	Rehabilitated land	9.11 ± 0.14^{b}	1.21 ±0.04^{b}	48.4 ± 1.5^{a}	11.2 ± 0.8^{a}	40.4 ± 1.5^{a}
	Natural grassland	7.85 ± 0.14^{c}	1.35 ± 0.07^{a}	44.3 ± 0.7^{b}	11.9 ± 1.1^{a}	43.8 ± 1.4^{b}
	LSD (P = 0.05)	0.2238	0.0679	1.9321	1.5348	2.9251
10-20	Bare land	10.77 ± 0.10^{a}		55.9 ± 0.9^{a}	12.9 ± 1.7^{a}	31.2 ± 2.3^{a}
	Rehabilitated land	12.42 ± 0.19^{b}		55.0 ± 0.7^{a}	13.2 ± 1.4^{a}	31.8 ±1.5^{a}
	Natural grassland	11.08 ± 0.17^{c}		50.6 ± 0.6^{b}	11.8 ± 0.8^{a}	37.6 ± 1.2^{b}
	LSD (P = 0.05)	0.2165		1.022	1.8369	2.3495
20-30	Bare land	12.82 ± 0.03^{a}		57.2 ± 1.4^{a}	12.6 ± 0.8^{a}	30.2 ± 2.2^{a}
	Rehabilitated land	14.41 ± 0.27^{b}		58.6 ± 1.1^{a}	15.9 ± 1.7^{b}	25.5 ± 2.6^{b}
	Natural grassland	13.09 ± 0.08^{c}		58.1 ± 0.9^{a}	15.1 ± 1.2^{b}	26.8 ± 1.2^{b}
	LSD (P = 0.05)	0.2193		1.5472	1.7481	2.8847

* Means with same letter in the same column and row indicate non significant difference (at P = 0.05 level). Results are expressed as mean ± Standard deviation

3.2 Selected soil chemical properties

3.2.1 Soil pH

The soil pH under the three land use types was significant at similar soil depth (at P = 0.05) (Table 2). The soil pH was in extremely acidic pH (4.17) at 20-30 cm soil depth for degraded bare land soil to medium acidic pH (5.63) at 0-10 cm soil depth for natural grass land according to Osman acidity rating (Osman, 2012). The soil of degraded bare land was more acidic than the other land use types under study at 0-10, 10-20 and 20-30 cm soil depths. Taking soil of degraded bare land as a reference point the soil pH of rehabilitated degraded bare land increased by 7.5, 12.9 and 12.0 % at 0-10, 10-20 and 20-30 cm soil depth range respectively.

A soil pH plays important role on nutrient availability. Its intensity, measured by soil pH, is the result of interaction among different factors. The factors include soil type, climate and vegetation (White, 2006). Crops grow best at pH range of 6.5 – 8.0 (Draycott and Christenson, 2003). There was improvement due to the rehabilitation practice on degraded bare land. The increase in pH at each soil depth of rehabilitated degraded bare land could be ascribed to different factors. In the first time, the increase in soil pH after degraded bare land rehabilitation could be attributed to decrease in aluminum ion activity due to complexation with organic matter (Lal and Stewart, 1990; Opala et al., 2012).

Table 2. Comparison of pH (H2O), OM, Av. P and TN in different land use types and same soil depth. Results are expressed as mean ± standard deviation

Parameters*	Land use types	soil depth (cm)		
		0-10	10-20	20-30
pH (H_2O)	Bare land	4.54 ± 0.04^{a}	4.27 ± 0.02^{a}	4.17 ± 0.07^{a}
	Rehabilitated land	4.88 ± 0.03^{b}	4.82 ± 0.02^{b}	4.67 ± 0.02^{b}
	Natural grassland	5.63 ± 0.03^{c}	5.28 ± 0.01^{c}	4.92 ± 0.01^{c}
LSD (P = 0.05)		0.0501	0.0257	0.0257
OM (%)	Bare land	1.46 ± 0.04^{a}	1.32 ± 0.04^{a}	1.13 ± 0.03^{a}
	Rehabilitated land	1.83 ± 0.07^{b}	1.49 ± 0.03^{b}	1.20 ± 0.03^{b}
	Natural grassland	2.45 ± 0.02^{c}	1.55 ± 0.04^{c}	1.18 ± 0.02^{b}
LSD (P = 0.05)		0.069	0.0558	0.0372
Av. P (ppm)	Bare land	4.46 ± 0.38^{a}	2.57 ± 0.29^{a}	2.38 ± 0.25^{a}
	Rehabilitated land	4.01 ± 0.29^{b}	2.71 ± 0.29^{a}	2.23 ± 0.19^{ab}
	Natural grassland	3.57 ± 0.08^{c}	2.17 ± 0.09^{b}	1.93 ± 0.21^{b}
LSD (P = 0.05)		0.3847	0.3361	0.2994
TN (%)	Bare land	0.080 ± 0.004^{a}	0.063 ± 0.001^{a}	0.058 ± 0.002^{a}
	Rehabilitated land	0.090 ± 0.001^{b}	0.072 ± 0.005^{b}	0.061 ± 0.001^{a}
	Natural grassland	0.108 ± 0.001^{c}	0.072 ± 0.003^{b}	0.064 ± 0.003^{b}
LSD (P = 0.05)		0.0033	0.0043	0.0029

*means in the same column and row with the same letters are not significant at P = 0.05

3.2.2 Soil organic matter

At the range of 0-10 and 10-20 cm soil depths the SOM contents of degraded bare land was significantly lower. Taking the degraded bare land as a base the percentage increase of SOM of rehabilitated degraded bare land were 25.3, 12.9 and 6.2 % at soil depth ranges of 0-10, 10-20 and 20-30 cm respectively. The status of organic matter in the study area is very low (1.0-1.5 %) for all land use types at all soil depths studied except at 0-10 cm depth for the soil of natural grassland and rehabilitated degraded bare land, and at 10-20 cm soil depth for natural grassland soil which is low (1.6-3.0 %) as per the ratings of Jones (2003).

The organic matter increase in the rehabilitated degraded bare land could be attributed to the addition of organic residues through litter, root biomass and manure applied before rehabilitation which is also explained by Arevalo et al. (1998). Similar finding on soil organic carbon is obtained during the study of the effect of dairy manure on maize yield (Iqbal, et al., 2012).

3.2.3 Soil total nitrogen

The soil total nitrogen contents at 0-10 cm soil depth were significant at the three sites (at P = 0.05). There were percentage increases of 12.5, 14.4 and 5.2 % soil total nitrogen contents of rehabilitated degraded bare land when compared with the degraded bare land in the soil depth 0-10, 10-20 and 20-30 cm soil depth respectively. The total nitrogen in soil usually ranges from 0.02 % - 0.5 % (Brady, 1990). The increase in soil total nitrogen contents of rehabilitated degraded bare land soil could be attributed to the vegetation cover which improved the soil organic matter (Table 2). Before the rehabilitation of the degraded bare land the added manure could also improve the total nitrogen.

3.2.4 Available phosphorus

According to the present study, the available phosphorus contents of the soil is significant at 0-10 cm soil depth at P = 0.05 (Table 2). The soil available phosphorus (Bray II method) is very low in the study area according to Ankerman and Large nutrient ratings. The ratings are 0-10 ppm - very low, 12-25 ppm - low, 26-42 ppm - medium, 43-60 ppm -high and higher than 60 ppm very high (Ankerman and Large, nd). Although manure was expected to increase the available phosphorus of the rehabilitated bare land, it failed to do so; this could probably be due to the acidic nature of the soil in which phosphorus is adsorbed and becomes locked in various phosphorus compounds of low solubility (Fageria, 2009). The lower content of available phosphorus from rehabilitated degraded bare land was in line with Kimble et al. expectation (Kimble et al., 2007). They noted that the available soil phosphorus is governed more by soil chemistry and chemical transformations instead of microbial activities. As a result SOM incorporated through manure could not be, most of the time, a major source of phosphorus for plants in low organic soils.

The available soil phosphorus content of degraded bare land was found to be higher than degraded rehabilitated bare land at only 0-10 cm soil depth (10.1% decrease). This could be attributable to the tillage practice during reseeding of grass. During plough there could be a relocation of clay separates and soil mix up which could increase phosphorus fixation by soil colloids (Whalen, 2012). The decrease in available phosphorus content was in line with previous study (Watkins et al., 2012) which was supposed to be due to tillage practice. Of course, in newly established grassland there could be a chance for the available phosphorus to be stored in organic form in soil microorganisms and uptake by plant. The low level of available soil phosphorus content of the natural grassland could be attributable to plant uptake.

3.2.5 Exchangeable basic ions

The study on exchangeable cations revealed that all the cations did not show similar trends throughout the land use types. The Ex. Mg content of natural grassland soil was significantly lower at 0-10 cm soil depth at P = 0.05. The Ex. Mg content of rehabilitated degraded bare land was significantly higher at 20-30 cm soil depth (at P = 0.05) (Table 3). According to Jones the Ex. Mg content of the study area is rated as medium (Jones, 2003). The exchangeable calcium (Ex. Ca) content of the different land use types was significant at the respective soil depth range. The Ex. Ca is low for degraded bare land soil, medium for rehabilitated degraded bare land soil except at 20-30 cm soil depth. The Ex. Ca content of natural grassland is rated as high (Jones, 2003). The exchangeable potassium (Ex. K) contents at 0-10 cm and 10-20 cm soil depth were significant for the three land use types (at P = 0.05) (Table 3). The Ex. K content of rehabilitated degraded bare land was significantly lower at 0-10 cm soil depth. The Ex. K content of degraded bare land soil was significantly lower at 10-20 cm and 20-30 cm soil depth. According to the ratings recommended by Jones, the Ex. K is high (Jones, 2003) in the land use types studied.

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The decrease in Ex. K for the rehabilitated degraded land could probably be explained from different point of views. First, due to the total removal of plant cover the capillary rise of soil water in the bare land during the dry season could increase the concentration of the cation before the onset of the long rainy season i.e. the evaporated water could leave the cations brought from higher soil depth increasing the cations. Therefore, there might be a chance to increase this cation for degraded bare land in relation to rehabilitated one. Secondly, the minimum tillage during the reseeding practice may increase the leaching of the cations during the onset of rainfall. Thirdly, after reseeding of the grass species the emerging grass species could remove Ex. K from soil resulting in a decrease in total exchangeable potassium. The Ex. Na followed the same trend as Ex. K at 0-10 cm soil depth the similar reason could be put for the difference observed.

The exchangeable magnesium content of soil of degraded bare land and rehabilitated degraded bare land did not show significance difference at the 0-10 cm and 10-20 cm soil depth. The Ex. Mg at these depths could not be explained similar to Ex. K. The less solubility of magnesium salts compared to potassium salts also limit the concentration of the magnesium ion in the soil capillary water, and the evaporation could leave low concentration of magnesium ion in the soil.

3.2.6 Cation exchange capacity

In this study, the cation exchange capacity (CEC) was significantly lower for the degraded bare land and natural grassland soil at 0-10 cm and 10-20 cm soil depth respectively at P = 0.05. According to this study the rehabilitation of degraded bare land by reseeding technique affected the CEC of soil at 0-10 cm soil depth. At 10-20 cm and 20-30 cm the intervention did not affect this important soil chemical property. Although the textural class of the soil under study was clay type, the CEC of the soil under study was small. This could be attributed to the type of clay that constitutes the soil. Kaolinite clay has usually low CEC due to low surface charge (Uehara and Gillman, 1981).

Table 3. Comparison of CEC and Exchangeable basic ions in different land use types and same soil depth. Results are expressed as mean ± standard deviation

Parameters*	**Land use types**	**soil depth (cm)**		
		0-10	**10-20**	**20-30**
Ex. Mg	Bare land	2.74 ± 0.04^{a}	1.84 ± 0.08^{a}	1.55 ± 0.12^{a}
	Rehabilitated land	2.64 ± 0.24^{a}	1.84 ± 0.08^{a}	1.87 ± 0.11^{b}
	Natural grassland	1.81 ± 0.09^{b}	1.99 ± 0.16^{a}	1.63 ± 0.13^{a}
LSD (P = 0.05)		0.2038	0.1599	0.1721
Ex. K	Bare land	0.60 ± 0.01^{a}	0.47 ± 0.01^{a}	0.42 ± 0.01^{a}
	Rehabilitated land	0.54 ± 0.01^{b}	0.53 ± 0.01^{b}	0.50 ± 0.01^{b}
	Natural grassland	0.72 ± 0.01^{c}	0.54 ± 0.01^{c}	0.50 ± 0.01^{b}
LSD		0.0127	0.0087	0.0096
Ex. Na	Bare land	0.21 ± 0.01^{a}	0.15 ± 0.01^{a}	0.15 ± 0.01^{a}
	Rehabilitated land	0.14 ± 0.01^{b}	0.14 ± 0.01^{a}	0.12 ± 0.01^{b}
	Natural grassland	0.18 ± 0.02^{c}	0.14 ± 0.01^{a}	0.14 ± 0.01^{a}
LSD (P = 0.05)		0.0178	0.0146	0.0157
Ex. Ca	Bare land	2.79 ± 0.22^{a}	2.03 ± 0.18^{a}	1.87 ± 0.12^{a}
	Rehabilitated land	6.33 ± 0.59 ^{b}	6.02 ± 0.42^{b}	2.70 ± 0.25^{a}
	Natural grassland	13.79 ± 0.20^{c}	15.22 ± 1.26^{c}	14.43 ± 1.32^{b}
LSD (P = 0.05)		0.5252	1.0641	1.0686
CEC	Bare land	8.82 ± 0.40^{a}	9.75 ± 0.22^{a}	10.49 ± 0.69^{a}
	Rehabilitated land	10.08 ± 0.58^{b}	9.98 ± 0.29^{a}	9.80 ± 0.83^{ab}
	Natural grassland	10.10 ± 0.29^{b}	9.08 ± 0.57^{b}	9.33 ± 0.77^{b}
LSD (P = 0.05)		0.6091	0.541	1.0614

*means in the same column and row with the same letters were not significant at P = 0.05.
Results are expressed in meq/100 g soil unit.

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3.2.7 Carbon to Nitrogen (C:N) ratio

The C:N ratio of the soil in the study area was significant at 0-10 cm soil depth at P = 0.05. The C:N ratio of natural grassland was significantly higher where as for that of soil of degraded bare land it was significantly lower at this depth (Table 4). The C:N ratio in the upper 15 cm usually ranges from 8:1 to 15:1 for arable soils (Brady, 1990). In his study on land use/land change, Sintayehu reported a 7.3 C:N ratio for degraded bush land. This value is lower when compared to the C:N ratio of the current study (10.6 at 0-10 cm soil depth) of the degraded bare land. Although it is difficult to explain the difference observed, it could be inferred that the soil texture could have large contribution to and could be the reason behind the difference. Sintayehu obtained sandy loam texture for degraded bush land in his study (Sintayehu, 2006).

Table 41. Comparison of soil organic carbon stock and C:N ratio in different land use types.

Parameters*	**Land use types**	**soil depth (cm)**		
		0-10	**10-20**	**20-30**
SOC %	Bare land	0.85 ± 0.03	0.77 ± 0.03	0.66 ± 0.02
	Rehabilitated land	1.06 ± 0.04	0.86 ± 0.02	0.70 ± 0.02
	Natural grassland	1.42 ± 0.01	0.90 ± 0.03	0.69 ± 0.01
CSt (Ton/ha)	Bare land	11.1 ± 0.4^{a}	-	-
	Rehabilitated land	12.9 ± 0.4^{b}	-	-
	Natural grassland	19.2 ± 1.1^{c}	-	-
LSD (P = 0.05)		0.9565	-	-
C:N	Bare land	10.6 ± 0.6^{a}	12.1 ± 0.5^{a}	10.7 ± 0.9^{a}
	Rehabilitated land	11.9 ± 0.4^{b}	12.0 ± 0.7^{a}	10.9 ± 0.6^{ab}
	Natural grassland	13.2 ± 0.2^{c}	12.5 ± 0.5^{a}	12.0 ± 0.7^{b}
LSD (P = 0.05)		0.598	0.8326	1.0685

*Results are expressed as mean ± standard deviation, Comparison was made at P = 0.05

Higher C:N ratio in soil could be attributed to the presence of a greater amount of undecomposed to partially decomposed organic matter. On the other hand, a smaller C:N ratio than 10:1 usually indicates greater nitrification in soil (Osman, 2012).

3.2.8 Soil Organic Carbon Stock

Increase in soil organic carbon stock in soil plays crucial role in reduction of carbon dioxide, greenhouse gas, in atmosphere. In this study the soil organic carbon stock for degraded bare land, rehabilitated degraded bare land and natural grassland was estimated. In the estimation of soil organic carbon stock it was assumed that bulk density in the 0-5 cm soil depth range was representative of the 0-10 cm soil depth range. The soil organic carbon stock was calculated using equation (Guo and Gifford, 2002).

$$Cst = \rho b \times \% OC \times l$$

Where,

Cst: Soil organic carbon stock in ton per hectare

ρb : Soil bulk density in g/cm^3

% OC: Percentage of organic carbon

l: soil depth in cm

The analysis of soil in the study area revealed that soil organic carbon stock of rehabilitated degraded bare land was significantly higher than that of degraded bare land (P = 0.05) at the 0-10 cm soil depth. The trend of soil organic carbon stock in the land use types studied follows natural grassland > rehabilitated degraded bare land > degraded bare land (Table 4). Degraded bare land as a reference point, there was a percentage increase of 16.2 % soil organic carbon stock in the rehabilitated degraded bare land. The result showed that the rehabilitation technique has contributed to the increase in soil organic carbon stock. Management practices that favor carbon

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sequestration including manure addition, grazing management to the rehabilitated degraded bare land should be maintained otherwise the carbon sequestration is temporary and will be depleted (Smith, 2007).

4. CONCLUSIONS

The objectives of the study were to generate data on selected soil physicochemical properties of the study area and to compare the soil properties of degraded bare land, rehabilitated degraded bare land and natural grassland. The rehabilitated degraded bare land was previously reseeded by rhodes grass species. The rehabilitation work had significant effect on improvement of selected soil physicochemical properties of degraded bare land, and revealed that there were almost significant differences between the rehabilitated degraded bare land and degraded bare land which could have a significant implication on the effectiveness of the intervention.

The soil moisture content of the rehabilitated degraded bare land was significantly higher than degraded bare land and natural grass land at a given soil depth. At all soil depths studied the soil moisture contents of rehabilitated degraded bare land were significantly higher (9.11 ± 0.14 %, 12.42 ± 0.19 % and 14.41± 0.27 % at 0-10 cm, 10-20 cm and 20-30 cm soil depths respectively) than the remaining land use types. There was also significant change in soil bulk density in which the rehabilitation practice had improved soil bulk density (from 1.31 ± 0.02 g/cm^3 to 1.21± 0.04 g/cm^3). The textural classifications of the soils of the study area were clay type.

Rehabilitation of soil of degraded bare land with rhodes grass resulted in significantly higher SOM, TN and soil pH at all soil depths studied when compared with degraded bare land. The maximum SOM content attained at 0-10 cm soil depth for soils of degraded bare land was 1.46 ± 0.04 % but it was 1.83 ± 0.07 % for rehabilitated degraded bare land at the same soil depth. The analysis of soil pH of the rehabilitated degraded bare land (4.88± 0.03, 4.82 ± 0.02 and 4.67 ± 0.02 at 0-10, 10-20 and 20-30 cm depth respectively) showed that it was less acidic than the degraded bare land. The soil organic carbon stock of degraded bare land was improved when re-vegetated with rhodes grass by reseeding technique (about 0.9 Ton/ha of extra carbon when compared with the degraded bare land per year). When degraded bare land is re-vegetated with good management practice, the carbon sequestration potential of the land could be improved which reduce greenhouse gases in the atmosphere, more soil organic carbon stock can be rebuilt in to soil of rehabilitated degraded bare land.

There was no management technique developed to make use of the rehabilitated degraded bare land in a sustainable way. The study on the selected soil physicochemical properties showed that they are low for rehabilitated degraded bare land; this implies that inputs either in the form of organic or inorganic fertilizer needs to be added so that the rehabilitated degraded bare land will continue to give ecological functions. What were the grass species that reside the current degraded bare land? Research need to be conducted if the grass species before 33 years ago can be a more success option for rehabilitation of degraded bare land and significant improvement in forage production and selected soil physicochemical properties. The coverage of degraded bare land in the district needs to be investigated.

5. ACKNOWLEDGMENT

The authors would like to acknowledge Oromia Agricultural Research Institute (IQQO) for the financial support of the research. We thank Holeta Agriculture Research Center and Zuway Soil Research Laboratory for soil analyses.

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