Original Research Article

Soil Chemical property variation under different conservation agriculture practices, in Bako Tibe District, West Shoa, Ethiopia

Abstract

*Conservation agriculture is claimed to be one of the solution for the problems of poor agricultural productivity in sub-saharan countries.The impact of conservation agriculture depends on environmental factors such as slope, vegetation, soil type, rain fall pattern and intended crops. This study was conducted from 2013 to 2014 with the objectives of assessing the impact of different conservation agriculture practices on soil chemical properties, using five treatment were selceted fo rthe study namely: Monocropping (maize) without crop residue, Monocropping (maize) with crop residue, Crop rotation (maize and haricot bean) with crop residue, Intercropping (Haricot bean with maize) with crop residue and including a near by grazing land (Orginal land use). A randomized complete block design with four replications was used. A total of 40 composite soil samples (4 replication * 5 treatments * 2 soil depth: 0– 10 cm and 10–30 cm) were collected and analyzed for selected soil propeties. Results showed that soils in the study area were moderately acidic, and contain medium level of available phosphorus (AP) (7.33*±0.58*), but low concentration of total N (0.176*±0.02*). Soil pH, soil organic carbon (SOC), total nitrogen (TN), C/N, and AP did not significantly differ* (p=0.958, p=0.998, p=0.219, p=0.140 and 0.568) respectively, *among the treatments after four years of conservation agricutural practices. Therefore, conservation agriculture has little effect on soil properties in short term, but it may take longer time to influence on different soil chemical properties in the study area.*

Keywords: Composite; Conservation agriculture; Crop residue; Intercropping; mono cropping;

1. Introduction

Soil is a base of nourishing life on earth and sustains the maintenance of all terrestrial ecosystems (Belay, 2003). Reducing soil resource degradation, increasing agricultural productivity, reducing poverty, and achieving food security are major challenges of the countries in tropical Africa. The causes of soil degradation in Ethiopia are cultivation on steep and fragile soils, erratic and erosive rainfall patterns, declining use of fallow, and limited recycling of dung and crop residues to the soil, limited application of external sources of plant nutrients, overgrazing and deforestation (Hurni, 1988; Belay, 2003). Management practices in the areas of intensive agriculture may affect soil properties as they vary according to soil formation factors such as parent material, topography and climate (Celik *et al.*, 2011). Continuous utilization of inadequate methods of soil management, including the removal of crop residues and burning, intensive tillage, and monocropping farming practices that expose the soil to leaching and erosion leads to decline of soil fertility. Compared to tillage based agriculture, conservation agriculture (CA) has the potential to decrease soil loss, enhance levels of soil organic matter, increase plant available soil water, and save costs due to fewer or no tillage operations (Teklu, 2011). Current uses of different conventional agricultural practices are the major threat to land productivity and soil fertility decline, but few studies identify the limitation of conventional agricultural practices. One of the main challenges in Western Oromia generally and particularly to Bako district, where maize is the main stable and major producing crop, is continuous mono cropping with residue removal through burning and/or used for other purposes (Wakene Negassa, 2001). Bako agricultural center has been undertaking a controlled study on different conservation agricultural practices on farmers land. Taking this opportunity, this research initiated to assess the impact of different conservation agricultural practices namely: Mono-cropping with Residues (MCR), Crop rotation with residues (CRR.), and Intercropping with Residues (ICR) on different soil properties. In Bako area maize is the main dominant crop and mono-cropping agricultural farming practices is common but the agricultural research institute is undertaking a controlled study on different conservation agricultural practices. Taking this opportunity, this research initiated to assess the impact of conservation agricultural namely minimum tillage, crop rotation, crop residue retention and intercropping agricultural practices on soil chemical properties.

2. Materials and Methods

2.1 Description of the study area

The study was conducted in Bako district, western Oromia. Bako is located at 9^o 08' N latitude and 37^o 03' E longitude; about 251 km from Addis Ababa. The altitude where the soil samples are collected was located ranged from 1670 to 1690 meter above sea level. The long term weather information revealed that the area has unimodal rainfall pattern extending from March to October, but the effective rain is from May to September (Legesse *et al.*, 1987). The mean annual rainfall is about 1237 mm, with a peak in July. It has a warm humid climate with annual mean minimum and maximum temperature of 14 ^oC and 29 ^oC, respectively and the mean annual temperature is 20 ^oC. Soils at the study site are dominantly Nitosols with reddish brown colour. They are generally clay dominated with a pH in between 5- 6 in surface soils (Legesse *et al.*, 1987).

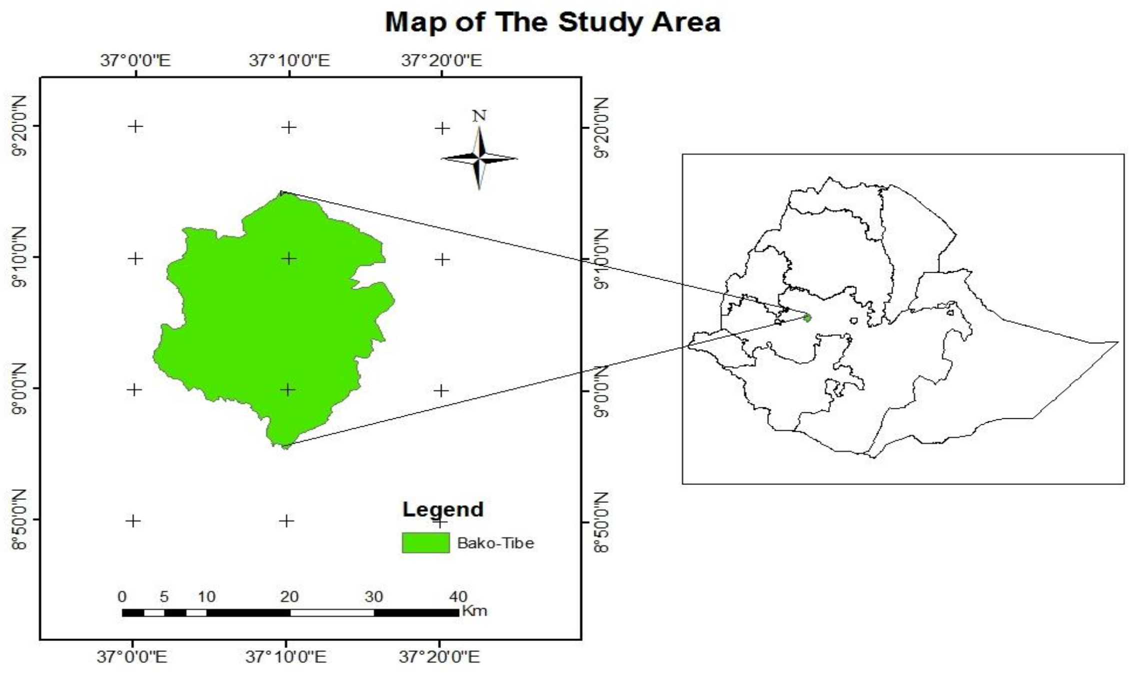

Figure 1: Map of the Study area – Bako district.

2.2 Experimental treatments and Design

Treatments: There are two factors were considered for this study: agricultural practices and soil depths.

Factor A: Five treatments

- Monocropping without crop residue (MC(-R)) were selected as a (control)
- Monocropping with crop residue, (MCR)
- Crop rotation with residue, (CRR)
- Inter cropping with residue (ICR)
- Grazing land (GL) a nearby grazing land (Original land use).

Factor B: Two level of soil depth

0 -10 cm representing the top soil, and

10 -30 cm representing the subsoil

Among the five treatments mentioned above (Monocropping with crop residue, (MCR), Crop rotation with residue, (CRR) and Inter cropping with residue (ICR) were represent conservation, whereas, Monocropping without crop residue (MC(-R)) used as a conventional agricultural practice.The agricultural lands were contiguous and have similar in practice year and environmental conditions (e.g in soil condition and slope) except the difference in management practices and the GL from nearby farmers land. The soil under GL was used as a reference to assess extent of changes in soil properties in other agricultural practices.

Design: A 2x5 factorial arrangement of treatments in randomized complete block design (RCBD) replicated four times, so in total making up 2x4x5 (40) samples were collected from all treatments.

2.3 Soil Sample Collection

Four plots (10m x 10m) were randomly selected in each of the five treatments arranged in a randomized complete block design (RCBD).To minimize the border effect soil samples were collected from 8m * 8m plot size since the main plots have a minimum distance of 1m between the plots. In each plot the soil samples were collected from two soil depths (0-10 and 10-30cm) at the corners and centre of the plots. Then the samples from each plot were bulked to have a composite sample at 0-10 and 10-30 cm layers, and a total of 40 composite soil samples were collected from the study area.

2.3.1 Soil Analysis

The soil samples were first air-dried at room temperature crushed and mixed with mortar and sieved using 2mm mesh size, and roots, litter and stones from the soil samples were removed. Then the collected soil samples were analyzed for their physical and chemical properties at BARC soil laboratory. The pH of the soils was measured in water and potassium chloride (1M KCl) suspension in a 1:2.5 (soil: liquid ratio) potentiometrically using a lass-calomel combination electrode (Van Reeuwijk, 1992). The Walkley and Black (1934) wet digestion method was used to determine the amount of soil carbon content in the soil. Total N was analyzed using the Kjeldahl digestion, distillation and titration method as described by Black (1965) by oxidizing the OM in concentrated sulfuric acid solution (0.1N H_2SO4).Available phosphorous (AP) was determined according to the standard procedure of Bray II method (Bray and Kurtz, 1945).

2.4. Data analysis

The soil chemical properties were subjected to analysis of variance using the general linear model (GLM) procedure of statistical analysis system (SAS) statistical software version 9.0.2004. The least significance difference (LSD) Analysis of variance (ANOVA) were employed to test the variations among the treatments. For significant differences, mean separation using LSD was used to separate significantly differing treatment means after main effects were found significant at $P < 0.05$.

3. Results and Discussion

3.1 Soil Chemical Properties

3.1.1 SOC, Soil pH, TN and C/N Ratio

The interaction among the agricultural practices including the grazing land with soil depth was not statistically significant for soil pH, SOC, TN, C/N ratio and AP at (p=0.958, p=0.998, p=0.219, p=0.140 and 0.568), respectively. In addition, SOC and TN under the soil depth were statistically significant (p=0.0035, and p= 0.0004), this indicate that as the depth increased the soil organic matter become less and less this is due to leaching and other related factors. On the other hand, soil pH and C/N ratio were not significantly (p=0.589 and p=0.460), respectively different at a given soil depths (Table 1).

Table 1: Summary of ANOVA for pH, SOC (%), N (%), AP (mg/kg), and C/N ratio under different agricultural practices and soil depths.

Source of variation	Df	pH		SOC (%)		TN (%)		C/N ratio		AP (mg/kg)	
		MS	P	MS	P	MS	P	MS	P	MS	P
Soil Depth (D)	1	0.041	0.589	2.618	0.0035	0.031	0.0004	3.310	0.460	9.180	0.087
Practices (P)	5	0.051	0.866	0.067	0.936	0.002	0.330	9.260	0.196	1.270	0.827
P*D	5	0.028	0.958	0.013	0.998	0.003	0.219	10.610	0.140	2.340	0.568
Error	36	0.138		0.267		0.002		5.940		2.979	

As displayed above in the (Table 1) the soil pH under different agricultural practices are not statistically different in the four year practices which means agricultural practices had no effect on soil pH within short period of time. On the other hand, although slight numerically variation was observed on the mean value of soil pH as indicated below in (Table 2) under all agricultural practices increased with soil depth this might be due to the reduction of Ca and Mg ions along soil depth which lowers soil pH from top to down the soil layers. As a result, the soil pH values observed in the study area are within the range of moderate acidic soil as indicated by Foth and Ellis (1997). Numerous scholars Abebe Yadessa (1998), Islam and Weil (2000), Wakene and Heluf (2003) and Gebeyaw (2007) reported that the soil pH was lower in cultivated land than grazing land, this might be due to the depletion of organic matter because of intensive cultivation and also due to the highest microbial oxidation that produces organic acids, which provide H ions to the soil solution. Similar to these studies, the mean value of soil pH was relatively lower under agricultural practices than grazing land but no statistical difference was observed among all agricultural practices, and grazing land. According to Du Preez, *et al*., 2001, report showed that soil pH was significantly higher under conservation agriculture than conventional agriculture practices after 11 years of practices. Based on this finding, the absence of difference under all agricultural practices could be attributed to the age of conservation agriculture practices which were only four years old.

Soil Organic Carbon (SOC) concentration was not significantly different among the agricultural practices and the grazing land, while the overall mean of SOC concentration was in the range between 2.23 to 2.41% (Table 2). Consistent with the present study, SOC was not affected by conservation agriculture within four year of practice when compared to conventional agriculture

Bielders, *et al*., (2002), Ben-Moussa., *et al.*, (2010). In contrast, Nyamadzawo, *et al.*, (2008) and Gwenzi, *et al.*, (2009), reported that SOC was higher under conservation agriculture after five and ten years of practice, respectively. They attributed the low SOC content in continuous cultivated soils of conventional agriculture to reduced inputs of organic matter obtained from crop residues and frequent tillage which encouraged oxidation of organic matter. So, according to Nyamadzawo, *et al.*, (2008) and Gwenzi, *et al.*, (2009), the SOC might change after practicing conservation agricultural for greater than four years.

The mean value of total N content varied from 0.15 to 0.20% under agricultural practices and the grazing land. After practicing conservation agriculture for four consecutive years, total N did not differ significantly when compared to conventional agriculture (Table 2). Following the rating of total N of > 1% as very high, 0.5 to 1% high, 0.2 to 0.5% medium, 0.1 to 0.2% low and < 0.1% as very low N status as indicated by Landon (1991), in the current all the agricultural practices and the grazing land have low content of total N. The low level of nitrogen in the practices may imply that fertilizer additions have not replaced the total N lost due to harvest removal, and /or leaching Malo *et al*., (2005). In agreement with the present study, Saito, *et al.*, (2010) reported that there was no significance difference in total N under conservation agriculture practices after practicing for four years in Benin. Whereas, Ben-Moussa., *et al.*, (2010), and Enfors, *et al*., (2010) reported that total N was significantly higher under four years' conservation agriculture practices than conventional due to the addition of manure on the experimental fields. Crop residue management, intercropping, and crop rotation in the present study can potentially increase total N in the soils, but the level of influence might depend on the age of the practice. In this study the values of C/N ratio was not significantly differ among the agricultural practices and the grazing land. Furthermore, the C/N ratio had a very narrow range between 12.2 and 15.4 as indicated in (Table 2) below. Hence, the C/N ratio was below 16.6 for all the soils in the study area which indicates that there could be release of available form of N to the soil system through the mineralization process of soil OM. The observed values of C/N ratios may suggest that there was no problem of N immobilization which could significantly affect the availability of N for crop uptake.

3.1.2 Available Phosphorus

The interaction of agriculture practices with soil depth was not significantly different (p=0.568) for available P (Table 1). According to Landon (1991) available soil P level of 5-15 mg/kg is rated as medium, and accordingly the available P of the study area was found in the medium range. Ben-Moussa., *et al.*, (2010) reported that available P was similar in the soils of conservation agriculture when compared to conventional agriculture practices within four years of practices in Tunisia. In contrast, conservation agriculture practice the 11 years showed that available P increased when compared to conventional tillage practice Du Preez, *et al*., (2001). Based on these findings, the present study may suggest that the available P could change after exercising conservation agriculture for greater than four years of time.

Table 2: Mean ± SE of total N (%), SOC (%), C/N ratio, AP (mg/kg) and pH of soil in relation to different agricultural practices including grazing land with soil depths.

Practices	Soil depth	TN (%)	SOC (%)	C/N ratio	AP (mg/kg)	pH
MC(-R)	0-10cm	0.16±(0.03)^{a}	2.44±(0.17)^{a}	16.62±(2.90)^{a}	7.50±(1.19)^{a}	5.50±(0.14)^{a}
	10-30cm	0.14±(0.01)^{a}	2.02±(0.29)^{a}	14.17±(1.23)^{a}	6.30±(0.48)^{a}	5.60±(0.28)^{a}
	Over all mean	0.15±(0.02)^{A}	2.23±(0.19)^{A}	15.39±(1.53)^{A}	6.88±(0.64)^{A}	5.55±(0.11)^{A}
MCR	0-10cm	0.20±(0.02)^{a}	2.57±(0.24)^{a}	12.67±(0.60)^{a}	7.80±(0.95)^{a}	5.50±(0.30)^{a}
	10-30cm	0.15±(0.02)^{a}	2.11±(0.30)^{a}	14.07±(0.80)^{a}	7.00±(0.71)^{a}	5.70±(0.20)^{a}
	Over all mean	0.18±(0.02)^{A}	2.34±(0.19)^{A}	13.37±(0.53)^{A}	7.40±(0.64)^{A}	5.60±(0.17)^{A}
CRR	0-10cm	0.20±(0.01)^{a}	2.61±(0.26)^{a}	13.30±(0.80)^{a}	7.00±(0.91)^{a}	5.60±(0.27)^{a}
	10-30cm	0.16±(0.03)^{a}	2.22±(0.40)^{a}	14.64±(0.80)^{a}	8.00±(0.90)^{a}	5.70±(0.21)^{a}
	Over all mea	0.18±(0.02)^{A}	2.41±(0.23)^{A}	13.95±(0.59)^{A}	7.50±(0.63)^{A}	5.65±(0.16)^{A}
ICR	0-10cm	0.18±(0.02)^{a}	2.53±(0.22)^{a}	14.50±(0.78)^{a}	7.30±(0.80)^{a}	5.60±(0.20)^{a}
	10-30cm	0.16±(0.02)^{a}	2.06±(0.28)^{a}	13.00±(0.94)^{a}	6.80±(0.85)^{a}	5.70±(0.18)^{a}
	Over all mean	0.17±(0.01)^{A}	2.29±(0.19)^{A}	13.75±(0.63)^{A}	7.00±(0.53)^{A}	5.65±(0.11)^{A}
GL	0-10cm	0.26±(0.05)^{a}	2.48±(0.19)^{a}	10.17±(1.34)^{a}	8.00±(0.75)^{a}	5.70±(0.10)^{a}
	10-30cm	0.14±(0.01)^{a}	2.01±(0.25)^{a}	14.17±(0.66)^{a}	7.50±(0.65)^{a}	5.80±(0.14)^{a}
	Over all mean	0.20±(0.02)^{A}	2.24±(0.09)^{A}	12.17±(1.03)^{A}	7.87±(0.48)^{A}	5.75±(0.04)^{A}

**Means within a column for the same depth followed by the same letter are not significantly different from each other at $p < 0.05$. **Monocropping without Residues (MC(-R), Monocropping with Residues (MCR), Crop rotation with residues (CRR.), Intercropping with Residues (ICR), Grazing land (GL).*

4. Conclusions and Recommendations

In the study area the local farmers widely practiced traditional farming systems. This farming system involves intensive and continuous cultivation which highly depleted the soil fertility which reduced the production of the land and exposed the soil for leaching and erosion.

Conservation agriculture per se is considered as one of the most effective management practices to obtain mutual benefits in terms of erosion control, carbon sequestration and reduced input of energy and labour. Based on this the objective of the present study focused on the impact assessment of different conservation agricultural practices on soil chemical properties. Accordingly, the results of the present study showed that the conservation agricultural practices did not influence the soil chemical properties like; soil pH, SOC, TN, C/N, and AP within four year of practice. Therefore; this finding suggests that conservation agricultural practices namely: addition of crop residue, crop rotation with crop residue, and intercropping with crop residue in Bako (study area) may require longer years of practice before their influence on different soil chemical properties are visible. Thus, further study on CA practices in chronosequence should be considered to identify the years needed for the practices to bring impact on soil properties.

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